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REVIEWS

The Physics of Fluid Turbulence. By W. D. McComb. Clarendon Press, 1990. 572 pp. £75.

Those who are engaged in teaching courses on turbulence and attempting to instruct graduate students in the methods and different approaches of turbulence research must welcome the increasing number of books being published on this subject. At the same time engineers and scientists engaged in solving industrial and environmental problems involving turbulent flow are making use of these new books, review articles and conference proceedings to guide their choice of appropriate models. So in reviewing another book, one first asks what is special about it and then looks to see whether it deals well with its special features, and finally one might compare it with other books or articles on these features.

The special feature of this book is its account of the recent contributions of statistical physics to the quantitative modelling of certain properties. The author does not mention what an old idea this is. Burgers (1929), Tollmien (1933) and later Batchelor (1953) discussed the possibility of how multi-component dynamical systems might provide a model of turbulence. In Chapter 4 McComb briefly describes ideal Hamiltonian systems and gives an interesting discussion of whether these models are appropriate to turbulence. Then, following Hopf, the space–time and the k-space–time formalisms for the characteristic functional are derived. This is justified on the grounds that this is a fruitful source of approximate models – a point that is not obvious to this reviewer. The chapter closes with a discussion of the importance of isotropic turbulence as a suitable test case for statistical models because of its general nature; a rather misleading impression is given that grid turbulence 'can be generated in an arbitrary fashion…', but decays to a form which is reasonably independent of these arbitrary choices!

I should have thought that much, or even most, modern turbulence research has focused on the limitations of this kind of naïve view of turbulence. Turbulence is *not* a limiting state of motion which distinguishes it from molecular motion. There is only a brief discussion here and elsewhere on the sensitivity of turbulence to initial or boundary conditions, although the author mentions later, *en passant*, that the subsequent evolution of the spectrum of homogeneous isotropic turbulence generally depends on its initial form.

Chapter 5 introduces the quantum theory concepts of renormalization perturbation theory and shows how, following Kraichnan (1959), Wyld (1961), Edwards (1964), Herring (1965), and others, it can be applied to the derivation of the statistics of turbulence. After detailed instruction in the manipulation of Feynman diagrams and other formulations, the author concludes (p. 222) 'Naturally we hope that the renormalized series has some advantageous properties – it might be convergent, or failing that, asymptotic. But…we simply do not know…the only reasonable approach is to truncate the series…where the complications are still tolerable…and make a comparisons with experimental results'. With this less than wholehearted encouragement the reader proceeds to the following chapters for explanations of the intricacies of the various kinds of theory based on these concepts.

Chapter 6 begins by pointing out that there are two fundamentally different approaches to renormalized perturbation theory (RPT). In the first approach the full equations are manipulated and approximated; then moments are taken; the approximations involve truncation of series and neglect of significant terms. A good explanation is given of how in Kraichnan's direct interaction approximations (DIA) only the *direct* interaction between wavenumbers $\boldsymbol{k}_1$, $\boldsymbol{k}_2$, $\boldsymbol{k}_1 - \boldsymbol{k}_2$ are considered, while the indirect interactions between $\boldsymbol{k}_1$ and $\boldsymbol{k}_2$ involving other wavenumbers are neglected. The DIA approach can be justified using simple model equations (as Leslie 1973 explains more fully). But for turbulent flows the DIA makes some wrong predictions. The later developments of the model, which have led to changes in the form of the energy spectrum, are reviewed here.

The Edwards approach uses the Fokker–Planck equation as a model for deriving an approximate solution for the probability distribution of the fluctuating velocity field and hence leads to an equation for the energy spectrum. These concepts may well have a wider application in modelling turbulent flows, but this possibility is not discussed.

