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REVIEWS

Supersonic Flow and Shock Waves. By R. COURANT and K. O. FRIEDRICHS. Springer, 1976. 464 pp. $19.80.

Spezialgebiete der Gasdynamik. By K. VON OSWATITSCH. Springer, 1977. 377 pp. DM 192.

Both books under review treat special topics of gasdynamics. The book by Courant & Friedrichs is the unchanged reprint of a famous and influential classic which was first published in 1948 as an extended and revised version of a wartime report. It is mainly a systematic exposition of nonlinear wave motion with two independent variables. This comprises one-dimensional unsteady motion of a gas and two-dimensional plane or axisymmetric supersonic flow. The mathematical tools needed for solving the hyperbolic equations governing such motions, essentially the method of characteristics, are expanded and discussed in detail. Basic types of solution like simple waves and shock waves are explained and it is shown how they interact and how by combining such basic solutions one can construct, and thereby understand, more complicated flow fields. Detonation and deflagration waves are discussed; sidelines include elastic–plastic wave propagation, shallow-water theory, one-dimensional flow through a Laval-nozzle etc. Though explicit results are mainly restricted to calorically perfect gases, the more fundamental aspects are usually discussed for quite general gases. The exposition, which strikes a healthy balance between the mathematical and the physical aspects, is aided by a large number of instructive graphs and geometrical explanations.

Of course, the question arises whether a book written more than thirty years ago on a subject which has rapidly developed and expanded in the meantime is still so valuable and usable that its reprint satisfies a demand beyond a purely historical interest. My answer is that I would hesitate to recommend the book by Courant & Friedrichs as an introductory textbook for students. Thirty years of honing and polishing have made it possible to present the classical material of the book in a simpler way. This was the first time that I read the book more or less systematically from beginning to end and, although it is written with didactic skill and clarity, I found it not always easy reading. However, the book contains an amazing amount of immediately useful results and formulae many of which are not well known and are missing from modern treatises. Moreover, the effort of working one's way through the concisely written book is rewarded in many places by surprising insight. The wealth of analytical results one can find in the book is too easily forgotten in our time when the lure of the big computers often leads to an overproduction of numbers and an underproduction of understanding.

Incidentally, apart from some inconsequential misprints I found at least one statement in the book which, I think, is wrong. The text on pp. 388–389 implies that for a plane underexpanded jet exact periodicity is impossible. I have checked some textbooks on gasdynamics published later than the book by Courant & Friedrichs and found that at least one of them repeats this incorrect statement though the accompanying pictures show jets of exact periodicity!

Whereas the book by Courant & Friedrichs covers much of the ground that belongs to the core of every course on gasdynamics the book by Oswatitsch contains a number of rather specialized topics. It is the second of two volumes forming the vastly expanded and revised replacement of the author's book on gasdynamics that was published in 1952 and is out of print now. Whereas the first volume contains much of the traditional textbook material the second volume treats the following four specific subjects: steady inviscid transonic flow, hypersonic flow, wings of finite span, wave propagation in space and time. Professor Oswatitsch and his many pupils and collaborators have made substantial and original contributions to all these subjects, and it is no criticism but the simple statement of an understandable fact that the treatise is heavily weighted in favour of these contributions. For example, the list of references of the first, and longest, part, on transonic flow, contains 58 references, half of which refer to papers by Oswatitsch and his collaborators. The book therefore has in many places the character of a monograph which, besides briefly explaining the fundamentals of the subject, tells us predominantly about the modern work done by Oswatitsch's school.

A prominent example is the extensive discussion of Sobieczky's rheograph method for steady plane transonic flow. This method allows the derivation of a considerable number of solutions of the transonic equation, some of which are new whereas some have been found already by other methods. Other topics discussed in the first part of the book include the parabolic method, the integral-equation method and the equivalence theorem for axisymmetric and three-dimensional transonic flow.

The second part, on hypersonic flow, is rather short. As a typical contribution made by Oswatitsch's school Schneider's treatment of blunt-body flow is presented. Real-gas effects, which are certainly important for hypersonic flow, are given only fleeting attention by deriving a few results for the 'two substance fluid model'. This is a model for a non-perfect gas in thermodynamic equilibrium whose equations of state contain an auxiliary variable with the meaning of a mass fraction. With this minor exception the whole book is restricted to flow of a perfect inviscid gas.

