Eur. J. Mech. B/Fluids 21 (2002) 139–141

Book reviews

Turbulent Flows

by Stephen B. Pope (Cambridge University Press, UK, 2000, 771 pp.) £29.95, US$ 49.95 hardcover ISBN 0 521 59886 9

This book is based on a course on turbulence taught by the author at a graduate level. Stephen Pope is a leading expert, highly respected in the field of turbulence research. He presents an interesting perspective on the subject. The text is divided in two parts. Fundamental, and relatively classical aspects of the problems are discussed first. More practical modelling aspects are addressed in the second part.

The first remark is that the book is very well presented. The text is clear and reads well. A number of important notions are introduced in appendices, and technical calculations in the text are left out for exercises.

The first part of the book presents a clear and interesting presentation of the phenomenon of turbulence. Some elementary considerations about important turbulent flows are first described. The fluid equations (the Navier Stokes and advection diffusion equations for a passive scalar) are then introduced (Chapter 2). Standard notions of probability theory are defined and explained in Chapter 3. The Reynolds decomposition and the underlying closure problem are presented in Chapter 4. Free shear flows, such as jets or mixing layers are discussed phenomenologically in Chapter 5. The Chapter 6 addresses the small scale properties in turbulence, and introduces Kolmogorov theory. Finally, more complicated wall bounded shear flows are discussed in Chapter 7. The main phenomena and concepts needed to understand and model turbulent flows are reviewed in this first part. To a large extent, this material is presented in other classic textbooks on fluid mechanics or turbulence. Pope's presentation does not obviously supersede other famous textbooks, but the thorough discussion, and with its own emphasis (and biases ...), is a welcome addition to the literature for graduate students and researchers wishing to familiarize themselves with the field of turbulence.

Part 2 presents various modelling attempts to deal practically with turbulent flows. Chapter 8 discusses the difficulties and constraints associated with such an endeavour. This lucid presentation discusses both fundamental issues (level of description completeness and accuracy), as well as more 'down to earth' aspects (range of applicability, and ... cost and easiness to use). This important chapter orients the line of thinking of the author. Effectively, a compromise has to be found, and some empirical considerations have to be used, for lack of a better solution. As an example, Direct Numerical Simulations, discussed in Chapter 9, are demonstrated to miss the fundamental objectives of a good model: their very high accuracy is obtained at way too high a cost .... The alternative is to cope with the theoretically daunting problem of closure .... The remaining chapters therefore present a number of approximations, of increasing complexity, to come up with a good model, both in fundamental as well as practical terms .... The merit of this book is that it does never tries to conceal the difficulty and goes intellectually for beyond the level of a simple book of recipes to compute this or that flow.

Turbulent viscosity models provide the simplest, and so far, the most commonly used models of turbulent flows. In particular, the famous k–ε model and its elaborations are discussed in Chapter 10. The Reynolds-stress models constitute the next step in the logical construction of models (the modelling assumption is made on the equation describing evolution of the Reynolds stress tensor, not on the Reynolds stress itself), and are described in Chapter 11. Chapter 12 describes the so-called PDF (Probability Distribution Function) models, based on Markovian modelling of the flow. Lastly, the Large Eddy Simulation (LES) approach is presented and discussed in Chapter 13.

As already emphasized, these are delicate issues. Many ad-hoc and heuristic approximations, often hard to justify are used. Some of the material reviewed in the last chapters is still the subject of active research. The author does a very good job to present these aspects in a rational and logical way, and to emphasize important scientific considerations. The result is a very good introduction to the current literature on some aspect of the modelling aspect of turbulent flows.