Chapter 7 describes those renormalized perturbation theories that are modified to account for the *localness* in wavenumber space of the dynamically significant interaction (i.e. if $\boldsymbol{k}_1$ is of the same order as $\boldsymbol{k}_2$, motions at these two wavenumbers interact more with other wavenumbers of the same order, rather than with motions at the much smaller wavenumber $\boldsymbol{k}_1 - \boldsymbol{k}_2$. The straightforward Eulerian DIA analysis does not distinguish between these *dynamical* interactions and the random *advection* of small-scale motions by large eddies. Allowing for this 'Lagrangian history' effect a better DIA model, LHDIA, then describes local interaction sufficiently well to 'predict' the Kolmogorov's inertial range spectrum. (I was surprised that this, like other recent reviews, omits any reference to the consequences of the random advection of small-scale by large-scale eddies on the kinematics and on the time-dependent statistics, which have been studied and confirmed experimentally, notably by Chase 1970, Tennekes 1975. Numerical simulations have recently confirmed the earlier work (Hunt *et al.* 1991).)

It is also a pity not to refer to the experimental attempt by Kellogg & Corrsin (1980) to test a key mathematical 'building block' of renormalized perturbation theory (in particular DIA), namely the Green's function response of a velocity field to a delta function input. In the wind tunnel they introduced a disturbance with a 'delta function' spectrum and measured how rapidly the spectrum adjusted. Although the experiment was not a critical test of the theory because it did not correspond closely enough to the theory, it is the kind of instructive example that might have been introduced to help non-quantum physicists understand about DIA! (This comment partly reflects the fact that this reviewer had the benefit of Stan Corrsin's explanation of his thinking behind this ingenious experiment!)

Generally McComb does not promote RPT models as a useful source of physical concepts. Another RPT concept that he might have discussed in physical terms is how the 'eddy' relaxation timescale, such as used in Edwards' or Orszag's models, varies with different lengthscales. In fact this concept was shown by Panofsky and others (1982) to be an excellent way of explaining and modelling the adjustment of the energy spectra of turbulent flows, as many atmosphere experiments have confirmed where the wind blows over changing surface roughness (e.g. land to sea).

In Chapter 8 comparisons are made between experimental measurements of energy spectra and skewness of decaying isotropic turbulence and the calculations based on Kraichnan's DIA theory and the modification introduced by McComb's 'Local energy-transfer theory' (LET). The differences in the predictions do not appear to be significant. There is an extended section discussing the merits and the future of calculation methods based on RPT. It is stated that their strength 'lies in their generality', but it is then pointed out that huge algebraic and computational efforts (more than is currently available) are required to use the theory for non-isotropic inhomogeneous turbulence. Although these theories have the merit that they do not include 'disposable constants' (nor do other truncated models), they cannot be regarded as 'rational approximations' (in the applied mathematical sense) because the errors cannot be stated or derived.

Renormalized group methods, the latest technique from theoretical physics to be applied to turbulence theory, is described briefly, but in an understandable way, in Chapter 3. An extended introduction to the theory is given in Chapter 9, which I did not follow. However I was interested to read the severe comments by McComb on the recent controversial theory of Yakhot & Orszag (1988) that applies renormalized group theory (RGT) to both isotropic and non-isotropic turbulence. He doubts whether (this) 'work...can be properly described as an RGT' and, because of unexplained arithmetical inconsistencies in the calculations, he is sceptical about their numerical predictions. The most useful application of RGT or, at least its underlying concepts, has been in the construction of statistical 'sub-grid' models for the scales of turbulence that are too small to be computed on the mesh used in large-eddy simulations. The developments in these models are reviewed in more detail by Lesieur (1990).

In the early chapters in this book, McComb introduced the standard statistical technique for analysing turbulence with computational methods. He describes some of the new experimental methods, such as laser Doppler anemometry. In the later Chapters 11–14, he introduces some other approaches to describing and analysing turbulence, including coherent structures in shear flows and Lagrangian statistical analysis. Then he reviews a wide range of applications of turbulence, including the effects of polymers on it, which he has himself studied.

The only connection made between the discussion of homogeneous isotropic turbulence in Chapters 4–10 and the topics in these chapters is the not very successful (or practical) application of DIA to scalar fluctuations, heat transfer and mixing.

