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REVIEWS

Gas Dynamics, Volumes 1 and 2. By M. J. ZUCROW and J. D. HOFFMAN. Wiley, 1976, 772 pp. £19.00 or \$35.00 and 1977, 480 pp. £18.95 or \$37.

One-Dimensional Compressible Flow. By H. DANESHYAR. Pergamon Press, 1976. 179 pp. £7.50 or \$15.00 (hardback), £3.75 or \$7.50 (flexicover).

The very long, 772 page, first volume of this two-volume text on gasdynamics by Professor Hoffman and the late Professor Zucrow is noteworthy for a number of reasons, all explicitly stated in the preface. It is written so that it may be used by the student of graduate or near-graduate status, without the aid of an instructor; it is self-contained, includes some discussion of real-gas effects and makes a feature of numerical examples, even to the extent of including FORTRAN programs for some calculations. In so far as these are the only features which make this volume different from established works on gasdynamics (certainly the contents are similar, and therefore unexceptional) they clearly deserve special attention. Volume 2 of the work explicitly adopts the philosophy that has just been outlined. However, it is a somewhat shorter book of 480 pages and is, in its style and outcome, substantially different from volume 1. With its heavy emphasis on the development and exploitation of the numerical method of characteristics, it represents an original contribution to the literature on gasdynamics and must therefore be judged differently from volume 1.

In pursuance of its self-contained character the first volume begins with a review of fundamental principles. For example, gas density is defined so that its average value $\bar{\rho}$ is defined as the quotient $\delta m/\delta V$, where δm is the mass contained in the element of volume δV. It is explained on page 10 that if one allows δV to diminish without limit the molecular 'graininess' of the gas makes $\bar{\rho}$ fluctuate widely as molecules enter and leave the element and that one must therefore put a lower limit $\delta V'$ to δV, in order to invest the concept of density with some meaning, especially in so far as the gas is to be modelled as a continuum. Later in this introductory chapter, in a discussion of flow-work on pages 31 and 32, one encounters the following: '...a system of fixed mass enclosed by a fixed boundary A. Adjacent to A is a small mass δm. Assume that the mass δm is forced across A and joins the system mass m. Let the pressure of the surroundings, denoted by p, force δm into the system. The work performed by the surroundings on the combined system comprising m and δm, by moving δm the distance dx into the original system, is called the flow work δW_{flow}. It is given by

$$\delta W_{\text{flow}} = F dx = (p dA) dx = p dV = pv\,\delta m \qquad (1.51)$$

where $v = dV/\delta m$' [*sic*]. After some few words about the meaning of pdV the section concludes with 'On a unit mass basis, equation (1.51) becomes

$$\delta W_{\text{flow}} = pv. \qquad (1.52)\text{'}$$

One will have met v for the first time on page 16, without explicitly learning that v is the reciprocal of the density and without encountering $\delta V'$ again. These matters are exhibited here at length, and with verbatim quotes, to illustrate what the instructorless student will have to struggle with.

They illustrate a feature of the first volume as a whole, namely that the more the authors set out to explain points in detail and with great care, the more tortured becomes the explanation and the more inaccessible the points at issue.

There is no excuse for the misdemeanour of mixing differentials with small but finite increments as if it did not matter, and the verbal descriptions of what *is* happening to δm, for example, do not fill one with enthusiasm either. Towards the end of chapter 1 the acoustic or sonic speed is introduced as follows: '...it can be shown (see any text on elementary physics) that the acoustic speed...is given by $a = (\kappa_s/\rho)^{\frac{1}{2}}$', where κ_s the isentropic bulk modulus. Hardly 'self-contained' if one needs an elementary text on physics, and it is so easy to introduce the concept of sound speed in a concise account of infinitesimal amplitude wave propagation anyway. It is necessary to wait until page 558 in the present volume before encountering the one-dimensional wave equation, with its solution and interpretation. There is a description of infinitesimal amplitude wave propagation, treated as a steady one-dimensional motion, on pages 125–128 but there is a certain amount of awkwardness generated over sign conventions for velocities and it is only a demonstration that a small amplitude disturbance will propagate at a speed whose square is the derivative of pressure with respect to density when the actual gas motion is isentropic. It does not therefore indicate the role of sound speed as an intrinsic thermodynamic property of the material; nor does it suggest how to define sound speed in non-isentropic systems.

