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REVIEWS

Turbulent Reacting Flows. Topics in Applied Physics, vol. 44. Edited by P. A. LIBBY and F. A. WILLIAMS. Springer, 1980. 243 pp. DM84. $49.60.

One of the most valuable public services that can be performed by a researcher or scholar is to write a good critical review of a developing research area. The authors of this monograph, two of whom are also the editors, have produced a generally excellent review focused on analytical developments in the study of one-phase, chemically reacting, turbulent flows. The emphasis is more on gas-phase (combustion) than on liquid-phase systems. The authors are all active researchers in the field, so the presentations are up to date. The presentations are also helped by a bit of cross-referencing among the chapters.

The chapter titles are as follows:

1. Fundamental Aspects (P. A. Libby & F. A. Williams);
2. Practical Problems in Turbulent Reacting Flows (A. M. Mellor & C. R. Ferguson);
3. Turbulent Flows with Nonpremixed Reactants (R. W. Bilger);
4. Turbulent Flows with Premixed Reactants;
5. The Probability Density Function (pdf) Approach to Reacting Turbulent Flows (E. E. O'Brien);
6. Perspective and Research Topics (P. A. Libby & F. A. Williams).

The reference lists are extensive, encompassing not only papers in East European archival journals, but also various symposium proceedings, and some reports from the unpublished and semi-published 'shadow literature'.

The chapters are fairly labelled. In most cases the approach is to formulate the relevant differential equations expressing total mass conservation, momentum balance (Navier–Stokes), species balances, and energy, then to look at necessarily indeterminate sets of the averaged forms of these equations and of more exotic averaged equations deduced from them. Most of the published fairly successful (and some less successful) 'closure' hypotheses for rendering determinate a subset of moment equations or probability–density equations are reported, often with useful comments about the inherent degrees of arbitrariness and (im)plausibilities. Most of the chapters, but especially the last, indicate some directions appropriate for future research. The last also skims added topics such as the effects of Mach number or of having two phases.

Two pervasive themes that are not routinely familiar to turbulent-flow workers are the exploitation of balance equations for probability–density functions (rather than the more popular covariance and spectral functions) and, in variable-density problems, the use of density-weighted averages ('Favre averages') of the random field variables. The probability density seems a natural function for the study of reacting chemicals because reaction rates depend directly upon the local concentration values (rather than upon the Fourier amplitudes of the concentration functions, for example). The density-weighted average has the apparent advantage of yielding some balance equations which look almost as simple as the familiar averaged equations of constant-density turbulence.

These simplified forms have encouraged some investigators to apply hypotheses identical with those that are physically plausible and somewhat successful in constant-density turbulence. Unfortunately, there is no *a priori* physical justification for this analogy. In fact, as pointed out in some of the chapters, the physical interpretations of some individual terms in the Fave-averaged balance equations are unknown. Two points of concern are the following. (i) In the continuum limit of the kinetic theory of gas flow, the velocity is already a (molecular) mass-weighted average. Therefore, the Favre average velocity is a density-weighted average of a mass-weighted average. (ii) With density-weighted averaging, the resulting 'fluctuation' in field does not have zero average value.

Inevitably, the reader will find a scattering of statements and expository strategies which may seem deficient or controversial. Two nearly ubiquitous shortcomings are (*a*) the lack of tables of symbols, and (*b*) the confusing practice (avoided only in chapter 5) of using the same symbol for two different things: (i) the value of a random field variable in physical space, and (ii) the value in probability space that that variable may take on.

No table of symbols would be needed for a reader who can read each chapter without interruption, but that is a luxury which few can manage. The symbolic confusion mentioned above is potentially risky, and has been known to lead to accidental errors; at the very least, it doubles the comprehension time required for a section. Even in chapter 5 the notation could be improved by the addition of subscripts to p.d.f.s whose arguments do not appear explicitly.

There is a sprinkling of misprints, mostly obvious. A few are uncertain because of the two shortcomings just detailed. Also there are a few inconsistencies in notation among the different chapters.

