

search in three-phase fluidized bed systems.

The monograph is divided into three parts. The first part outlines the scope of the monograph and identifies the practical relevance of the subject matter. A very large number of practical examples are delineated and various classifications of three-phase fluidized bed systems are outlined. The second part deals with the major theme of the monograph. The available literature on the hydrodynamics, mixing, mass- and heat-transfer characteristics of three-phase cocurrent upflow, slurry bubble columns, counter-current flow and batch liquid fluidized bed systems as well as other miscellaneous systems such as draft tube systems, semifluidized bed systems, annular systems and transport systems, is outlined in detail. The third part gives descriptions of various practical applications such as fermentations, aerobic biological wastewater treatment, flue gas desulfurization and particulate removal, hydrotreating and conversion of resids, and other miscellaneous systems such as electrodes, granulation and adiponitrile production, calcium bisulfite acid production, sand filter cleaning, crystallization, flotation, polymerization, coal gasification and

methanation, and Fischer-Tropsch synthesis and methanol synthesis which use three-phase fluidization bed systems.

It is clear from the literature reviewed in part 2 of this monograph that during the past two decades, significant research has been carried out to improve our understanding of the physics of three-phase fluidized bed systems. Because of the complexity of these systems, the results for various design parameters are largely presented in the forms of empirical correlations. Wherever appropriate, some theoretical derivations are also outlined. The author has made a good attempt to summarize the present state of knowledge and make appropriate recommendations for each section; however, some recommendations could have been focused more toward practical applications. This could have been done by assessing the applicability of the design parameter correlations for each of the practical applications outlined in part 3.

The author has given an in depth description of various applications for three-phase fluidized bed systems. A review of aerobic biological wastewater treatment is particularly interesting. While it is treated in some cases, models for the reactors and their use in the reactor de-

sign and scale-up for each application would have been interesting. Appendix A describes one such model for the catalytic reactors.

While the monograph is generally thorough in its coverage, there are certain points that might also have been included. A brief assessment of micromixing in three-phase fluidized bed systems would have been useful. Important engineering considerations for the operability of various types of columns at various scale and associated instrumentation considerations would have better satisfied the scope of the monograph. Finally, some example calculations illustrating the use of various design parameters would have been useful to the readers.

Overall, the author has done a fine job presenting a detailed review of a very complex and timely subject. The monograph will be an excellent reference guide for the researchers in this area and it can also be used as reading material for a graduate course on the multiphase reactor design.

Y. T. Shah  
College of Engineering and Applied Sciences  
University of Tulsa  
Tulsa, OK 74104

## Advances in Turbulence

W. K. George and R. Arndt, ed., Hemisphere Publishing Corp., New York, 1989, 234 pp., \$60.

This book is a compilation of seven papers that describe recent theoretical and experimental research in turbulence. The papers deal primarily with incompressible, Newtonian fluid mechanics.

Two of the papers describe experimental techniques. The paper by Buchave reviews measurement techniques including hot wire/hot film anemometers, laser anemometry, and recent advances in particle velocimetry. The paper contains references to more than 100 published papers including papers published as recently as 1987. The paper should be useful to beginners as well as people who have some experience in the area.

The paper by Mueller describes the use of smoke visualization and hot-wire anemometry in the study of transitional flows. The paper is comparable in breadth and depth to Buchave's and includes an extensive set of references.

Two papers deal with numerical stud-

ies of turbulence. The paper by Taulbee discusses the use of single point closure models. The author focuses on the kinetic energy/dissipation model and the Reynolds stress model for incompressible, isothermal flow.

The paper by Moin and Spalart describes the use of direct numerical simulation to provide information about turbulence. The flows discussed in the paper are low Reynolds number turbulent channel and boundary layer flows. The databases considered were developed by the authors and their collaborators. The main focus is on the use of databases to extract information about eddies rather than on the numerical techniques used in the simulations.

Chevray reviews some of the ideas of dynamical systems and fractals. The Ruelle-Takens theory is described as well as experiments on rotational Couette flow and thermal convection and the various routes to chaos that have been identified. In addition, the phenomenon of chaotic advection in laminar flows is described.

Finally, the papers by George and

Lumley discuss some current issues associated with the study of coherent structures. George discusses jet and wake flows, while Lumley discusses ideas about the possible relationship between coherent structures and dynamical systems.

Current research on particle motion in turbulent flow, drag reduction, turbulent heat or mass transfer, compressible flow and several other areas of turbulence research are dealt with tangentially or not at all. On the other hand, the articles in the book are, for the most part, carefully written and should be useful to researchers in the field. Several of the papers, especially the ones on experimental methods, should be helpful to graduate students who are beginning their research projects.

In my opinion, the book would be a useful addition to any engineering library.

John B. McLaughlin  
Professor of Chemical Engineering  
Clarkson University  
Potsdam, NY 13676