There are far too many obscurities in the language and in the mathematics. For example one cannot substitute equation (3.13) on page 113 into (3.8) on page 111 because (3.13) is *not* an equation; it is a statement in mathematical symbols about the constituents of a particular net force acting on an element of fluid and there is no equals sign to be seen in (3.13). On page 148, below the statement that the maximum mass flux through a convergent–divergent duct is equal to a product of density, duct cross-sectional area and gas velocity (stated to be equal to a 'constant'), one is invited to differentiate the relation logarithmically and to *divide the result by dx* (my italics: dx is a differential element of length along the duct axis). This invitation is followed by a demonstration that the velocity at the throat of the duct is equal to the local isentropic sound speed. The demonstration is false in that it fails to recognize the important fact that both velocity and pressure gradients can and will be zero at the throat when the flow is *not* choked, coupled with the fact that the original statement of steady-state mass conservation is *not* limited to choked conditions.

It only becomes clear as one reads on through this large first volume that the real-gas effects referred to in the preface are restricted to the case of temperature-dependent specific heats. There is no discussion of relaxation processes, nor is there any of the influences that chemical change can produce in a gas flow; there is indeed no hint that either of these phenomena is associated by most people with the conveniently, if slightly misleading, named topic of real-gas flows and one must wait until volume 2 for this to be rectified. However, the occasional inclusion of variable specific heats in the solution of a problem does illustrate when such effects may be important even though, usually, relaxation effects are of equal importance under the same circumstances.

One must not allow an accumulation of complaints to foster the view that volume

1 is all bad. Even the curate's egg had its edible portions and one can point to worked examples, exercises for the (instructorless) student to work for himself and compendia of useful formulae as analogous to those more palatable parts of the cleric's meal. The authors are at their best when writing about engines and propulsion, as one would expect from Professor Zucrow's long and distinguished involvement with such matters, but this is not really an adequate justification for an uninspiring account of the fundamentals of gasdynamics. Books like this, far from making instructors unnecessary, make them essential.

As stated in the opening paragraph, volume 2 is a different proposition. It opens with an introduction to chemical thermodynamics and immediately sets the style that is to be followed throughout by emphasizing the role of numerical solutions and the use of the digital computer. Of course such methods of solution are essential if one is to cope with the complexities of multiple chemical reactions in even such simple systems as one-dimensional steady flow with area change and one indeed finds just this problem illustrated by the example of a fluorine/hydrogen fuelled rocket motor, with the treatment covering chemical equilibrium flow, chemically frozen flow and flow with finite-rate kinetics. The opportunity is taken to illustrate the stability of an implicit numerical technique and to contrast it with the potentially unstable behaviour of an explicit method when applied to the so-called 'stiff' differential equations that are inevitable in most situations involving finite-rate chemistry.

When one discovers that the problems just described are extrapolated into the field of gas/particle flows in nozzles it is clear that authors' interests are firmly rooted in propulsion matters. This view is reinforced by the second chapter in volume 2, whose title is 'Three-dimensional acoustic waves and steady two-dimensional transonic flow', and which dicusses these two rather unrelated phenomena entirely for their relevance to rocket-motor combustion-chamber instabilities and to the 'true' inviscid flow in the neighbourhood of a convergent–divergent nozzle throat running under choked-flow conditions.

This all takes the reader up to page 111, so that brevity is not something that the authors are seeking. However, I find that the detail that has gone into these first hundred or so pages of volume 2 is almost invariably helpful and does not engender the kind of tedium nor breed the kind of errors that are evident in volume 1. Suffice it to say that the next 346 pages (the remaining 23 pages are taken up with tables of thermodynamic properties and the index) continue in this steadily helpful manner. They are exclusively concerned with the development of the numerical method of characteristics applied to steady two-dimensional irrotational supersonic flow, isentropic supersonic flow (by which is meant constant entropy along but not necessarily across streamlines, so admitting the kind of rotational flow that is found behind curved shocks in chemically inert gas flows), steady two-dimensional flow of non-equilibrium reacting and gas/particle mixtures, unsteady one-dimensional flow and, finally, three-dimensional steady and two-dimensional unsteady flow.

The treatment makes use of 'unit processes' for such situations as points wholly interior to the flow, points on solid walls, shock waves, constant-pressure boundaries, and the axis of symmetry where the latter is required. The provision of FORTRAN subroutines for all of these elements essentially provides the reader with a complete bag of tools for the numerical solution of a wide class of inviscid supersonic flow fields, backed up by a painstaking user's manual in the shape of detailed expositions of all facets of the calculations, with full number-by-number illustrations of specific examples. Not very exciting reading, perhaps, but undeniably useful.

The final chapter, on three-dimensional flows, drops this ultra-detailed numerical style of description but it does provide a substantial service by making a methodical progress through the analysis, which involves such not altogether easily visualized concepts as normal cones and bicharacteristics; the diagrams here are especially helpful.

