BOOK REVIEWS

Flow Visualization V
Edited by R. Řezníček
Hemisphere Publishing, New York, © 1990, 1052 pp., $9.95 (US and Canada)

The International Symposium on Flow Visualization has been one of the most popular conference series within the international fluid mechanics community since it was founded in 1977. The Fifth in this series was held in Prague, Czechoslovakia in August 1989 and the proceedings are published in *Flow Visualization V*. This volume was edited by R. Řezníček and is similar to the previous four proceedings, Flow Visualization I–IV, because it chronicles the advances in techniques and computer aided methods and presents a considerable collection of flow visualization applications.

Of the approximately 150 papers included in the volume, about one third specifically discuss visualization methods and computer techniques, and the remaining papers elaborate on the broad spectrum of applications of flow visualization. In the methods section, contributions from Soviet researchers abound and primarily exploit the effects of streaming fluid on passing radiation/field. Over half of the computer aided flow visualization section is from Japanese authors who detail several microcomputer based digital image processing systems. The main body of the Flow Visualization V volume consists of papers describing applications of flow visualization techniques in the extensive array of fluid mechanics interests, including aerodynamics, external and internal flows, engines, heat and mass transfer, and atmospheric, oceanographic and chemical engineering. The variety of contributions from Japan, the United States, the Soviet Union, Czechoslovakia, Germany, France, the United Kingdom and others make the publication a relatively well balanced selection of applications.

The book presents a wealth of recent information on what people are doing and which techniques are continuing to evolve. The trend toward qualitative results generated by computer based imaging systems is evident and it appears that the Japanese are spear-heading this effort with several promising approaches. The book is highly recommended for libraries and researchers who frequently make use of visualization methods.

Mark C. Schmidt

The Kinetics of Mixing: Stretching, Chaos and Transport
J. M. Ottino
Cambridge University Press, 1989, 364 pp.

This book is one of the series Cambridge Texts in Applied Mathematics. The series mainly aims to provide textbooks at the advanced undergraduate and beginning graduate level for students of applied mathematics, engineering science, engineering or physics. Authors are encouraged to provide plenty of worked examples and exercises and to give as a high priority a clear and careful exposition and a sound pedagogic presentation of the mathematical techniques and theories relevant to the topic in question. To me, it appears that this book on the kinetics of mixing sets out to achieve those aims and in most respects clearly does so. However, the level of mathematics involved appears to be significantly higher than suggested, judging by my knowledge of undergraduate and postgraduate students of chemical engineering that I have acquainted over many years. Indeed it appears that for most industrial engineers, the mathematical level is beyond them.

A detailed analysis of the contents of the book clearly shows these aims. Whilst Chapter 1 sets the scene as an introduction, Chapter 2 gives the basic kinematical foundation of fluid mechanics and is entitled "Flow, Trajectories and Deformation." Chapter 3 extends this basic material and covers conservation equations, change of frame and vorticity whilst Chapter 4 starts to relate this foundation material to mixing. It is entitled "Computation of Stretching and Elongation" and essentially defines mixing in these terms alongside folding of material elements. Certain idealized, mainly two-dimensional flows, e.g., constant stretch history motions and steady curvilineal flows are analyzed in terms of the rigorously defined mathematical definitions of mixing based on stretching and elongation. The importance of material reorientation during the mixing process, if mixing is to be efficient, is also brought out. The chapter also shows that whilst steady two-dimensional flows are good for understanding and developing ideas, they do not give a good indication of what happens in three-dimensional and unsteady flows as found in real mixers.

Chapter 5 is another background chapter, introducing the reader to the fashionable concept of chaos in dynamical systems. This introduction covers fixed and periodic points, invariant manifolds associated with hyperbolic points and various signatures of chaos, such as homoclinic points and horseshoe maps. This chapter contains many difficult, and for me rather new, features. It does not explain them as well as I hoped, in spite of recently having read the best seller, *Chaos*, by James Gleick.

Chapter 6 continues the exploration and analysis of chaos, covering chaos in Hamiltonian systems. As with all chapters up to this point except Chapter 1, this chapter is essentially a further mathematical development to enable mixing itself to be analyzed. These developments occupy the first 150 pages and to this should be added the 20-page appendix on Cartesian vectors and tensors to properly appreciate the care taken in setting the sound pedagogic presentation that is the aim of the series.

Chapter 7 is entitled "Mixing and Chaos in Two-Dimensional Time-Periodic Flows." Making use of Chapters 2 through 6, it considers two idealized flows that admit analytical treatment, namely the tendril-whorl flow and the blinking vortex flow and two flows capable of experimental simulation, namely the journal-bearing flow and cavity flow. The latter somewhat simulates flow inside a screw extruder and although extremely idealized experimentally, there is stated to be no analytical solution of the velocity field. For the journal-bearing flow, some excellent pictures of Poincaré map sections from color-coded computer printouts can be compared with experimental photographs obtained by visualization of the flow using glycerine and fluorescent dye.

Chapters 8 and 9 consider the most realistic problems. Chapter 8 is entitled "Mixing and Chaos in Three-Dimensional and Open Flow" and Chapter 9 is entitled "Epilogue: Diffusion and Reaction in Lamellar Structures and Microstructures in Chaotic Flows." By Chapter 8, two three-dimensional flows are treated under creeping flow conditions. Of these, one, the partitioned pipe-mixer, is periodic in space and is compared to the Kenics static mixer; the other is the eccentric helical annular mixer (or the journal-bearing flow with a superimposed throughflow), which is time-periodic. This superposition of periodicity greatly enhances mixing (stretching and area generation). Finally, three examples relevant to turbulent flow are also briefly considered.

