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REVIEWS

Modern Developments in Gas Dynamics. Edited by W. H. T. LOH. Plenum Press, 1969. 386 pp. $ 25.00

This volume is based on part of a course on modern developments in fluid dynamics and heat transfer given by guest lecturers at the University of California at Los Angeles. Over the last decade there has been rapid growth in gas dynamics, particularly in those aspects of the subject related to hypersonic aerodynamics, and most of the chapters deal with recent work in this field.

The first chapter, by W. H. T. Loh, deals with the 'Theory of the hydraulic analogy for steady and unsteady gas dynamics', and gives a useful review of the topic. The most recent reference, however, is to a 1960 paper, and most of the chapter refers to work done ten or more years before that.

Chapter 2, by E. R. G. Eckert, is on 'Combined heat and mass transfer processes'. The author first discusses generally the basic processes involved, and derives the equations describing them. The equations are then applied to the boundary-layer flow of gases at high temperatures and with chemical reactions.

'Hypersonic viscous flows' are considered in more detail by A. Henderson of NASA in chapter 3. He deals first with induced pressure effects due to viscosity and nose blunting, and then with solutions for compressible laminar boundary layers using local similarity approximations. Current experimental evidence on factors affecting boundary-layer transition is clearly and concisely presented, and the chapter finishes with a section on turbulent compressible boundary layers.

Chapter 4, by H. K. Cheng, is on the 'Hypersonic gas dynamics of slender bodies'. This is one of the most interesting chapters in the book, and gives an account of the many flow régimes and layers which appear. The entropy wake, the blast-wave analogy and some current work on strong blowing and on drag minimization are discussed, as is the problem of vorticity external to a hypersonic boundary layer. A final section reviews recent work on needle-like bodies in viscous hypersonic flow, and gives a formulation of the three-dimensional interaction problem.

In chapter 5, J. F. MaCarthy presents an account of 'Hypersonic blunt body gas dynamics', and gives some of the methods and techniques being used in the aerospace industry for the calculation of the complete flow field past space capsules of the Apollo type, including the wake region.

Chapter 6, by S. A. Schaaf, gives an introduction to 'Rarefied gas dynamics', including free molecular flow and slip flow, and draws attention to the growing complexity of recent work on the latter. The chapter is, however, too brief to cover the subject adequately and there are only three references.

Two chapters are concerned with radiative heat transfer: chapter 7, by S. I. Pai, on 'Fundamentals of radiation gas dynamics', and chapter 8, by F. K. Moore, on 'Some problems of radiative heat transfer'. Chapter 7 gives first a broad treatment of the subject and goes on to deal with channel and Couette and boundary-layer flows and stagnation point heat transfer. Chapter 8 handles some specific areas of current research including adsorption coefficients, the differential approximation and a problem of thermal choking by radiation.

The final chapter, chapter 9, is also by S. I. Pai and gives a review of theoretical plasma dynamics. He deals mainly with single-fluid models of magneto- and electro-fluid dynamics, although a short section on multi-fluid theory is given at the end of the chapter. Much of the material in this chapter and in chapter 7 has already appeared in Pai's books although a few new topics have been added.

The volume attempts to present an integrated picture of recent work in hypersonic gas dynamics. However, the standard and method of treatment vary considerably from chapter to chapter, and the result is a heterogeneous collection of review monographs. The book is likely to be of most interest to those who wish to bring themselves up to date in certain specialized areas of hypersonic aerodynamics and heat transfer, and chapters 2–5 are particularly recommended in this respect.

R. N. Cox

Dynamic Stability of Bodies Containing Fluid. By N. N. Moiseyev and V. V. Rumyantsev. (Translated by Scripta Technica and edited by H. N. Abramson.) Springer-Verlag, 1968. pp. 345. DM 66.40 or $16.60.

