PERGAMON International Journal of Multiphase Flow 27 (2001) 1657–1658

International Journal of Multiphase Flow

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Book review

Turbulent Flows by Stephen B. Pope (Eds.); Cambridge University Press, 770 pp.; $130; $49.95 (paper), Int. J. Multiphase Flows

Probably the most popular text in turbulent fluid mechanics for the past 30 years has been Tennekes and Lumley. Now Lumley's colleague Pope has produced a much more extensive work and one that is up to date. Designed as a graduate text, it is a massive work that covers most of what an engineer needs to know about the subject. It is divided into two major parts: the first is devoted to fundamentals and the second to modeling and simulation.

After a short introductory chapter, the book opens with the introduction of the basic concepts and equations. It is assumed that the reader is familiar with the basics, and topics such as Lagrangian behavior and frame indifference are discussed. This is followed with a chapter in which the statistical concepts of randomness and probability are introduced. The next chapter presents the Reynolds averaged Navier–Stokes equations; the author calls them the 'Reynolds equations' but this risks confusion with a simplified set of equations used in lubrication theory.

The chapter on free shear flows presents experimental results on the important statistical quantities for several simple flows together with the idea of self-similarity and modeling with a constant eddy viscosity. Particular attention is paid to the round jet, and less detailed results are given for the other two dimensional free shear flows and two kinds of homogeneous turbulence. It is an excellent chapter. One might fault it for using the term 'boundary layer equations' rather than the more accurate 'thin shear layer equations', and also because the notion of coherent structures is given only a very short mention at the end of the chapter.

The following chapter is on length scales in turbulence and introduces all of the important scales, the concept of the energy cascade, energy spectra, the Kolmogorov hypotheses and its refinements and more. All in all, this is a useful and interesting chapter but its placement between two chapters on major classes of flows seems a bit odd.

The final chapter of Part 1 is the counterpart of the one free shear flows for wall bounded flows. It starts, quite appropriately, with channel flow and then proceeds to pipe flow and, finally, to the boundary layer. Included in this chapter is material on the balance for the second moments of the velocity, the underlying structure of the flow, and proper orthogonal decomposition. The position of the last subject in this chapter seems out of place.

Part 2, the one on modeling and simulation, starts with a short introduction presenting the difficulties and laying out the types of models. This is followed by a chapter on direct numerical simulation that is rather short and presents a very small selection of material on this subject.

Next come two chapters on turbulence modeling. The first deals with the eddy viscosity models including constant viscosity, mixing length, the k–ϵ, k–ω and Spalart–Allmaras models. Special models for the near-wall region are not treated in this chapter but are found in the following one, which also presents the Reynolds stress or, as they are sometimes known, second order closure

0301-9322/01/$ - see front matter
PII: S0301-9322(01)00022-2

models. A good selection of models of this type is presented including wall treatments and elliptic relaxation models. The chapter ends with a short discussion of algebraic stress models. No two people would agree on the choice of subjects but these two chapters represent an excellent introduction to the subject of turbulence modeling.

The following chapter covers methods based on using probability density functions (PDFs). This rather specialized subject, which has been extensively applied to combusting flows, has been developed almost single-handedly by the author and his students. This chapter, of about eighty pages, gives an excellent summary of the methods and models that the author has produced.

The final chapter is on large eddy simulation. It gives a good general introduction to the approach and some of the models that have been used although the discussion is more or less limited to methods that are used for rather academic flows.

An extensive set of appendices covers some of the mathematical details and more theoretical aspects of the subject.

There are, of course, some weaknesses. Probably the chief among these is the lack of significant material on flow separation and/or compressible flow. There is essentially no mention of two phase or reacting flows but this is certainly understandable, as including them would have made an already long book considerably longer.

Coherent structures are mentioned but this subject is generally given little space. Apparently this is because, as the author states in the introduction, their study 'has not led to a generally applicable quantitative model'. This is undoubtedly true but the insights that knowledge of coherent structures has produced has led to some significant advances in equipment design and flow control. Finally, there is essentially no mention of the transition process, another approach that can give a great deal of insight into the physical nature of turbulence.

There are other books that cover many of the segments of the material in this one in more detail. However, there is no book that provides as broad coverage as this one and yet provides reasonable depth.

There are also problems at interspersed points throughout the book. They make this an excellent textbook that can be heartily recommended to anyone teaching a course in this subject. It is the best book on the market today that covers the entire field and should be adopted for courses, especially since the paperback edition is priced quite reasonably for the size of the book.

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