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REVIEW

Turbulent Flows in Engineering. By A. J. Reynolds. Wiley, 1974. 462 pp. £10.00.

Can one "present in a rational way the methods of predicting turbulent flows now used in engineering practice"? This is a different question to: can one present in a systematic way a set of methods for predicting turbulent flows in engineering situations? The answer to the second question is probably yes, but that to the first question certainly no. Yet in his introduction Alan Reynolds states that the primary aim of his book is to answer the first question. This reviewer's limited experience of the prediction methods used by practising engineers is that a bewildering variety of different techniques are used by different organizations. The variety reflects the diversity of prediction methods being developed and propagated by the different research groups in turbulence. The engineers are certainly not to blame. The fact is that predicting turbulent flows is an uncertain and somewhat subjective, but rapidly developing art. Therefore, despite the author's ambitious aim, it is inevitable that this book is a survey of those theories, experiments and physical explanations of turbulent flows which the author considers are relevant to the training and practice of engineers, in particular, mechanical, aeronautical and process engineers.

The first chapter, entitled "The problems of turbulence", is a useful introduction to the terminology and concepts of turbulence in 38 pages; Reynolds' experiment, wall roughness, separated flows, free turbulence, entrainment, intermittency, eddy viscosity, vortex stretching, the energy cascade, time and ensemble averages, self-preservation, Eulerian and Lagrangian descriptions, and the problem of closure are all discussed. This list shows that any student wishing to master the underlying physical or mathematical arguments would have to refer elsewhere. There is one awful howler in this chapter (p. 18). It was Lewis Fry Richardson who wrote "Great whirls have little whirls...", not E. G. Richardson. Really!!

The second chapter, on experiments and their analysis, begins by describing the techniques for visualization and measurement of turbulent flows. The recent development of hot-wire calibration by vibrating a wire in a moving air flow (not a stationary air flow, p. 69) is mentioned, but the reference to Perry & Morrison (*J. Fluid Mech.* vol. 47, 1971, p. 765) is not given. Spectral analysis is introduced, and some values given of the typical frequencies of energy-containing and dissipation eddies for pipe flow and atmospheric air flow. The data analysis problems of calculating spectra are not mentioned. Taylor's hypothesis is mentioned but no reference is given for the reader to find out its limitations. Kolmogorov's hypotheses for the spectra of turbulence are briefly described with none of the experimental evidence cited which should give sceptical engineers some confidence in the basic idea, although, as Kraichnan and others have pointed out, the experimental data raise almost as many questions as they answer.

Chapters 3, 4 and 5 are on channel flows; fundamentals, friction and flow rate; and heat and mass transfer. The emphasis is on calculating the gross features of channel flows which engineers need for their calculations: mean velocity, concentration and temperature profiles across the channel; and at the surface, the values of the shear stress and mass and heat transfer. A physical picture of the fluid motion and forces is developed in the conventional way via the turbulence energy equation. It is very disappointing that there is no mention of the recent discoveries that the dominant physical mechanisms in turbulent shear flows near a rigid surface are connected with bursts of fluid upwards from the buffer layer (e.g. Kline, Reynolds, Schraub & Runstadler, *J. Fluid Mech.* vol. 30, 1967, p. 741; Corino & Brodkey, *J. Fluid Mech.* vol. 37, 1969, p. 1). Simple calculation methods based on eddy viscosity and eddy diffusivity are described in detail and a brief introduction is given to Townsend's prediction of the shear stress near a wall based on the turbulent energy equation. Seven semi-empirical forms for the buffer layer are given. The effects of rough walls on channel flows are described without introducing any of the new ideas developed since the 1950s; e.g. the roughness function (Clauser, *Adv. in Appl. Math.* vol. 4, 1956, p. 14) or the classification of types of roughness by Joubert, Perry and others at Melbourne. Data for head losses along open channel flows and channel junctions are given. Boundary layers are treated cursorily in chapter 8. Only the general principles and no details are given of calculation methods. For example Head's entrainment method, which is widely used in the aeronautical industry, is explained in general terms in 13 lines and no results are presented. Also Head, along with many authors cited in the text, does not have an entry in the index. There is no mention of boundary layers over rough surfaces. Both here and in the treatment of channel flows there are no data or discussion of spectra, or correlations of viscosity and pressure, which surely ought to be made familiar to aeronautical engineers, who are concerned with aerodynamic noise from jets and the vibration of aircraft surfaces: 'panel flutter'.

Chapter 9, on more complex flows, is about more elaborate prediction methods involving transport equations for Reynolds stresses and other quantities. These methods have been used in flows more complex than channel flows and thin shear layers, but no examples are given. Where the only diagram of an eddy is introduced, on p. 253, to explain turbulent transport processes in a channel flow it misleadingly has a regular oval shape. Surely a more informative picture would be a vortex line in the form of a hairpin or tangled piece of spaghetti to demonstrate the interaction of vortex stretching, molecular diffusion and the violent nature of turbulent motions near the wall of a channel.

Chapters 6, 7 and 8 are on developing flows such as jets, wakes and boundary layers. The treatment begins with a clear and useful general examination of "thin spreading flows": the conditions at the turbulent interface, the measures of the thickness of these shear layers and the relations between the shear layer and the outer flow. Momentum, energy and conservation equations are used to derive equations involving integral properties. For jets and wakes the assumption of Reynolds number similarity and self-preserving velocity and shear stress distributions are fully explained (a better introduction than Townsend's book).

Particular profiles are calculated using mixing-length assumptions. An interesting account is given of the effect on wakes and jets of altering the outer flow.

There is a large and informative index, which is primarily a subject index and only selectively an author index. Unusually for a book on turbulence, each chapter ends with about 20 questions, mainly of a computational nature, though a few would make the student think hard about the physical ideas. The references to results used in the text are incomplete.

To sum up I must confess to being disappointed that the book is not an assimilation of the latest physical ideas, calculation methods and general theories. Excluding the recent advances in the understanding of turbulent shear flows does not simplify the presentation or the understanding. Some of the ideas stemming from recent flow visualizations and measurements in fact make it easier to envisage the structure of turbulent shear flow.

This book is really a textbook for undergraduates and design engineers aimed at clarifying selected aspects of pre-1965 results about turbulent shear flows; the assumptions are well laid out and explained, but the mixing-length and self-preserving flow calculations do not differ greatly in substance from those described in Hinze's and Townsend's books of the 1950s.

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