The spectacular nature of the interaction between a spinning rigid body enclosing fluid was first demonstrated by Lord Kelvin in 1877. He showed that a thin shell full of water spins stably when slightly oblate but is violently unstable when slightly prolate. And even without rotation the sloshing problem was of course already well known to train travellers trying to drink from a cup or eat soup. Scientific interest in these phenomena has been maintained subsequently and in recent years has reached major proportions as a result of the onset of the missile and space age. In the west the main foci of endeavour have been the elucidation of the nature of the instabilities, which seem to be due primarily to resonance between the free periods of oscillation of the enclosed liquid and the rigid container, and the development of means of suppressing them. As the western work has been largely independent of Russian scientists, this book, written by two of their leading experts in this field, is especially to be welcomed. Incidentally the lack of interaction is mutual; few western contributions are quoted and all are 60 or more years old.

The book is divided into two parts which may be regarded as independent. The first part, written by Professor Rumyantsev, describes a general theory of the dynamics of a fluid-filled body and proves a number of theorems on stability, making extensive use of Lyapounov functions. Essentially the fluid is supposed to be either in irrotational motion or initially to have a uniform vorticity. In the first case the stability problem may be reduced to that for an equivalent rigid body, provided the cavity is full, and in the second case a sufficient condition for stability is established, broadly that the equivalent rigid body is oblate. A number of general theorems about the motion are proved including some with partially filled cavities and viscous fluids. These results are of considerable interest and show that substantial progress has been made in the rigorous theory.

The second part, written by Professor Moiseyev, considers the small oscillations of a rigid or elastic container of fluid about a position of rest. After some general preliminaries an extensive discussion is given for beams. These are a special class of containers, well known to students of elasticity, whose motion and distortion can be described in terms of functions of one space variable and time only. It is established that a necessary and sufficient condition for the stability of a beam-fluid system, even when the cavity is only partially filled, is the stability of an equivalent beam not containing fluid. A general account of the spectral properties of the governing integro-differential equation is also given and the use of the Ritz method of determining them is advocated. Short sections on particular problems are also included, among them the effects of viscosity and surface tension.

After reading the book it becomes clear why the referencing between East and West is mutually exclusive, for essentially the directions of research are different. Basically Russian scientists have been interested in providing general theorems about stability and in developing the powerful ideas originated by Lyapunov and Zhukovsky. However, the almost total lack of reference to experiment has led to a very one-sided picture of the field and has meant that a number of highly interesting mathematical problems have been left untouched. Thus although much solid progress in the rigorous theory is reported in the first half of the book, the theorems proved are not very helpful in getting to grips with the problems found by engineers having to design spinning containers, which of necessity usually have to be quite prolate. In addition to the spin-up, which can lead to initial instabilities, the resonance problem of the steady state has two intriguing features: (*a*) the motion of the fluid depends on the solution of a hyperbolic equation with elliptic boundary conditions, and (*b*) the spectrum of the frequencies of the free oscillation of the fluid is unbounded in both directions. At present a general theory on the lines of Part I does not seem likely to lead to a full understanding of the mathematical issues raised.

It is natural to compare the second part with another book also edited by Dr H. N. Abramson, *The Dynamic Behaviour of Liquids in Moving Containers* (SP-106 N.A.S.A. Washington D.C., 1966). This book discusses the experimental information at length, examines the numerical problems of finding the eigenvalues, looks at the non-linear properties of the fluid motion, comments on possible damping devices, and gives a fuller account of the surface tension problems that arise in low gravity situations. Consequently the engineer will find it a much more useful source book than the present volume under review, while the applied mathematician is recommended to read both for a complete picture of the present state of development of the static stability of bodies containing fluid.

K. STEWARTSON

Topics in Nonlinear Physics. Edited by N. J. Zabusky. Springer-Verlag, 1968. 724 pp. $13.50 or DM 54.

A natural effort on the part of physical scientists has been to decompose the complicated behaviour of the physical world into non-interacting modes. This has led to the development of the powerful techniques of linear analysis that underlie so much of the present physical theory. But always there is some interaction between modes, the linear theory is an approximation, and the physical system is, in truth, non-linear. Unfortunate as this may be for the analyst it saves us all from the disaster of some most rapidly growing mode. The waves break and we survive to try to understand something of non-linear systems.

