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REVIEWS

Topics in Applied Physics. Volume 12. Turbulence. Edited by P. Bradshaw. Springer, 1976. 335 pp. DM 97.00.

This book is written as an introduction to our current 'state of knowledge of turbulence in most of the branches of science which have contributed to that knowledge'. It is made up of a series of essays by a number of authors chosen to emphasize the *breadth* of the study of turbulence; in particular where it helps 'people who need to understand or predict turbulence in real life'.

Some important applications are intentionally omitted: turbulent mixing, which is to be treated in a forthcoming volume of this series; noise production, because it is too specialized, and architectural aerodynamics and hydraulics, which 'have turbulence problems which are basically duplicates or syntheses of those in other subjects'.

The reasons for the latter omissions are somewhat misleading, especially in the context of the particular choices of theory and measurement presented in this book, where, surprisingly, the statistical description and analysis of turbulence, the characteristic large-scale eddying and turbulence of separated flows receive scant attention. All are important aspects of many practical turbulent flows, but are especially important aspects of flows studied in architectural aerodynamics. It seems hard to believe that the editor's contact with 'people in real life' apparently excludes people concerned with these aspects of turbulence!

The first chapter, by P. Bradshaw, is a highly readable and provocative introductory essay, summarizing in 43 pages most of the basic ideas about homogeneous and inhomogeneous (mainly shear) turbulent flows. The style is a racy mixture of mathematics, physical arguments and some more or less familiar anthropomorphisms. The hoary old question of the validity and usefulness of mixing-length and eddy-viscosity methods is discussed at length. An unnecessarily direct connexion between the two is made, I should have thought. The damning judgement on the use of these methods is not reconciled with the fact that the second half of chapter 5 is devoted to the use of eddy viscosity! What is a person in 'real life' meant to think? The final section of this chapter is devoted to the 'eddy structure of shear layers'. It is emphasized that the study of these eddies by correlation, sampling or visualization methods is of great value in developing realistic models of turbulence structure. However, Bradshaw points out that these large eddies are effectively ignored by most proponents of closure models for turbulence shear stresses. Bradshaw concludes by hoping that this chasm between the different research groups, which he calls 'current confusion', is transient!

The second chapter, by H. H. Fernholz, is on 'External flows', by which he means turbulent boundary layers and the effects on them of surface and free-stream perturbations. Quantitative and mathematical descriptions of the flow are restricted to the mean velocity profiles. The main emphasis is on describing measurements and the physical processes which may account for the observations. Some of the topics covered are the mechanics of the turbulent boundary layer (including 'bursts', 'sweeps', etc.), low Reynolds number effects and transition, free-stream turbulence, wall roughness, wavy walls, curving walls, and separated flows due to protuberances. Fernholz's own specializations of three-dimensional and compressible boundary layers are briefly reviewed at the end of the chapter, which includes some 446 references. The chapter seems to underline the differences, controversies and uncertainties in the understanding and measurement of these turbulent flows, rather than the areas of agreement, which makes it a challenging review, but a disconcerting initiation to the subject.

Chapter 3, on 'Internal flows', is by J. P. Johnston. The developing and fully developed states of turbulent duct flows are described with particular emphasis on curved and secondary flows, and the particular kinds of separating and reattaching flows found in internal flows; for example in expansions of pipes, in ejectors, and in diffusers (a particular speciality of Stanford). The ways in which turbulent boundary layers affect turbomachinery performance are briefly reviewed, with some emphasis on the special problems of the periodicity of these turbulent flows.

Geophysical turbulence and buoyant flows are reviewed in a short fourth chapter by P. Bradshaw and J. P. Woods. The purpose of this chapter is to 'review the subject for workers concerned with buoyant flows in the laboratory or in engineering', partly with the unusual aim of showing that geophysical insight into the turbulence of buoyant flows may help in the understanding of some engineering buoyancy problems. Particular emphasis is given to the atmospheric surface layer, upper-ocean turbulence and buoyant turbulent convection. Laboratory models of geophysical flows are mentioned without any reference to the various limitations involved, an important aspect for a student to understand.

The 'Calculation of turbulent flows' is the subject of the fifth chapter, which is in two parts. The first, by W. C. Reynolds, is a synopsis of his recent paper in volume 8 of the *Annual Review of Fluid Mechanics* (1976) on the varying degrees of complexity and various approaches to modelling Reynolds stresses that are now in use. It is a difficult subject to make interesting, but by bringing out the physical assumptions involved Reynolds succeeds. The really new approach that is mentioned here is the use of large computers to calculate the three-dimensional Navier–Stokes equations for the large scales of turbulence with the only approximation being in the modelling of the smallest-scale motions which produce 'sub grid scale Reynolds stresses'. The second part of the chapter, by T. Cebeci, is an account of the simpler methods of calculating the development of turbulent boundary layers either by integral methods or through assumptions about the eddy viscosity. These methods are widely used in industry and the author (who works in the aircraft industry) shows that, without too many special empirical factors, they can now be applied to three-dimensional boundary layers, even those undergoing significant spanwise strain.

