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International Journal of Multiphase Flow 30 (2004) 347–349
International Journal of Multiphase Flow
www.elsevier.com/locate/ijmulflow

Book review

Two-Phase Flow: Theory and Applications, Clement Kleinstreuer; Taylor and Francis, New York, London, 512 pages, $125, ISBN 1-59169-000-5

Considering the wide applicability of multiphase flows in industrial processes and in nature, and the extensive research activities on these topics, there are relatively few textbooks that can be used to introduce students to the field. *Two Phase Flow: Theory and Applications* is a new entry in this market. It is intended for graduate students who already have a good understanding of single phase fluid dynamics. The topics and arrangement of the book give a definite orientation toward preparing the reader to do engineering or research computational of multiphase flows. The entire focus of the book is on fundamental concepts, governing equations and solution procedures. There is no discussion of experimental techniques or reliability of experimental data. If I were to give it a descriptive title, it would be *Fundamentals of computation of multiphase flows*. It should be quite good for a graduate course on this topic and can provide researchers, inexperienced in computation, the background necessary to begin work in the field. It is not a handbook so the reader will need to invest time in learning the material, if he/she wants to implement the techniques described in the book.

The book is arranged into five chapters. The first chapter (67 pages) *Review of single-phase flow*, covers basic topics of fluid mechanics including flow field kinematics, conservation laws and turbulence concepts. The treatment assumes readers will already have seen most of this material. While solutions to laminar flow problems such as nearly parallel transient flows are shown with their analytical solutions, the "flavor" of the chapter is slanted toward the numerical solution techniques. An interesting section is "solution techniques" which gives a *blueprint* for solving fluid flows ranging from simple single phase to very complex multiphase problems. Solution methods such as separation of variables, similarity methods, weighted residual techniques are listed, but not described. A table describes the general approach of classifying the differential equation, using appropriate transformations or approximations, looking up textbook solutions or solution procedures and using appropriate algorithms or software for linear and nonlinear algebraic and differential systems of equations. A quick summary of inviscid, parallel, creeping and boundary-layer flows, as limiting forms, is given.

Chapter 2 (62 pages), *Basic concepts of two-phase flow theory*, begins with terminology for two-phase flows and then classification of regimes and modeling approaches. It is here we begin to see that this book is foremost intended to provide knowledge and background for computational solution of multiphase flow problems and is not intended as a handbook for solution of multiphase flows. The description of gas–liquid flow regimes is very brief and sheds no light on the subject beyond a reference to the Taitel–Dukler papers from the mid 1970s. This point is an example of a limitation of the book. There is relatively little in the way of "advice" or critical examination of background information or the various solution techniques presented in the book. Other topics in this chapter include a nice table of multiphase flow occurrence in natural or industrial processes, a figure of the hierarchy of multiphase models, several simple examples intended to give physical insight into particular aspects of particulate flows. The chapter concludes with "Illustrations of some practical dispersed flows" in which the author gives more motivation for study and physical insight into particulate flows. The chapter ends with eight conceptual questions and seventeen homework type problems. Many of these are very advanced and elaborate and affirm the book as a useful graduate textbook.

Chapter 3 (93 pages), *Derivations of the two-phase flow modeling equations*, shows a progression of increasingly more complex models for describing gas–liquid and solid–fluid flows. It starts with a table that gives parameter ranges which help define which of the possible models might be appropriate to accurately model a given flow. Next is a section on constitutive equations and mixture models. With the mixture models, examples of expressions for effective density or viscosity are given, but there is little guidance for their use. The chapter continues giving the formulation for drift flux models along with some examples. It then presents a separated flow model and finally gives the two-fluid formulation with enough detail and discussion for it to be the first source for readers who have never encountered the subject before. Again numerous homework type problems are provided.

The next chapter (69 pages), *Analysis and numerical simulations of basic two-phase flows*, begins with a discussion of computational fluid dynamics codes (e.g., CFX, CFD-TWOPHASE, Fluent) and mathematical analysis packages (e.g., Matlab, Maple) that can be useful for solving multiphase flow problems. An extended discussion of particle tracking is also given. A detailed calculation of blood flow through a constricted vessel shows vortex development downstream of the stenosis. Other examples in this chapter include use of a drift flux model for suspension flows using CFX, which is compared to some experimental data and a two-fluid model for bubble column flow, also solved using CFX. This chapter includes 10 possible "projects" which require extensive computations by the students.

The last chapter (111 pages), *Selected case studies* starts with exposition about the engineering development process and the role that modeling, specifically computational fluid dynamics, can play. The case studies include submicron aerosol transport and deposition in a T-junction, laminar and turbulent suspension flows at T-junctions and transient blood flows at vascular branching points. This last topic is intended to give insight into how to best do surgical repairs of damaged or diseased blood vessels. Final examples include two-fluid model solutions for bubble columns and sparged reactors.

Professor Kleinstreuer has produced a book that is unlike any of the other books on two-phase flow, recent or classic. There is no doubt of the increasing importance of computational fluid dynamics to the development of multiphase flow understanding and application. This text should play an important role in advancing the field. The book is very readable and the explanations are clear. While "opinions" of how well different solution procedures and computational strategies work is always contentious, particularly for multiphase flows, the reader might have benefited from more of this. However *Two-Phase Flow: Theory and Applications* is a welcome addition to the multiphase literature.

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doi:10.1016/j.ijmultiphaseflow.2004.01.001