The International School of Non-linear Mathematics and Physics (Munich, Summer 1966) hoped to identify the common aspects of non-linear problems. The lectures in the Physics Section collected in this volume tend to show instead their diversity. The volume begins with a fascinating survey by Professor Heisenberg of the many non-linearities that he has encountered. In a series of lectures Prigogine discusses his approach to non-equilibrium statistical mechanics through approximations to the Liouville operator. He translates thereby statistical mechanics into the language and diagrams of quantum field theory. This will be appealing to some and repulsive to others. Prigogine's ideas are extended to relativistic plasmas in lectures by Baus. Bloembergen's lectures cover the theory of non-linear optics and lasers. John Wheeler's contribution on geometrodynamics describes his theory of all possible universes and should at least be read as entertaining science fiction. But of most interest to the readers of this journal are likely to be the lectures by Truesdell on continuum mechanics and by Saffman on turbulence.

The rigorous extension of continuum mechanics beyond the domain of linear elastic solids and Navier–Stokes fluids into the domain of materials obeying more general constitutive equations, e.g. non-linear and with memory, has been the work of a small and dedicated group during the last twenty years. A principal recorder of this work in rational continuum mechanics has been the modern schoolman Clifford Truesdell whose 18 lectures on 'The Nonlinear Field Theories in Mechanics' are included in this volume. These are based on material covered more fully and, I believe, more satisfactorily in his 30 lectures published as *The Elements of Continuum Mechanics* (Springer-Verlag, 1966). Both sets of lectures include problems well designed to draw the reader into the work, but the shorter set has sacrificed much of the rich explanatory prose for which Truesdell is famed. Of course, the text to accompany the lectures must be the encyclopaedic work of Truesdell and Noll, *The Nonlinear Field Theories of Mechanics* (Handbuch der Physik, Band III/3, Springer, 1965). Many readers will be attracted by the beauty of the mathematical methods even if they have no real interest in polymer solutions climbing rotating rods.

For the mathematician turbulence deals with the statistical properties of solutions to the Navier–Stokes equation; for the physicist it deals with the interaction of eddies of different sizes. Philip Saffman's 'Lectures on Homogeneous Turbulence' are from the physicist's viewpoint. The pessimistic tone of the lectures suggests to me that physical intuition is insufficient to the task. I agree, on the other hand, that the mathematical methods have been most valid in artificial situations of little physical relevance.

Saffman includes here his recent work on the structure of the largest scales of turbulence. These scales are so dependent on the nature of the production of the turbulence that they obey few universal laws. Fortunately numerical simulation by computers now becoming available should give us the large-scale response to all possible kinds of forcing.

An excellent example of 'physical explanation' in turbulence is Saffman's still incomplete model of energy cascade and dissipation in which the significance of the Taylor microscale λ and of the Kolmogorov dissipation scale η is displayed. The model involves a primary cascade in which the straining induced by the energy-containing eddies produces a collection of vorticity sheets of thickness λ. These sheets in turn break down in a secondary cascade to produce cells with dissipating boundary layers of thickness η. An intriguing aspect of this model is that the collection of sheets may have a lognormal distribution of strengths and thus may account for recent observations and theories of intermittency. A disturbing aspect is its reliance on detailed physical arguments that are difficult to test by observation.

Saffman concludes his lectures by discussing two of the recent mathematical turbulence theories. Of these he is optimistic about the Wiener–Hermite expansions and critical of the direct-interaction approximation. However, subsequent work has shown that the Wiener–Hermite expansions do not have in their present form the relaxation properties thought necessary to avoid 'turbulence' in the energy spectrum. His most severe criticism of the direct-interaction approximation is of the factorizations of moments of products of velocities and impulse response functions, for he objects that these do not follow from statistical homogeneity. They were, however, originally correctly deduced from the additional assumption that widely separated regions of flow are statistically independent. The most serious difficulty of the original direct-interaction approximation is its sensitivity to random Galilean transformations imposed on the flow, and indeed over the ensemble of such transformations widely separated regions become dependent and the factorizations become invalid.

For readers already involved in non-linear problems this volume will show how others go their different non-linear ways, but the newcomer should not expect to find here any simple guiding principles.

C. E. LEITH