In the third part of the book an account is given of linearized aerodynamics of wings of finite span in steady supersonic flow. Subject matter and presentation are traditional. It seems to me that this part is less influenced by the author's and his pupils' work than the closely related fourth part, on wave propagation, which relies heavily on such work. In this part mainly the geometry of steady wave fronts in three dimensions and unsteady wave fronts in two dimensions is discussed and the ideas of Oswatitsch's 'analytical method of characteristics' are explained. This method is a systematic expansion procedure for improving on the linear acoustic theory which is closely related to the PLK-method. Applications include wave fronts, weak shocks and sonic booms in the flow around wings of finite span.

Like the book by Courant & Friedrichs, Oswatitsch's book is also a collection of much useful information and many original ideas. As a comprehensive survey of important topics which have been advanced considerably by Oswatitsch's school it is certainly a welcome addition to the gasdynamicist's library. Yet I think its usability is impaired by the way in which the information is presented. Despite the contrary statement in the preface the book is difficult to read without continually consulting the first volume. The text abounds with references to that volume, and an appended list of formulae from that volume is so incomplete that it is more exasperating than helpful. Even the notation remains unclear in some instances without recourse to the first volume. Furthermore, the text seems to me in a number of places somewhat verbose and discursive rather than succinct, and it is hard to pick out the essential and important results from the inconsequential and unimportant paraphernalia. This deficiency in pedagogical finesse will most probably deter readers who seek an introduction to the subjects treated in the book and will restrict the readership mainly to specialists, for whom it is certainly a very valuable source of information. For these reasons I doubt that the book will exert an influence on the further development of the subject which is comparable to that which the first book reviewed here has had, and that it will receive the attention which the manifold results of several decades of important and original work by Oswatitsch and his school deserve.

E. BECKER

The Elements of Wave Propagation in Random Media. By B. J. USCINSKI. McGraw-Hill, 1977. 153 pp. £13.35.

The subject of wave propagation through random media can be said to have begun with the brief but beautiful description in Newton's *Opticks* of the effect on telescopic resolution of the 'perpetual tremor' of the atmosphere. Of course Newton referred to rays, and not until Hamilton developed his method of characteristics was the correspondence between the ray and wave theories rigorously proved for arbitrary media. The history of wave propagation through random media is thus intimately tied to optics, and this relation has continued with the rapid development in this field over the last thirty years. Recent development has been spurred largely by applications in the propagation of light through the turbulent atmosphere and radio waves through interplanetary plasma. Sound transmission through the ocean was seen by many workers to be a related problem, but little progress was made until the last few years owing to a lack of understanding of ocean structure.

The motivation for the study of wave propagation has been very indirect. One desires the properties of a source such as a radio star or a submarine, but the source is viewed through a fluid medium such as interplanetary plasma or the ocean, causing irregularity in the signal. Thus the fluid medium is regarded as a generator of signal distortion, and this distortion is to be understood only for the purpose of eliminating or unfolding it to reveal the properties of the source. Only recently has understanding become sophisticated enough so that observations of waves through fluids of these types can reveal interesting characteristics of the intervening fluid medium itself. The spatial and temporal scales of such fluids as the atmosphere, the ocean or interplanetary plasma can now be investigated through wave propagation.

A classic treatise in wave propagation is *The Effects of the Turbulent Atmosphere on Wave Propagation* by V. I. Tatarskii (1971), in which the medium is treated as filled with homogeneous isotropic turbulence. By the time of Tatarskii's work, the theory of wave propagation in the unsaturated regions (where intensity fluctuations are much less than unity) was well understood, and was treated either by geometrical optics methods or by the method of Rytov for cases where diffraction was dominant. However, in the saturated region (where intensity fluctuations are large), only a few results were known, and no theoretical method was recognized as complete.

There has been little appreciation in the literature of the fact that theoretical attacks on the saturated region are strongly dependent on the fluid-dynamical character of the refractive-index fluctuations in the medium. The medium almost universally treated in the literature is one in which the irregularities are isotropic, homogeneous, and Gaussianly distributed in strength and size. Less often, a spectrum of sizes is treated; in this case, a $k^{-\frac{5}{3}}$-spectrum derived from turbulence theory is used. This work has good applicability to optical transmission through the atmosphere, or radio transmission through interplanetary plasma, but has limited applicability to the ocean, whose sound-speed fluctuations are inhomogeneous, anisotropic and have a k^{-2}-spectrum in the 50 m to 10 km range.

