REVIEWS

Advances in Applied Mechanics. Vol. VI. Edited by H. L. DRYDEN, TH. VON KARMAN and G. KUERTI. New York: Academic Press, 1960. 294 pp. $9.00.

This latest volume in the series includes five articles on a diversity of topics in the field of fluid mechanics. The first two of these are concerned with boundary layers, 'The theory of unsteady laminar boundary layers' written by K. Stewartson and 'Boundary layer theory with dissociation and ionization', by G. Ludwig and M. Heil. W. Chester discusses 'The propagation of shock waves along ducts of varying cross-section,' and K. Oswatitsch, in the longest of the five articles, deals with 'Similarity and equivalence in compressible flow'. The book concludes with a short account, by R. Wille, of some recent work under the heading of 'Karman vortex streets'.

After a short introduction, the first two chapters of Stewartson's article examine Rayleigh-type problems (in which the solid boundaries move parallel to themselves). The importance of the relatively simple analytical solutions, which can be obtained from studies of this kind, in helping to understand more complicated phenomena is emphasized. Of particular interest are the current attempts to tackle Rayleigh problems via kinetic theory. The discussion here centres mostly about the use of Grad's thirteen-moment equations, by Lees and Yang, but the pessimistic conclusions to this section would seem to be of satisfaction only to the most superstitious gas kineticist!

Schaaf's use of the Navier–Stokes equations with a simple slip velocity boundary condition is commented upon as a '...somewhat crude approximation'. This seems rather harsh comment in view of the fact that this approximation links both free-molecule behaviour at small times with continuum behaviour at large times, preserves some of the essential physics of the problem throughout, and does all this with considerable analytical simplicity; not very refined, perhaps, but not crude.

The remaining chapters are concerned with boundary layers proper. A discussion of the boundary-layer equations in incompressible flow brings out their mixed wave-like and diffusive character and leads to the distinction between two types of unsteady boundary layer. These are then examined separately under the headings 'Stagnation boundary layers' and 'Leading edge boundary layers'. Fluctuating boundary layers are treated next (e.g. a cylinder in a free stream whose velocity oscillates about a mean value) and the article concludes with a review of shock-tube boundary-layer theory.

The next article, by Ludwig and Heil, is rather misleadingly titled. In fact about 70% of their space is devoted to a discussion of the kinetic theory of a dissociating, ionizing and relaxing gas, without any special reference to boundary-layer problems as such. This is not in any way to be implied as a criticism of the article in general. Indeed this (necessarily brief in places) discourse on molecular encounters and the Boltzmann equation and its application to problems of modern continuum gas dynamics is most valuable. It should at the very least serve as a salutory warning to the gas dynamicist not to treat his transport coefficients lightly and might even make some of the braver spirits reach for the nearest book on wave mechanics. One of the most stimulating aspects of present day gas dynamics lies in its close link with 'respectable' subjects like physics and physical chemistry.

The use of the binary collision approximation in Ludwig's and Heil's article restricts their treatment of the ionized gas problem to low degrees of ionization. Furthermore, the absence of sufficient data on the multitudinous cross-sections required by the formal kinetic theory is a little depressing. With current work under way on this question we may hope that it will not be too long before sound theoretical predictions of viscosities, conductivities, etc., can be made for the complicated gas mixtures of interest. There is a strong need to know how these quantities behave, especially in gases which are far removed from chemical and internal state equilibrium, but which are otherwise according to 'Navier–Stokes'.

The boundary-layer part of this article discusses first the usual Prandtl approximations applied to a dissociating gas flow, and then deals with similar and locally similar solutions for flat plates and stagnation point regions. The catalytic wall boundary condition is given incorrectly as 'dissociation fraction equals zero', the authors remarking simply, 'However, see also reference 59'. Reference 59, by Scala, presents the correct boundary condition, as does other work which was presumably available to the authors at the time of writing. The failure to present this quite important boundary condition properly must count as something of an omission in an article with the stamp of authority.

Chester's article returns to Utopia, in which γ is constant. After introducing the exact steady-state theory and its need for the presence of contact discontinuities, the majority of the remainder of the article is concerned with Chisnell's and Whitham's approximate theories (which are capable of handling the time dependent problem). Chisnell's theory is developed first via Chester's own linear theory results for the change of shock Mach number brought about by a small change in duct area.

