AIAA Journal
Vol. 35, No. 12, December 1997

Book Review

Introduction to Turbulence

Paul A. Libby, Taylor & Francis, Bristol, PA, 1996, 341 pp., $64.95

For someone who has taught turbulent flow to graduate students for a number of years, this is a most welcome addition to the library. In 341 pages, Professor Libby has produced a book that is timely, current, and above all, most readable. Although there are books with somewhat similar titles, and other "how-to" books on turbulent flow, none is really this appropriate for use in an engineering curriculum, be it aerospace, civil, or mechanical.

The book is divided into 10 chapters. A summary at the end of each chapter keeps the reader focused on what was learned. Cartesian tensor notation is used throughout, with the subscripts (x_1, x_2) retained even for two-dimensional flows, where a switch to more conventional (x, y) notation might be preferred by some, for pedagogical reasons.

Following a brief (perhaps too brief?) Introduction on the history and examples of turbulent flow in the first chapter, the "Conservation and Transport Equations" are given in Chapter 2. Here, it becomes clear that the reader is expected to be familiar with these equations and particularly with the underlying concepts of incompressibility, rates of strain, constitutive relation, vorticity, and particularly the nuances of temperature variations in an incompressible fluid. A less abrupt introduction to the equations, and restrictions thereon, may be desirable for some. Direct and large-eddy simulations are introduced in this chapter, along with references to recent work.

Chapter 3, titled "Statistical Tools," describes averaging, probability density functions, space and time correlations, and spectra. This early and general introduction to these concepts is, in the opinion of this reviewer, a particularly nice feature of the book. Other types of averages are introduced here, and the material, as a whole, sets the stage for the derivation of the "Averaged Conservation and Transport Equations" in Chapter 4. This chapter provides a straightforward listing of the averaged equations, along with equations for the second moments, and concludes with a discussion of the need for closure. This reviewer would have liked to see some discussion of the underlying physics even if it is qualitative at this stage. Chapter 5 returns to statistical tools under the title "Length and Time Scales of Turbulence" and presents two-point correlations, spectra, and their evolution and sketches the fundamentals of isotropic turbulence without identifying it as a canonical turbulent flow. The separation of the two chapters on statistics by one on the averaged equations is curious, except that the equations are needed to discuss the evolution equations for the correlations and their spectra.

The discussion of the equations and statistical tools in the previous chapters sets the stage for Chapter 6 on "Simple Turbulent Flows." Included in this category are grid turbulence and Couette flow and homogeneous shear flow. These are followed by discussion of the effects of rotation, plane rates of strain, and rapid distortion. Equations in noninertial coordinates are introduced for the first time in the discussion of rotation. In most cases, the author develops the material to include temperature distribution and the effect of buoyancy. Throughout the chapter and for each flow considered, the author emphasizes the nonisotropic nature of the Reynolds stresses and presents model equations, but to do so, frequent reference has to be made to the end of the book (specifically, Sec. 10.10, which is concerned with Reynolds stress models). Although the author acknowledges this juxtaposition of material, both in the Preface and by later references, it may be inconvenient from a teaching point of view. Also, note that most of the results shown here are based on current turbulence models and constants, and therefore they may have a somewhat shorter life span than the more basic material in the book. Previous writings on these topics have emphasized results of experiments rather than models.

A short Chapter 7 deals with "Closure by Classical Means" and describes eddy viscosity and mixing length concepts and their limitations. Free shear flows are treated in Chapter 8. Conspicuously absent are the axisymmetric counterparts of the two-dimensional wakes and jets, as are buoyant plumes. The latter omission is particularly unfortunate insofar as the rest of the book attempts to carry through temperature fluctuations and buoyancy effects more than previous texts.

Chapter 9 is titled "Wall-Bounded Flows." The treatment is more or less standard, except for a fuller treatment of equilibrium boundary-layer analysis. The chapter ends with a statement of the three-dimensional boundary-layer equations and mean-flow and Reynolds stress transport equations for two-dimensional flow in curvilinear coordinates with a view to explain the effects of longitudinal surface curvature. Unfortunately, little is said about the turbulence and its dynamics in this chapter (these being relegated to the following chapter), although much of what we know and apply about turbulence comes from explorations of these flows.

The final chapter is titled "Higher-Order Moment and Related Methods," and it is here that the issue of turbulence is picked up, but from the perspective of modeling. Thus, there is a comprehensive but introductory treatment of current thinking on the k–ε and Reynolds stress models, along with near-wall issues. Once again, model results are shown in favor of laboratory data when plotting such things as energy balances and distributions of Reynolds stresses.

The foregoing is a straightforward summary of the book, along with the reviewer's observations on various chapters, which are, to be sure, biased. However, this bias comes from a desire to find a book for use in a graduate-level course in turbulent flow (a term I prefer rather than turbulence for a book with these contents). The author recommends this book for a year-long course or selected aspects of it for a one-semester course, and this reviewer agrees with this. The scope of the material covered and the depth of treatment are entirely consistent with this recommendation. However, from what has been said already, it is felt that each instructor would blend material from different chapters in different ways. Also, the absence of problems at the end of each chapter will be sorely noted. It is hoped that the author will remedy this in a future edition of the book.

Among other shortcomings are use of an awkward notation (e.g., $y\hat{}$ instead of y^+, N_R for Reynolds number instead of Re, and so on), lack of a concerted effort to make connections between the primarily two-dimensional flows that are treated in the book and practical flows that are invariably three dimensional (and require the full power of the advanced models of Chapter 10), and, finally, omission of surface roughness and high Reynolds number effects, both of which are likely to haunt us for a long time to come.

On balance, I am very happy to see this book on my desk because it will be used inside and outside the classroom.

V. C. Patel
University of Iowa