Three methods have been developed over the past few decades to deal with the saturated region. The first is the transport equation, which allows calculation of the angular spectrum of wave intensity but gives no phase information. The second is the method-of-moment equations, where differential equations for moments of the wave field (particularly the second and fourth moments) are developed. One must solve these partial differential equations for each physical situation; few exact solutions are known, but computers have been used to gain insight through numerical solutions in some cases. These two methods are directly related (through a Fourier transform), and they have both found reasonable success for homogeneous isotropic media. However, attempts to extend their validity to the ocean case have so far been unsuccessful. In the last few years, a third method which allows for homogeneity and anisotropy from the outset has been developed specifically for the ocean case. This third method (called micromultipath) is based on the path-integral formalism, and is thus a generalization beginning from ray theory. It is important to remember that all of these theories start from the approximation of *small-angle* scattering, leading to the parabolic wave equation. From that point the method of moments and the micromultipath method diverge, the former emphasizing wave (or diffraction) theory and the latter emphasizing ray theory.

Theories of wave propagation in random media often speak of the unsaturated and saturated regions as regimes of 'single scatter' or 'multiple scatter', respectively. This concept has a reasonably direct interpretation in quantum mechanics when perturbation theory is used, but to speak of scattering as an event that is undergone by a continuous classical wave can lead to confusion. Classical scattering is an artifact of the mathematical methods used, and should be carefully explained as such.

B. J. Uscinski's book is an introduction to the method of moments, designed 'to make multiple scatter theory available to physicists and engineers for use in practice and to enable research articles to be read with understanding'. It is noted in the introduction that 'no attempt will be made to review current theories. One particular approach will be presented which it is hoped will take the reader through some of the more important aspects of the subject.' The book is quite brief (153 pages, including mathematical appendices and subject index). In each chapter an important subdivision of the theory is introduced, the basic principles are presented in an exceptionally clear pedagogic manner, and references to important journal articles pertinent to that subdivision are given. Thus the second purpose of the book, 'to enable research articles to be read with understanding', is admirably fulfilled in a very concise manner, at least if the research articles deal with the method of moments.

The book begins with a short history of wave propagation theory from the 1950s to the present, with no attempt to relate to the previous mathematical history of ray and wave theory. A description of medium fluctuations (chap. 1) is followed by a clear derivation of the general moment equations with no scatter (chap. 2) and with scatter (chap. 3). Derivations of some wave moments in terms of medium moments (chap. 4) are provided only in simple cases; the lack of any discussion of the problems that arise in complicated cases will make it difficult for an engineer attempting to apply the theory to a practical problem. A deliberately non-rigorous derivation of results for impulse response (chap. 5) is applied to media with Gaussian autocorrelation functions for both single- and multiple-scatter cases, presenting Williamson's results. A derivation of the intensity angular distribution (chap. 6) is given from photon flux arguments, and the result is shown to be identical to that obtained from a Fourier transform of results obtained by the method of moments. The surprising statement is then made that this equivalence of result is unexpected! No mention is made of the large body of literature associated with the transport equation (which is the 'photon flux' approach), nor is it explained that the equivalence in this domain can be established by direct Fourier transformation of the equations. Intensity fluctuations in the single-scatter regime (chap. 7) are treated by integration of the phase screen effect, and it is noted that this treatment is ill suited to extension to the multiple-scatter region. Intensity fluctuations in the multiple-scatter region (chap. 8) are discussed heuristically, starting from the fourth-moment equation. Computer solutions for the scintillation index as a function of distance into the medium are given, and scale sizes of intensity fluctuations are discussed. The probability density of the wave field (chap. 9) is also discussed, starting from a two-dimensional diagram whose co-ordinates are two parameters calculated from properties of the medium and the wavelength of the propagated wave. The author has developed his own physical intuition with regard to the various regions in this diagram, and this intuition is qualitatively presented as a survey of wave propagation. Essentially equivalent diagrams have been developed by others previously (for example, de Wolf), but no mention of or connexion with these previous results is made. Finally, two more specialized areas of interest are briefly discussed: results for spatially incoherent sources (chap. 10) and for cases where the source or medium is in motion (chap. 11).

For an elementary treatment, not enough discussion is devoted to the exact meaning of 'single scatter' and 'multiple scatter'. In fact, the relationships of 'single' and 'multiple' scatter to the geometrical optics region, ray theory, diffraction, and Rytov's method of smooth perturbations are not at all trivial. However, if the reader is aware of these difficulties, they will not detract unduly from the very clear explanations that generally fill the book.