Comparisons between the exact and approximate theories show up the way in which accumulated wave interactions behind the shock ultimately modify its strength.

The article concludes with some previously unpublished results, derived by the author using an extension of Chisnell's hypothesis. These refer to the case in which a steady flow exists in the duct before the advent of the shock wave. Of especial interest here is the suggestion that second-throat flow breakdown in wind tunnels may be associated with wave propagation effects as well as with those arising from the boundary layer.

The fourth article, by Oswatitsch, is a formidably comprehensive account of similarity and equivalence theory in inviscid gas dynamics. There is no limit to the Mach number range of this study, each of the four ranges of sub-, trans-, super- and hypersonic receiving its share of attention. The first twenty or so pages are devoted to basic considerations; for example, differential equations, shock equations, boundary conditions, and their simplification and linearization are all included here.

The linear theory and its resulting Prandtl–Glauert analogies is dealt with (both for wings and bodies) in the next chapter, followed by a short chapter on higher approximations. Transonic similarity is examined for wings and profiles at incidence and zero incidence. Bodies of revolution in this Mach number régime are also considered, a special section being devoted to the flow about right-circular cones. Hypersonic similarity comes next and unsteady flow is treated, mostly within the domain of the linearized two-dimensional equations. Flutter problems receive some attention also. A chapter on bodies of low aspect ratio, involving the equivalence laws and area rules, concludes the article.

The text is liberally supported by diagrams representing the results of theory and experiment. This compact and thorough account of an important topic is a valuable addition to the literature.

The final article in this volume comes as a suitable epilogue to what has been, largely, a discussion of theoretical fluid mechanics. Two remarks in particular caught the reviewer's eye. The opening sentence of the introduction reminds the reader that the phenomenon of periodic vortex shedding and the formation of vortex streets have been engaging the attentions of experimenters and theoreticians for the past 50 years. Then, in the summary, while commenting on the results of vortex street stability theory and their (not wholly encouraging) relation to observation, the author remarks, 'Whether this is a contradiction between theory and experiment, so often lightheartedly referred to, or whether theory and experiment actually refer to two entirely different subjects is worthy of clarification'. Truly, applied mechanics has advanced, but there remains a great deal of interesting mopping-up to be done.

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Incompressible Aerodynamics. Edited by BRYAN THWAITES. Oxford University Press, 1960. 636 pp. 75*s*.

This is the first volume of a new series, the Fluid Motion Memoirs, sponsored by the Aeronautical Research Council. It is a comprehensive review of certain flows of incompressible fluid, which are of special importance to aeronautics. The central theme of the book is the up-to-date theoretical and experimental treatment of the uniform flow of air and other viscous fluids past two-dimensional aerofoils and three-dimensional wings. The motion is assumed to be steady, and the effect of compressibility is neglected. Two more volumes of Fluid Motion Memoirs, on laminar boundary layers and on turbulence, are in preparation, and the three volumes will cover in the main the same ground as the now classical *Modern Developments in Fluid Dynamics*, edited by Sydney Goldstein and published in 1938.

The editor of the present volume is Bryan Thwaites, and the book is a synthesis of original contributions by D. G. Ainley, L. F. Crabtree, M. B. Glauert, D. Küchemann, M. J. Lighthill, A. W. Mair, E. C. Maskell, T. R. F. Nonweiler, R. C. Pankhurst, J. H. Preston, A. G. Smith, D. A. Spence, B. Thwaites, J. Weber, L. G. Whitehead, L. C. Woods, with the assistance of other well-known authorities. The result is a homogeneous work, not merely a collection of chapters by several authors.

The chapter headings are: (1) Some general principles (60 pages). (2) The calculation of the boundary layer (30 pages). (3) Theoretical models of real flows (20 pages). (4) Uniform inviscid flow past aerofoils (64 pages). (5) Uniform viscous flow past aerofoils (30 pages). (6) Boundary-layer control (49 pages). (7) The displacement effect of wings in uniform flow (36 pages). (8) The lifting effect of wings in uniform flow (78 pages). (9) Uniform flow past bodies of revolution (53 pages). (10) Uniform flow past joined bodies (41 pages). (11) Rotary flows (35 pages). (12) Some miscellaneous topics (75 pages). References (38 pages).