In my view this is not a useful book for students who are not familiar with the modern mathematical techniques of theoretical physics. Even applied mathematicians familiar with theoretical fluid mechanics will find it heavy going and would need to study other texts before tackling this. But one wonders about encouraging those theoretical physicists who may want to study turbulence to read this text when its conclusions about the value of their techniques are so pessimistic! Having said that, I must compliment the author for a well produced, scholarly book that will be a useful reference text for anyone wishing to have an introduction to the main concepts and the directions of recent turbulence research using the renormalized perturbation theory and renormalized group theory.

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J. C. R. Hunt

Vibrations des Structures. By R.-J. Gibert. Eyrolles, 1988. 673 pp. 645 F.

This is the first of two volumes arising out of a Summer School in 1986 on the dynamics of structures, and appears in a series of studies and research monographs of Électricité de France. This first volume (in French) is devoted wholly to the course of lectures given at the Summer School by R.-J. Gibert, and gives an extensive treatment of dynamics of structures, fluid–structure interaction, and stochastic excitation of such structures, running to over 20 chapters and more than 600 pages. The treatment is at a straightforward level, but the analysis is pushed through to the point of detailed application to structures of interest in mechanical and aerospace engineering, and especially in nuclear engineering. The first 12 chapters deal with structural dynamics, taking both general systems and specific structures of engineering interest, and analysing them by normal-mode and wave theory methods for the case of simple mechanical excitation. The next four chapters are concerned with fluid–structure interaction, dealing in particular with added-mass effects for simple modes of vibration of structures, and also with various dissipation mechanisms. The final three chapters are devoted first to the characterization of random processes and general features of the linear response of vibrating structures to random inputs, then to particular types of stochastic excitation associated with turbulent pressure fields and the incidence of seismic waves. Many of the structures and flow configurations studied in the book do not lend themselves to exact or rational analysis, and a considerable degree of modelling skill is needed to separate the overall problem into tractable sub-problems. These modelling aspects are clearly and effectively separated out in the book, and are then followed by clearly explained analysis, using straightforward techniques. The book should serve as a very useful compendium of concepts, approaches and detailed results suitable for reliable application in fluid–structure interaction problems, especially in nuclear engineering. The second volume contains more specialized material presented at the Summer School by several different lecturers.

D. G. Crighton

Whither Turbulence? Turbulence at the Crossroads. Edited by J. L. Lumley. Springer, 1990. 535 pp. $60.00 or DM102.

This volume provides a detailed account of a three-day turbulence workshop held at Cornell University in March of 1989. The workshop was unusual in this field in that it brought together representatives of different approaches, to compare perspective and argue merit. For example, those dedicated to bringing low-order nonlinear dynamics/chaos tools to bear on turbulence would be expected to see things differently from proponents of *ad hoc* phenomenological closures. In this book one can find what various people really think. Workshop structure was, for each of six topics, an introductory keynote lecture followed by formal comments from three speakers and then free-ranging discussion led by a reporter. This volume contains all of this material. As far as this reviewer (who attended the workshop as an observer) can tell, the discussions are recorded faithfully. This is important, since these discussions are by no means the least of what made this workshop, and makes this book, so interesting and stimulating. The issues raised go beyond turbulence into the political arena. They are both fundamental and subjective: what approach should be taken? what is meant by traditional approaches? is turbulence at some crossroads? what should be the role of sponsoring government agencies? Naturally, no definitive answer is possible, but everyone tries. Because of the wide range of often contradictory opinions, all well documented, there is a danger of confusion to the uninitiated. Nevertheless, this reviewer believes everyone interested in turbulence, from seasoned veterans to students, would benefit from studying this volume. The six keynote papers are (1) The utility and drawbacks of traditional approaches (R. Narasimha), (2) Future directions in turbulence research and the role of organized motion (B. Cantwell), (3) Can dynamical systems approach turbulence? (P. Holmes), (4) The potential and limitations of direct and large eddy simulations (W. C. Reynolds), (5) What can we hope for from cellular automata? (G. Doolen), (6) Phenomenological modelling: present and future? (B. E. Launder). There are opening and closing remarks by J. L. Lumley, and a contribution by H. Aref which this reviewer is unable to characterize but regards as alone worth the cost of the book. It concerns a chaotic interaction between a tortoise, a hare, and Achilles. The formal comments, in length approaching and even exceeding some keynote papers, are from: J. L. Lumley, M. Lesieur, J. Herring, J. Bridges, H. S. Husain, F. Hussain, P. Bradshaw, R. A. Antonia, H. K. Moffatt, H. Aref, K. R. Sreenivasan, J. P. Boris, M. Y. Hussaini, C. Speziale, T. A. Zang, J. Wyngaard, C. E. Leith, U. Frisch, A. Roshko, and D. M. Bushnell. In summary, the papers, formal comments and discussion in this book combine to give a glimpse into the frankly expressed, personal perspectives on the art and science of different approaches to turbulence from a distinguished and diverse group.

