AIAA Journal
Vol. 40, No. 9, September 2002

Book Reviews

Closure Strategies for Turbulent and Transitional Flows

Edited by B. E. Launder and N. D. Sandham, Cambridge University Press, New York, 2001, 600 pp., $120.00

When I first heard of this book I thought it was an original work by Launder and Sandham, and I confess to being somewhat disappointed when I found that it is nominally a conference proceedings edited by them. However the word "nominally" is necessary because this is a collection of 26 authoritative review papers based on presentations at the Programme on Turbulence held at the Isaac Newton Institute for Mathematical Sciences in Cambridge, England, in 1999. The editors describe the book as "a more polished version of the original material" and punctiliously apologize for the resulting delay in publication (by no means disreputable even for conventional conference proceedings). They also apologize for "some variations in nomenclature," but these are almost unnoticeable. The style is admirably uniform: LaTeX helps, but the editors must have worked very hard to achieve consistency in matters like the format of reference lists (curiously, slightly different from the format of the Cambridge University Press's *Journal of Fluid Mechanics*). The English is also uniformly good, although it is the native language of only 11 of the contributors. Eight authors are British, 13 are from "mainland" Europe, and 9 come from farther abroad (United States, Canada, Japan). Obviously the authors are a subset of the attendees at the Newton Institute and are therefore filtered by geography: this is regrettable but unavoidable.

The review papers are of very high quality, the editors have done an excellent job of integrating them, and this book is a "must" for the library of any turbulence research group. The authors include most of the leading research workers, and the contributions of the more notable absentees are adequately reviewed. The average length of the articles is 30 pages, with up to six pages of references each. These are weighty, detailed reviews. The object is a practical one: the development of turbulence prediction methods for use by engineers and Earth scientists. Aeronautical engineers, who need higher standards of accuracy than most other users of turbulence models, are inevitably the prime customers. Discussion of transitional flows is limited to bypass transition (high freestream turbulence, as in turbomachinery). There is only a brief mention of the dubious, but usually unavoidable, technique of triggering a low-Reynolds-number turbulence model at an assumed transition point in a flow with low freestream turbulence.

The book begins with a five-page introduction by the authors, which is an extended list of contents with very useful comments setting the following papers in context. These papers are grouped in three parts: Physical and Numerical Techniques; Flow Types and Processes and Strategies for Modeling Them; and Future Directions. The first part contains mainly introductory papers, in conformity with the statement that the book "is designed to serve as a graduate-level textbook...." The other two parts deliver the rest of the promise "...and, equally, as a reference book for research workers in industry or academia." It is emphatically not a handbook for design engineers, and there are no extensive comparisons of models with data (or with each other).

Naturally, the emphasis is on Reynolds-averaged models, and the main types are treated in detail. Additionally, there are four papers specifically on large-eddy simulation (LES) and three on direct numerical simulation (DNS). It may be objected that DNS does not involve modeling but only the purely numerical problem of solving the time-dependent Navier–Stokes equations. However the "turbulence club" is less exclusive than most, and it is clear that the final goal of computational fluid dynamics (CFD), like that of any branch of mechanics, is the solutions of the exact equations (for which the fluid mechanics community is insufficiently grateful: economics, for example, has no exact equations of "motion" at all). There are no papers on spectral closures or other basic topics, but Claude Cambon contributes two papers on two-point closures, with emphasis on the (very difficult) problem of applying them to inhomogeneous flows. Solving this problem would almost certainly lead to a considerable improvement in Reynolds-averaged turbulence models: the restriction to only one length scale is a great hindrance even to otherwise-sophisticated models.

There is only one paper specifically on numerical methods for Reynolds-averaged models, but of course this topic appears at frequent intervals in the other papers. Errors in predictions have always been the joint responsibility of the model and the algorithm (and of course the user!). Grid independence, the standard demonstration of numerical accuracy, is difficult to apply to calculations of wall-bounded turbulent flows. The near-wall grid usually has to be set up to suit the near-wall model, and even a factor-of-two variation in grid size may be outside the model's tolerance.

Most of the papers are on the core problem of predicting single-phase, constant-density flows, but there are three on combustion (probability-density-function methods), four on buoyant flows, one on compressible high-speed flows, and one (an introductory paper) on heat transfer. Modeling of multiphase flows is not discussed: this is an enormously important problem but also an enormously difficult one, and progress has been so slow that the topic still belongs in specialized journals rather than a general review volume.