Chapter 9 is the epilogue and *speculates* on how the earlier idealized conditions might be applied to real mixers, i.e., mixers where diffusion between fluids also occurs, where rate (or transport) processes (including chemical reaction) are important and where two immiscible liquids are present, though the latter is treated only for elongation and shear in laminar flow.

In Chapters 8 and 9 and in some of the copious Chapter notes, some very interesting philosophical points are made. The author discusses the relative difficulties and advantages of mathematical analysis, computation and experiment, including computational observability (round off errors and pixel size) and experimental observability (allowing low probability events to be seen but perhaps not repeated!).

For me, the author's statement in the preface is important. He states that there is nearly universal recognition amongst researchers that mixing problems are very difficult. In agreeing with that view, one must welcome the new and very rigorous approach covered by this book. However, the implied claim in the preface and publisher's blurb, that the present approach enables an overall unified attack on the problem of mixing, seems excessive. Those concerned with multiphase mixing problems (gas–liquid, solid–liquid and, except in a very limited sense, liquid–liquid systems) will find little to help them here. An undue emphasis on the significance of this present approach could be considered dangerous if it leads to expectations of giving answers to problems better tackled by the more traditional, if not so scientifically well-founded, methods, problems too difficult to benefit from this approach in the foreseeable future.

Mixing is a difficult subject. It is also of enormous importance to a whole range of practical problems and industries, not least the process industries. An estimate of its cost to these industries in the USA was recently made at a joint meeting of US "mixing academics" and industrialists to which I was invited; it was $1 to 10 billion per annum. Perhaps a bit of US "hype", but there is clearly a demand for an improvement of our understanding. Computational fluid dynamics is another powerful modern tool, steadily increasing the areas to which it is able to make a real contribution. Like the concepts in this book, its strengths and weaknesses are difficult to appreciate except for those really "skilled-in-the-art." However, it too is certainly not a panacea and solutions to multiphase complex rheology problems with transport and reaction certainly pose difficulties to CFD; as well as to solutions based on chaos. There is still a case for well-designed experiments. Indeed, most mixing problems are multi-dimensional, requiring a whole range of tools (theoretical, computational and experimental) to tackle them. The author of this book would in fact appear to agree with that view.

Overall then, this is a thought-provoking book, well-presented, mathematically rigorous with a good bibliography and references, and excellently illustrated with many fine diagrams and photographs. However, it will be a demanding book for many undergraduate and graduate engineers and scientists and of limited value to most people concerned with mixing problems in the process industries.

Alvin W. Nienow

Numerical Computation of Internal and External Flows, Volume 2: Computational Methods for Inviscid and Viscous Flows
C. Hirsch

In a relatively young and rapidly evolving field such as computational fluid dynamics, there normally is a dearth of good textbooks on the subject. This is understandable; hardly a word is written before new ideas and methods emerge to supercede or supplement what is known. It was therefore with eagerness that I reviewed this book with the hope that it would not only survey some of the latest techniques in particular areas but also give a complete overview of the subject as the title would suggest. Alas, I was disappointed in the latter expectation as the book turned out to focus only on some specific areas at the expense of the wider perspective of the whole field of CFD, a fact that perhaps the title of the book should have reflected.

Thus, of the 683 pages, less than 15% are allocated to the treatment of the Navier-Stokes equations; this is even less than the number devoted to potential flow. The rest of the book is occupied by methods relating to the solution of the Euler equations, mainly in the context of finite difference/volume schemes applied to inviscid compressible flow. With this imbalance, the book falls short of addressing many of the issues that face the majority of CFD practitioners in industry. These, contrary to the opinion of the author, are surely engaged in applications relating to flow dominated by large stresses, either turbulent or laminar, have significant recirculation zones, and are more likely to be incompressible than compressible.

An issue that deserves prominence is one that occupies much of the time of those involved in the application of implicit schemes (and these are now becoming more widespread than explicit ones), namely to find a robust and efficient algorithm for solving the simultaneous set of discretised equations. The book has very little time for this issue, and when it is dealt with, it is treated as a matter auxiliary to what is considered to be the central issue: the discretisation scheme. Thus, pressure and pressure-correction based methods, which probably by now account for the majority of CFD applications in industry (other than aerospace) and now are invading the preserve of the traditional compressibility based methods in the area of aerodynamics, are accorded a cursory, almost dismissive, treatment.

Nevertheless, the book offers a thorough account of the material and covers the ground with considerable depth. Where it really scores is in the presentation of a comprehensive up-to-date survey of discretisation schemes including Flux Vector Splitting and TVD methods. This is accompanied by an in-depth, detailed assessment of the characteristics and performance of each scheme considered; the book is worth acquiring for this reason alone. To support the theoretical presentation, many calculation examples are included to illustrate the applications; these are mainly in the field of aerodynamics. Though the schemes are presented in the context of the discretisation of the Euler equations, application to the Navier-Stokes equations is alluded to in the text. How this could be done may be lost on the novice reader who may not (understandably) refer to the Euler equations chapters, which would be a pity as there is much to learn there.

Also included in the book is an expansive treatment of boundary conditions in the context of transient compressible flows that are obviously more complex than their incompressible counterpart. I find these chapters to be especially useful. I also was impressed by the number of sample problems appended to the end of each chapter; I have no doubt these will be particularly helpful in exercising and reinforcing the knowledge gained from the text.

My verdict is therefore mixed. The book is no doubt very useful in specific areas; I for one will be making regular use of it. However, a reader, especially an uninitiated one, will need to have other books handy to bridge the gaps left.

R. I. Issa