Turbulence experts will find a small number of statements that merit more extensive qualifications; those less familiar with turbulence will wish for more explanation in a few places. Here are a few examples. In the turbulence Reynolds number discussion in chapter 1, equation (1.69) relating the Kolmogorov microscale to a kind of integral scale is written as an equality when it should be a proportionality; the best estimates of the constant of proportionality do not give 1·0. Shortly thereafter it is suggested that a significant 'chemical length' is $U\tau_c$, where U is mean flow speed and τ_c is a chemical reaction time. But this cannot be a basic length because it is not Galilean-invariant. In chapter 4, one of the turbulence Reynolds numbers mentioned is constructed from the r.m.s. turbulent velocity and the Kolmogorov microscale, certainly an 'odd couple'. In chapter 3 it appears that a uniformly moving frame is called a 'Lagrangian reference frame'; in fact it does not seem to follow the (turbulent) fluid motion, and thus seems Eulerian.

But these small complaints do not detract from the value of this monograph. It is a timely and authoritative outline of a major modern research area.

STANLEY CORRSIN

Engineering Calculation Methods for Turbulent Flow. By P. BRADSHAW, T. CEBECI and J. H. WHITELAW. Academic, 1981. 331 pp. £18.60/$45.00.

This will be an extremely useful book for the engineer with a need to calculate turbulent flows. If the price were not so high, it would also serve as an excellent text for a course on calculation methods. It is written in the now-familiar Imperial College style, with a panel introducing each section, summarizing the major points. The book is not, nor does it pretend to be, a place to learn about turbulence fundamentals, although chapter 2 (Conservation Equations and Boundary Conditions) is sound. The turbulence models presented are primarily the k-ϵ model (an eddy-viscosity model with a technique for calculating the local value) and, to a lesser extent, the stress-equation model (in which one or more terms of the Reynolds stress are calculated). The authors quite rightly remark that a book like this is no place to survey this year's models, although they do indicate that more advanced models are under development, and suggest names for the reader to look for.

The formal presentation of the models absorbs two chapters, and the remaining eleven are devoted to presentation of solution methods for particular types of problems: thin shear layers; two-dimensional external boundary layers; inverse boundary layer problems; unsteady 2-dimensional and steady 3-dimensional flows; recirculating flows; viscous–inviscid interactions and corner flows; stability and transition; wings; turbomachinery; and combustion. Understandably, the major emphasis is on Cebeci's box method; listings of numerous subroutines are included. Each of these problem areas presents its own difficulties, and in each area unique ways of circumventing them have been developed. It is salutary for the non-specialist in this area to discover that choosing the k-ϵ model (for example) is by no means the end of the matter; there is a great deal of good fluid mechanics involved in setting the problem up for solution in complex situations. The treatment of separation bubbles in boundary layers, and of three-dimensional separation on bodies of revolution at angles of attack, are just two interesting areas that come to mind. It is also striking how much can be computed, and how well, using relatively simple assumptions regarding the turbulence. Presumably this is because, in most of these flows, the turbulence is simply a mechanism for momentum transfer, and usually downhill; its replacement by another reasonable mechanism which transports about the right amount, and which carries a guarantee of thermodynamic realizability, will not change the flow much so long as the mean motion is handled correctly. Of course, when the role of the turbulence is more complex, as in combustion, the simplistic approach is not so successful, and the authors are conscientious about pointing out the shortcomings. They also mention that there is no guarantee of realizability connected with the Reynolds-stress models (as there is for the eddy-viscosity models), but they do not discuss realizability in general, presumably feeling with justification that this subject would be out of place in a work of this sort.

The authors spend very little time on heat transfer, and none on buoyancy; in this connection, the reader may be interested in a related volume that does cover this area from a very similar point of view: *Turbulence Models and Their Application in Hydraulics*, by W. Rodi (Delft: IAHR, 1980).

The authors raise in several places the issue of universality of the models, and are quite careful not to encourage in the reader belief in universality, emphasizing that models currently available are applicable only to groups of related flows for which they have been optimized, and cannot safely be applied outside their range of calibration. This was certainly the finding of the AFOSR–HTTM–Stanford Conference on Complex Turbulent Flows, and is surely a wise position to take in such a book. At the same time, I would like to comment to other specialists that I hope we will retain a faith in the possibility of deriving models from first principles, so that models will be related in known ways, and their range of applicability will be clear. Otherwise we will fall back on strict empiricism, and the result will be that modelling will cease to contribute indirectly to the understanding of turbulence, something that I feel it has been doing splendidly up to the present.

JOHN L. LUMLEY