The heat and mass transport in turbulent flows is reviewed by B. E. Launder. The emphasis is on the comparison between turbulence transport closure models (which are explained well) and laboratory measurements of heat and mass transfer (for which many references are given) rather than the basic physical processes. Some of the important topics covered are: the variation of the turbulent Prandtl number between different shear flows, and as a function of Reynolds number and molecular Prandtl number; modelling heat fluxes in stratified flows; the transport and dissipation of scalar fluctuations, and heat transport in separated flows.

Two-phase and non-Newtonian flows are covered in the last chapter, by J. L. Lumley. First there is a fine introduction to the distinctive physical features of various particle-laden flows and the practical situations where these flows arise. Next there is a detailed discussion of the motion of a suspension of effectively isolated, heavy, rigid, spherical particles, showing how, depending on the size of the particles, their motion depends on the Lagrangian or Eulerian statistics of the turbulence. Then the effects of the particles on a shear flow are analysed, which leads to a discussion of drag reduction by additives.

This rather expensive volume is a coherent and readable introduction to current turbulence research, particularly research into closure models for the Reynolds stresses. There is not much discussion of how these research findings are being applied, though the research described is obviously aimed at application in the fields of aeronautical and mechanical engineering. Even within this field there are important aspects of the analysis, description and measurement of turbulence that are excluded. There is a good subject index, but it is disappointing that the references do not include the titles of articles. The editor is to be congratulated on bringing these essays together, and I would urge fluid-mechanics libraries to make sure that they have this book.

J. C. R. HUNT

Turbulent Jets. By N. RAJARATNAM. Elsevier, 1976. 304 pp. £23.45.

G. N. Abramovich's *Theory of Turbulent Jets*, which appeared in an English language edition in 1963, remains a landmark in the literature of turbulent free shear flows. Part of its significance lies in its presentation of numerous Soviet experimental studies which, were it not for the translation, would remain largely unheard of in the West. A larger contributor to the book's impact is its sheer comprehensiveness. For every conceivable self-preserving shear flow, numerical or analytical solutions are presented using both the mixing-length and the uniform eddy viscosity models of momentum transport. After that Abramovich plunges into an exhaustive treatment of non-similar flows by way of approximate integral treatments. As a research student at the time the book appeared, what impressed me most was the range of very practical yet seemingly intractable flow problems that had been tackled and brought at least to superficial order by the resolute application of simple analytical methods.

Dr Rajaratnam's new book *Turbulent Jets* displays all the symptoms of having evolved in the shadow (and light) of Abramovich's volume. In a number of respects the present volume is more attractive than its predecessor: the diagrams are clearer and of better proportion while the standards of 'camera-ready' production have advanced a long way in the intervening years. The text too is clearly and intelligently developed, having sympathetic regard for difficulties that graduate students may encounter. In some respects the present volume is less ambitious in scope than *Theory of Turbulent Jets*; heat transport processes are not considered, nor are variable-density flows. These exclusions inevitably narrow the appeal of the volume. Nevertheless the important topics of jets in cross-flow, swirling free shear flows, and the wall jets are given one or more chapters each while they are either omitted or receive only brief attention in Abramovich's volume. A particularly attractive feature is the wealth of figures on the mean-flow characteristics – some culled from papers published as recently as 1975.

Free shear flows are the concern of workers with such a range of interests that nearly everyone will find aspects of style or content that he will wish had been treated differently. As suggested above the content appears to have been trimmed to serve most directly the interests of graduate and research students in civil engineering. I should personally have preferred a more critical examination of the data presented and some discussion of the turbulence structure of the shear flows under study. Fortunately W. Rodi's extensive review in volume 1 of *Studies in Convection* and A. A. Townsend's *Structure of Turbulent Shear Flows* partly remedy these omissions, though these works do not cover all the types of shear flow in Dr Rajaratnam's book.

The most serious limitation of the volume lies in its theoretical treatment. The author's approach has been to clarify and simplify Abramovich's methods, introducing for this purpose a skillful blend of similarity analysis and integral treatment. Yet, over the years since Abramovich's volume appeared theoretical fluid mechanics has experienced the vast changes in methodology that have sprung from the ready availability of large digital computers. Even though hydraulics has traditionally been conservative in its use of detailed flow models, several groups in this area now make routine predictions of three-dimensional jets and plumes, solving, by finite-difference methods, the three-dimensional Reynolds equations. These methods, though not without their own shortcomings, greatly enlarge our ability to simulate the complex flows that arise in rivers, bays or lakes. Against this background many university faculties will find the treatment in *Turbulent Jets* largely irrelevant to the methods of flow analysis they believe should be emphasized in postgraduate courses and in research.

B. E. Launder