

Preface

Multiphase flow phenomena abound in many materials processing operations, including gas-stirred ladles, blast furnaces, and the like. This book focuses primarily on systems in which liquid and gaseous phases coexist. In general, such systems are complex and difficult to characterize. The phases can be continuous or dispersed, with mass, momentum, and energy exchange across the interfaces. For the past few years, there has been a heavy focus on relating the interfacial fluxes to measurable macroscopic properties of the flow so as to provide a fundamental understanding of the mixing process. Significant advances have also been made in the application of computational and experimental techniques to multiphase transport phenomena in materials processing operations. This book presents the application of these modeling tools to dispersed gas–liquid metallurgical systems.

The book is an outgrowth of recent research activities of the authors in the modeling of multiphase flow phenomena in materials processes. It emphasizes the synergistic relationship that should exist between physical and mathematical modeling techniques through a variety of validation examples. The primary intended audience is materials researchers in industry and academia faced with practical problems of modeling multiphase flow phenomena in metallurgical reactors. The book can also be used as a secondary reference for an upper-level multiphase flow course, and serve as a research monograph for graduate students. The typical reader would have had previous exposure to the scientific basis of physical and mathematical modeling techniques.

Several new features are included in the book beyond the traditional texts on multiphase flow. For example, the conflicting roles of hydrodynamic instability in materials processing are discussed. Numerical methods are presented for modeling the complete continuous casting operation, including gas–liquid and solid–liquid multiphase systems, with examples. Nanoscale and microscale multiphase phenomena are reviewed, bringing into focus recent advances in this emerging field. The book is organized into 11 chapters as follows:

Chapter 1 provides a general overview and introduction of the principles and techniques of physical and mathematical modeling discussed in the book. It provides the rationale for modeling two-phase flow in gas-agitated reactors of materials processes. Chapter 2 presents the turbulence structure of two-phase jets and the impact on the mixing and chemical reaction rates in materials reactors agitated by

gas injection. Chapter 3 describes the principle of the Coanda effect, including the diversion of bubble path near the vessel walls as well as the merging of bubbles generated from multiple sources. The implication is also discussed of these phenomena on the mixing intensity and mixing time in the reactor. Chapter 4 focuses on the interaction between bubbles and walls, including dynamic wettability associated with the advancing contact angle, and the effect on bubble shape and size. Experimental results are also provided for bubble and liquid characteristics in systems with walls of varying wettability.

Chapter 5 discusses swirling flow, the underlying hydrodynamic instability, and the impact on the mixing process. Chapter 6 describes the interaction between molten metal and top slag in a gas-agitated reactor, and its effect on mass transfer mechanism and the mixing phenomena. Chapter 7 focuses on surface control of the reactor and the effect on mixing time. Chapter 8 discusses mold powder entrapment in molten steel in continuous casting molds and the impact on product quality. Results from flow visualization and particle image velocimetry (PIV) techniques are presented to elucidate the underlying mechanism.

Chapter 9 describes the mathematical techniques for modeling two-phase gas–liquid multiphase systems. A variety of methods are assessed with the aid of examples comparing predictions with the experimental data. Chapter 10 presents a detailed description of the application of numerical techniques to continuous casting systems in general, including alloy solidification. Finally, Chapter 11 reviews nanoscale and microscale multiphase phenomena in materials processing. The important global and local characteristics relevant to understanding and modeling of such phenomena are described, and examples are presented on fluid flow and heat transfer in such systems. There is an Appendix that summarizes the transport data for common fluids, including air, water, argon, helium, hydrogen, etc.

The modeling of multiphase transport in materials processes is multidisciplinary, involving concepts and principles not often associated completely with one particular field of study. We have therefore ensured that this book is self-sustaining through the variety and breath of topics covered. The text could therefore serve as a useful guide to the types of questions that should arise in the modeling of gas-agitated metallurgical processes and how to seek relevant answers.

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