I believe that volume 2 of this work offers a most useful service to the present-day computer-oriented community, of both students and qualified engineers and others. It is a pity that it is preceded by a cumbersome and largely unattractive first volume and one might hope that an eclectic combination of the two volumes, with a little of the first and all of the second, could be produced in the near future.

Dr Daneshyar's book is a contrast to the Zucrow/Hoffman text in every possible way. As its title clearly states, its aims are more modest in that it confines itself to one-dimensional steady and unsteady flows. It is possible to learn a great deal about gasdynamics by exploiting this restricted geometry, and a wealth of material is laid out in this short (about 100 pages of text) book with a commendable economy and precision in both the mathematics and the verbal descriptions. For example, the careful, compact and helpful discussion of the phenomenon of choking is an illustration of the difference between this book and the Zucrow/Hoffman volumes. There are a few worked examples and somewhat more exercises for the reader, with numerical answers, using S.I. units, where these are relevant. There are some 60-odd useful pages of tabulated data at the end of the book. The level is that of final-year undergraduates, although the work makes a good base for a number of possible courses. The introduction of entropy and the second law of thermodynamics has a slightly shaky feel to it in one or two places. However, this opinion will not stop me from recommending this excellent text to my own students, and indeed to you too.

J. F. CLARKE

Elastohydrodynamic Lubrication, SI Edition. By D. DOWSON and G. R. HIGGINSON. Pergamon, 1977. 235 pp. £6.50 (hardback) or £3.75 (paperback).

Elastohydrodynamic lubrication is the name given to the conditions of lubrication of two solid surfaces by a fluid film in which the pressure generated in the film by hydrodynamic action gives rise to significant elastic deformation of the solids. These conditions arise either when the solids are very deformable as in a rubber seal, or when high loads are carried by non-conforming surfaces such as gear teeth or rolling bearings. The pressure developed in the film depends on the shape of the gap between the surfaces; the shape of the gap is determined by the elastic deformation of the solids due to the pressure in the film. A theoretical treatment, therefore, requires the simultaneous solution of the differential equation for viscous creeping flow in the fluid film and the integral equation for elastic deformation of the surfaces.

Early attempts to solve these equations by straightforward iteration of the pressure and deformed shape did not achieve convergence until Dowson & Higginson recognized that in the entry zone the pressure is predominantly determined by the hydrodynamic equation whereas in the nip the pressure is largely determined by the elasticity of the surfaces. By treating the two zones separately a complete numerical solution was found by hand computation and published in 1959. At the same time J. F. Archard & A. W. Crook at the former AEI Laboratory were developing a technique for measuring the thickness of the film based on the electrical capacitance of the solid surfaces and the intervening fluid. The good agreement found between theory and experiment, coupled with its engineering importance, led to rapid development of the subject among lubrication engineers. The first edition of this book, with two chapters on the experimental aspects contributed by Archard & Crook, was published in 1966. It was concise and easy to read and understand: an ideal introduction to a new and important aspect of lubrication theory and practice.

Unfortunately the first edition has been out of print for some years, during which time the subject has developed rapidly. The theory has been extended from two- to three-dimensional contacts. The rheological properties of lubricating oils have been shown to be viscoelastic and nonlinear. This characteristic dominates the frictional behaviour, in sliding, which makes the original chapter on 'Friction and Viscosity' out of date and frankly misleading. There have been striking developments on the experimental side, notably the use of optical interferometry, with one transparent solid, to reveal the thickness of the film and also the regions in which cavitation occurs or where the film is starved of oil. Semi-conductor gauges have been evaporated onto the solid surfaces to measure both pressure and temperature; local temperatures have also been measured using infra-red radiation through a transparent surface.

All these developments should have found their way into the second edition but the only changes which have actually occurred are that inches have become millimetres and pounds have become kilograms. We should be grateful that the original book is again available, but an up-to-date monograph on elastohydrodynamic lubrication is called for and who better than the present authors to write it?

K. L. JOHNSON

SHORTER NOTICES

Annual Review of Fluid Mechanics, Volume 10. Edited by M. VAN DYKE, J. V. WEHAUSEN and J. L. LUMLEY. Annual Reviews Inc., 1978. 475 pp. $17.50.

The tenth issue of this interesting series of review volumes is now available. The articles for 1978 are as follows.

Some notes on the study of fluid mechanics in Cambridge, England, A. M. Binnie.
Monte Carlo simulation of gas flows, G. A. Bird.
Hydrodynamic problems of ships in restricted waters, E. O. Tuck.
Drag reduction by polymers, N. S. Berman.
Viscous transonic flows, O. S. Ryzhov.
Dust explosions, W. C. Griffith.
Objective methods for weather prediction, C. E. Leith.
River meandering, R. A. Callander.
Rossby waves – long-period oscillations of oceans and atmospheres, R. E. Dickinson.
Flows of nematic liquid crystals, J. T. Jenkins.
The structure of vortex breakdown, S. Leibovich.
Flow through screens, E. M. Laws & J. L. Livesey.