Chapter 1 on general principles gives a brief but readable account, touching on, for instance, the Navier–Stokes equation, boundary layers, inviscid flow, irrotational flow, free and forced transition to turbulence. Chapter 2 on boundary layers examines critically various formulae which have been proposed for laminar and turbulent boundary layers, under various conditions. Chapter 3 describes the decomposition of the field of flow into regions of inviscid flow, boundary layers, bubbles, cavities, etc., and discusses the appropriate flow models and the interaction of the various flow regions. These first three chapters lay the foundation for the later chapters.

Chapter 4 gives a detailed exposition of the inviscid model in two dimensions. Here it is necessary to distinguish between unmixed and mixed boundary conditions; the former are appropriate to unseparated flows and state that the velocity normal to a given boundary is zero, the latter are appropriate to separated flows bounded partly by the aerofoil (where the normal velocity is zero) and partly by a hypothetical line representing the edge of the separated region (where the velocity is regarded as known). For unmixed boundary conditions it is further necessary to distinguish between the direct problem where the shape and incidence of the aerofoil are given and the velocity distribution on the surface is required, and the inverse problem where the velocity distribution is prescribed and the shape of the aerofoil is required. The thorough treatment given in this substantial chapter is a fine example of applied mathematics. Chapter 5, concerned with viscous effects, is necessarily less elegant in its mathematical aspects. Important problems here are the determination of the drag and lift both for unseparated and for separated flows. Chapter 6 describes boundary-layer control by sucking and blowing, and introduces some challenging problems where more work is needed.

We now come to consider wings of finite span. Chapter 7 treats the effect of wing thickness in inviscid flow when there are no trailing vortices in the flow. The effect of the wing is approximated by a distribution of sources inside the wing, where an approximation to the source strength may be determined from a linearized theory. Difficulties arise near the wing tips and for wings of small aspect ratios; for the latter a slender-body theory is described. The discussion also includes swept wings, wing-tip effects, and wings of general planform.

Chapter 8 treats inviscid lifting-surface theory; here a sheet of trailing vorticity accompanies the thin wing and is associated with the lift and the induced drag. Further approximations are appropriate when the wing is of large or small aspect ratio; the former case is by now classical, the latter has become important only recently. The present state of knowledge of both cases is presented in considerable detail in this chapter. Chapter 9 deals with the problem, not covered by previous chapters, of flow past bodies of revolution. For axially symmetric inviscid flows the body is replaced by distributions of sources, either on the axis or on the surface of the body, where the source strength must be found by numerical computation. Alternatively, a slender-body approximation may be used. These methods can all be extended to lateral flows without separation. Some very interesting numerical comparisons are given, and it is shown that in certain circumstances the agreement with experiment is also very close. The calculation of the boundary layer at incidence presents a difficult problem which is discussed at length.

So far the flows have been past simple geometrical configurations. The treatment for joined bodies, described in Chapter 10, is much more complicated and often much less exact, but is clearly of great practical importance. Chapter 11, on rotary flows, considers fluid flows such as are encountered in axial-flow compressors, and in particular the model of the actuator-disk on which the velocity vector and pressure are assumed discontinuous.

Chapters 4 to 11 give an up-to-date account of a number of well-defined classical topics of lasting importance; chapter 12 treats a number of more recent fringe topics which are likely to be of importance in the future. These include the analysis of a theoretical model of the jet flap; wings with non-planar vortex sheets; wings with bubble-type flow separation; non-planar lifting systems such as biplanes, annular aerofoils and cascades; and the effect of a non-uniform mainstream on bodies, from tail-planes behind wings to Pitot tubes in boundary layers.

This book presents a rational theoretical basis for an understanding of aerodynamical phenomena. Comparison of theory and experiment is one of the main themes of the work, and it is seen in many places how theories have been modified and generalized in the light of observations. The very good style, presentation, and printing make this book a pleasure to read. It is warmly recommended to all who take an interest in fluid mechanics, whether specialists or not. It is also recommended to workers in other branches of engineering where a more scientific approach might sometimes be used with profit.

F. URSELL