To this date, turbulence remains, from a fundamental point of view, an open and in many respects, unsolved problem. The merit of this book is to emphasize that approximate solutions (of various validity) have been worked out to deal with practical problems. In making this point, the book deliberately chooses to ignore a number of more 'fundamental' aspects of the problem. The studies of small scale beyond the Kolmogorov original theory is considered in this book "as having minor impact on the

0997-7546/2002 Published by Éditions scientifiques et médicales Elsevier SAS.

study and modelling of turbulent flows". It is true that some of the fundamental aspects of turbulence research has not been very helpful in coming to grips with practical problems. Yet, as one reads the second part of the book, one wonderswhether a rational understanding of the small scales may not help for modelling purposes after all. Time and again, arbitrary approximations have to be made, whose ultimate validity depends precisely on the behavior of the small scales. As an example, the small-scale properties of the flow are at the origin of the failure of the gradient-diffusion hypothesis, demonstrated by the Tavoularis and Corrsin experiments, and briefly discussed p. 362. Remarkably, scalar mixing is relatively little discussed. It may be worth mentioning that this particular problem has recently been the subject of important theoretical progress (see, e.g., the two review articles of Warhaft, Annu. Rev. Fluid Mech. 32 (2000) 203 and of Shraiman and Siggia, Nature 405 (2000) 639), which show that some of the essential assumptions used in modelling, such as the postulate of local isotropy, should be regarded as highly suspect. These aspects are indeed significant for modelling of mixing by LES, as demonstrated recently (e.g., by Kang and Meneveau, J. Fluid Mech. 442 (2001) 161). The prediction of turbulence structure near a wall, or more generally, in the presence of rapid temporal and spatial variations (see, e.g., J.C.R. Hunt et al., J. Fluid Mech. 436 (2001) 359) is another example where the success of LES (and modelling) has been somewhat limited. Clearly, small scale motion *is* important in these cases, and its understanding is likely to be part of the solution.

In spite of these limitations, Stephen Pope's book is definitely an important text on the subject of turbulence. The book will be very useful for students, engineers and scientists alike. The caveat is that turbulence has many facets, and some of the aspects dismissed as too academic (of too narrow a range of applicability) may turn out to be important, even for modelling purposes. As such, it would be unwise to learn the subject of turbulence from Pope's textbook alone. Complementary reading from other textbooks, such as Tennekes and Lumley (First Course in Turbulence, MIT Press, 1971), or Frisch (Turbulence: the Legacy of A.N. Kolmogorov, Cambridge University Press, 1995) or others, will provide much additional insight on the subject. On the other hand, Pope's textbook clearly fills a gap towards applications.

As such, Stephen Pope's book is well worth reading and studying.

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S0997-7546(01)01166-9

Dynamics of Droplets

by A. Frohn and N. Roth (Springer-Verlag, Berlin, 2000, 286 pp., 193 figures) DM 149.00, öS 1 088.00, sFr 136.00, £51.50, US$ 82.00 hardcover ISBN 3 540 65887 4

The book 'Dynamics of Droplets' by Arnold Frohn and Norbert Roth, affiliated with the 'Institut für Thermodynamik der luft- und Raumfahrt' (ITLR) of the University of Stuttgart, Germany, covers much more than the title suggests. Of course, the dynamics of droplets is the major theme, but the book also describes the basic physical properties of droplets, thermodynamics, surface tension, phase equilibrium, evaporation and combustion, and the interaction of droplets with light. The latter is important for understanding optical diagnostic methods with which droplet sizes, velocities and temperatures can be determined. The book describes how droplets are formed, how they interact, how they can be captured by subjecting them to forces of different nature, electrical, magnetic, optical, acoustical. The chapter on experimental and measurement techniques gives a nice concise overview with attention to recent developments such as rainbow techniques for measuring individual droplet size and refractive index. The book contains beautiful pictures of droplets colliding with (heated) walls and of mutually colliding droplets. This is really the heart of the book, reporting on work done at ITLR. It is fascinating to see how droplets strongly deform during collision, how they separate or bounce, depending on the position in parameter space. Attention is also given to very successful numerical modeling of these complicated phenomena. A variety of other topics is treated with emphasis on the experimental approach: evaporation, combustion and micro-explosions in individual droplets, flame propagation in sprays, disintegration of droplets due to shock wave passage, wetting phenomena. The book is a very valuable overview of our current knowledge on the dynamics