S. C. Traugott

Fundamentals of Hot Wire Anemometry. By C. G. Lomas. Cambridge University Press, 1986. 211 pp. £35.

Cross Correlation Flowmeters – Their Design and Application. By M. S. Beck and A. Plaskowski. Adam Hilger, 1987. 240 pp. £35.

It was a pleasure to review the first of these books, which admirably lives up to its fly-sheet by providing a very 'clear and concise summary of the theory and practice' of hot-wire anemometry. Indeed the depth and breadth of the book is impressive, and it certainly performs a valuable service to the community by bringing together in one handy reference volume many elements which 'until now have only appeared in technical journals'. The author discusses technical matters such as probe and circuit design, the thermodynmamics of hot-wire and hot-film probes, and possible probe interference problems, as well as the practical application of such anemometers in a wide range of incompressible and compressible fluids, including two-phase flows. The measurement of mean and turbulent velocity fields, vorticity and temperature (including simultaneous temperature and velocity data acquisition) are considered; although the measurement of dissipation and multi-point data is not.

The list of those acknowledged reads like a *Who's Who* of experimental fluid mechanics. However, the European reader, at least, might notice the absence of several names (and contributions) including those of L. S. Bradbury and I. P. Castro (pulsed wall probe), A. A. Townsend (multi-probe arrays and many other fundamental contributions to anemometry), U. R. Muller (calibration of multi-sensor probes), R. Houdeville (hot-fibre wall probe), and also J. M. Wallace (vorticity probe) and R. J. Adrian (simultaneous pressure–velocity probes). It is also surprising to find no mention of flying hot wires, particularly as the use of these by Perry and others has indicated that a larger included angle is needed between cross-wires, and that a modified King's law can be extended to lower velocities. Perhaps these omissions are excusable since the present volume provides all that many readers would require. Certainly for one who was attracted to the field of fluid dynamics largely because worthwhile research could be carried out using simple equipment, very much in the spirit of G. I. Taylor, it was particularly satisfying to find home-made hot-wire anemometers discussed in such simple, but serious terms. Indeed this is the essence of the whole book: straightforward presentation being achieved without the appearance of superficiality.

The second book complements the first in that it considers the technical and practical difficulties of making flow measurements in the, possibly particulate-laden, multi-phase flows encountered in many industrial plants. Since the use of intrusive hot wires may not be adequate or even practical under such circumstances, alternative two-point cross-correlation methods using various non-intrusive sensor techniques are considered (although some comparison of results with hot-wire data is included). The book is intended for the specialist reader in both academia and industry, for whom it provides an extremely comprehensive discussion of the signal-processing theory, and practical installation and application of cross-correlation flow meters. Surprisingly, no mention is made of the NMR techniques which are now being used in a variety of applications, but otherwise the book provides both an excellent introduction to the topic for the novice and a self-contained reference volume for the expert user. A final point perhaps worth noting is that neither book considers the potential use of numerical flow simulations to validate, calibrate, complement or even improve current flow-measurement techniques.

A. M. Savill