Turbulence and mixing in stably stratified waters, F. S. Sherman, J. Imberger & G. M. Corcos.
Prospects for computational fluid mechanics, G. S. Patterson.
Relativistic fluid mechanics, A. H. Taub.
Turbulence-generated noise in pipe flow, G. Reethof.
River ice, G. D. Ashton.
Numerical methods in boundary-layer theory, H. B. Keller.
Magnetohydrodynamics of the earth's dynamo, F. H. Busse.

Advances in Applied Mechanics, Volume 17. Academic Press, 1977. 389 pp. $43.00.

The articles in this volume are

Long starts his article with two introductory chapters for readers who have no background in turbulence and consequently reviews dimensional analysis and simple results for turbulence in homogeneous fluids. He then considers the effects of stratification and rotation, of prime importance in geophysical flows, with particular reference to recent work of his own on topics such as high Rayleigh number convection and a novel attempt to match a theory for this with the similarity theory of plumes. The chapter on turbulence in stably stratified fluids discusses mostly the results of laboratory experiments; some of the conclusions drawn are, however, still controversial. The final chapter is devoted to third-order closure schemes applied to turbulence in a stably stratified fluid; it centres on recent work by Mellor and does not make comparisons with other models.

The aim of the article by Ogilvie is to explain 'slender' ships to those who know at present only about 'thin' ships. To understand the difference between these terms, consider the ratio of beam to length for a ship as a small parameter. As this parameter tends to zero, a 'thin' ship reduces to its centre-plane projection, i.e. its draft remains finite, while a 'slender' ship reduces to a line, i.e. its draft goes to zero with the beam. The main mathematical tool used in slender-ship theory is the method of matched asymptotic expansions, which the author approaches in the 'physical' style of Van Dyke's *Perturbation Methods in Fluid Mechanics.* The main material of the article is presented in three chapters on 'Slender ships in unsteady motion at zero speed', 'Slender ships in steady forward motion' and 'Slender ships in unsteady forward motion'. These chapters describe the solutions to a wide range of problems although, as the author acknowledges, there is no attempt at comprehensiveness in the treatment or in the bibliography.

The articles by Ericksen and Chadwick & Smith are on branches of solid mechanics. Ericksen's main interest lies in the problem of selecting definite forms for constitutive equations in elastostatics; Chadwick & Smith discuss their title subject using, in particular, new insight which has come from exploiting ideas originating in the theory of dislocations. Finally, Hsu takes up the problem of nonlinear parametric excitation. Basically, parametric-excitation problems arise when a vibrating system is excited not by an external force, but by the periodic variation of one of the parameters describing the system; a simple example would be the variation of a spring constant with time. Hsu considers two topics for nonlinear vibrations: asymptotic analysis of weakly nonlinear second-order systems and the application of the theory of nonlinear difference equations.

Hydrodynamics of Estuaries and Fjords. Proceedings of the 9th International Liège Colloquium on Ocean Hydrodynamics. Edited by J. C. J. NIHOUL. Elsevier, 1978. 546 pp. $57.00.

The twenty-eight articles in this book constitute a valuable survey of the range of methods that are being used to predict the detailed dynamics of that part of the sea most immediately important to mankind. These methods include field surveys, elegant mathematical analyses, numerical computational methods and laboratory experiments. Some articles are merely abbreviated versions of work published elsewhere. The original contributions show that rapid progress is being made in this subject area, and thus this book is necessarily of transient interest. However, for the next few years it will spend little time neglected upon library shelves. The detailed subject index is most helpful to a research worker in a hurry.

Ultrasonics International 1977. Edited by Z. NOVAK. IPC Science and Technology Press, 1978. 507 pp. £17.00.

This book contains the proceedings of the most recent biennial conference and exhibition held at Brighton in June 1977. The three invited papers include one on 'Sonar studies of the continental shelf', by W. D. Chesterman & M. Heaton, with impressively clear 'aerial' views of sand waves and many other features on the sea bottom. Typical session headings are 'Medical and biological applications of ultrasound', 'High power ultrasonics', 'Visualisation' (e.g. of three-dimensional objects detected ultrasonically), 'Physics of ultrasonics' and 'Underwater ultrasonics'. Of specialist interest to some JFM readers would be five papers on Doppler ultrasonic anemometry, one on diffraction of laser light by an ultrasonic wave, and one on 'A comparison of ultrasonically generated cavitation erosion and natural flow cavitation erosion'.