It is now generally accepted that Reynolds-averaged models are, and always will be, limited in accuracy and breadth of application: Reynolds averaging is a brutal simplification of the Navier–Stokes equations. Therefore, if the final goal of CFD is a cheap, easy-to-use DNS code, the intermediate goal is the application of LES to complex, industrial flows, and there are two papers on this topic. It is significant that the titles of both end with a question mark... there is still a lot to do on LES. One's only serious criticism of the papers on LES is that insufficient space is devoted to sub-grid-scale (SGS) modeling near a solid surface, which, as mentioned elsewhere in the book, is certainly the most intractable part of the problem. (A fine grid means that the total number of points in the field approaches that needed for full DNS, and a coarse grid implies excessive trust in the SGS model, which in conventional LES is almost always cruder than a Reynolds-averaged model.)

There is one paper on what has come to be known as very large eddy simulation (VLES). Here the grid size is much coarser than in LES and divides the energy-containing range into two, the SGS model being a full-strength, Reynolds-averaged model. Apart from the hope of getting LES-standard accuracy in general turbulent flows at a lower price, there is an application to turbulent flows with superimposed large-scale unsteadiness, and the technique is equivalent to what is sometimes known as the unsteady Reynolds-averaged Navier–Stokes (URANS) method. The difficulty is that in most flows of this sort the length scales of the unsteadiness and the true turbulence overlap. Spalart's detached eddy simulation approach is related, but with a more limited and more realistic objective: the Reynolds-averaged model calculates the boundary layer upstream of separation and then turns into an SGS model in the unsteady separated region.

As any theologian will acknowledge, arguments on uncertain subjects become more heated as the positions of the competing groups grow closer. This is certainly true of turbulence modelers, and this favorable review should not be taken as unqualified approval of the contents. (I regard nonlinear eddy-viscosity models as potential death-traps in highly distorted flows and strongly disapprove of determining major coefficients in a turbulence model by requiring correct limiting behavior in the special case of flow very close to a solid surface.) However, the editors of this book are to be congratulated on assembling a distinguished team of contributors and achieving a reasonably homogeneous treatment, resisting the temptation to include topics (or models) of minority interest. The organizers of the Newton Institute program are also to be congratulated on attracting the contributors in the first place. (Isaac Newton's own contribution to fluid dynamics is very properly hushed up, as it is relevant only in the hypersonic limit, where it did find application in a simple theory, many years ago.) It would be nice to think that the book will rapidly become outdated by the research work it inspires. Alas this is not likely to happen: this book will undoubtedly be the standard reference for research workers, for this decade at least.

Peter Bradshaw
Stanford University

Parallel Computational Fluid Dynamics—Trends and Applications

C. B. Jenssen, T. Kvamsdal, H. I. Andersson, B. Pettersen, A. Ecer, J. Periaux, N. Satofuka, and P. Fox, Elsevier Science, Amsterdam, 2001, 602 pp., $123.00

Parallel Computational Fluid Dynamics—Trends and Applications is the Proceedings of the Parallel CFD 2000 Conference held in Trondheim, Norway, 22–25 May 2000. Parallel CFD 2000 is the 12th conference in a series that provides a recurring international forum for interested parties to gather and discuss current research, developments, and applications of computational fluid dynamics (CFD) on parallel computers. These interchanges are essential for the continued advancement of parallel processing technologies. This high-quality hardbound publication is organized into 13 topics that include 8 invited lectures and 59 contributed papers.

The invited lectures give broad overviews related to numerical simulations in numerous fields of study including automotive, offshore structures, astrophysics, and aerodynamics. Although the invited lectures do not disclose much detail of their parallel underpinnings, these overviews provide a snapshot of the capabilities of parallel CFD and the impact of their applications throughout industry at the turn of the century.

The contributed papers address issues intimately associated with parallel processing, discuss several numerical models that are enabled by parallel processing, and augment the invited lectures with industrial applications. The issues addressed include affordable platforms, performance, load balancing, development environments, and algorithms. The models discussed include optimization, lattice-gas, large eddy simulations, fluid-structure interaction, multiphase reacting flows, and unsteady simulations. Many of these papers detail the fundamental algorithms employed for parallel processing and present the resulting scalability. It should come as no surprise that the parallel performance of certain problems scale linearly up to hundreds or even thousands of processors, whereas the performance of other simulations round over with only tens of processors. Pushing the scalability of all of these methods up more than an order of magnitude will require research directed to both the software and the hardware.

The combination of invited lectures and contributed papers on such diverse topics provides something for everyone. Collectively, these papers reflect the current direction of research within the parallel CFD community as well as clearly illustrating that industry is now exploiting the economical and performance benefits that come with parallel processing. This trend must continue to grow, as Moore's law has only a finite number of generations left. As we approach the limit in raw CPU speed, our only recourse to faster throughput will be to expand in concurrency. *Parallel Computational Fluid Dynamics—Trends and Applications* is a book worth the investment for anyone wanting a time capsule of the state of affairs in parallel computing during the advent of the new millennium.

John C. Vassberg
The Boeing Company–Phantom Works