For those interested in the general mathematical aspects of wave propagation, Uscinski's book provides a pleasantly elementary introduction to one branch of the field. Although other applications are often mentioned in passing, the few specific examples in the book are from astrophysics or ionospheric physics. For those interested in a particular medium which is approximately homogeneous and isotropic, such as the atmosphere or interplanetary plasma, the book provides a good introduction. The avoidance of specialized applications, mentioned as a virtue on the jacket blurb, will make it difficult for engineers interested in practical, realistic situations. Finally, those interested in acoustic propagation at moderate frequencies where anisotropy and inhomogeneity are crucial will not find much of direct use here.

S. M. Flatté

Flow-Induced Vibration. By ROBERT D. BLEVINS. Van Nostrand Reinhold, 1977. 363 pp. £13.75.

This is a timely, interesting and useful book which will find a place on many engineers' bookshelves. Its aim is to provide engineers and students with analytical tools for the analysis of the vibrations of structures exposed to a fluid flow. The author bases much of his book on the experience he has gained during eight years of research in this field. The treatment of fluid mechanics is less commanding than, say, that to be found in the paper by Parkinson on mathematical models of flow-induced vibrations published in *Flow Induced Structural Vibrations* (Springer, 1974). The style is clumsy in places and the arguments are not always presented with the utmost rigour. We should not let these criticisms overshadow our judgement, however, and in the author's defence it may be pointed out that fluid/vibrating-structure interactions are extremely complex and some compromise in both the fluid and the structural dynamics is inevitable if practical solutions are to be sought. Although the book is described as an introductory text students will find some of the assumptions presented, which can only be justified on the grounds that they produce an acceptable answer, hard to swallow.

The book is attractively laid out and sensibly organized according to fluid excitation mechanism rather than by type of structure. The worked examples to be found throughout are one of the book's most valuable features. The text is well supported by references and nearly 250 are cited, the most recent being dated 1977, the year of publication. The only penalty that seems to be paid for having such up-to-date material is that the author was left with little time to check the proofs. One of the more intriguing typographical errors concerns 'Aeolian tubes'.

The final two chapters, entitled 'Vibrations of a pipe containing a fluid flow' and 'Ship motion in a seaway', do not fit comfortably with the rest of the text. Their inclusion is particularly puzzling since the author states at the outset that his book 'explores the vibrations of bluff structures induced by a subsonic flow'. In their place it would have been interesting to have presented case histories of structures that have vibrated and to have given more detailed guidance as to what type of excitation a given structure might experience.

Chapter 1 serves as a short introduction and this is followed by a disappointing chapter on dimensional analysis. The important combined mass and damping parameter is introduced without any discussion of why and when we can lump these together. Dimensional analysis is applied to a 'two-dimensional building model'! and no mention is made of the importance of approaching flow conditions.

Vortex-induced vibrations are the subject of chapter 3 and much prominence is given to the wake-oscillator model of Blevins & Iwan. Their model does not seem to offer any advance over the earlier work of Hartlen & Currie and their attempts to justify the use of a van der Pol type equation on fluid-mechanical arguments is not altogether convincing. The treatment of galloping oscillations in chapter 4 is excellent and is marred only by the lack of any discussion on how bluff structures generate negative lift-curve slopes and the statement that galloping and stall flutter are terms for the same phenomenon. Chapter 5 describes the very complex problem of vibrations of tube banks. Vibrations induced by oscillatory flow are presented in chapter 6 and the discussion centres around bluff bodies exposed to planar flow.

Wave-induced vibrations are not treated in detail apart from a worked example on the vibration of a marine pipeline. The author points out the desperate need for improved analytical models in this field. His simple model for oscillations induced in the lift direction predicts, in the pipeline example, an amplitude of 20 pipe diameters whereas experience suggests that the amplitude never exceeds one diameter. Vibrations induced by stream turbulence are the subject of chapter 7, which also includes a useful section on random vibration theory. The approach is pragmatic and follows closely the lines of the early work of Davenport. Little space is devoted to discussing the physics of turbulence, the influence of turbulence on the flow field around bluff bodies and the problem of turbulence distortion. Turbulence-induced vibrations of buildings is treated more comprehensively than in more specialized books on architectural or building aerodynamics. I was particularly pleased to see that the author had devoted the whole of chapter 8 to the important topic of damping. This chapter contains useful information on the measured damping of various structures. Chapter 9 explores the interesting problem of sound induced by vortex shedding. This enterprising book concludes with a list of unsolved flow-induced vibration problems and, in keeping with the general theme, all have considerable practical significance.

I enjoyed reading this book although for my own taste I should have preferred more emphasis on the physics of fluid/structure interactions. It is an important work and is strongly recommended to those working in the many branches of engineering where flow-induced vibrations are encountered.

P. W. Bearman