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Book Review

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Flows of Reactive Fluids

R. Prud'homme, Springer, New York, 2010, XXIII, 476 pp., $179

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My impression is that this book represents a labor of love. Inspired by Marcel Barrere, the author has devoted his lifetime to studying the material covered in this volume. In fact, the dedication is in the memory of Marcel and his wife Simone, both of whom were first-rate people, a conclusion to which the reviewer and his wife can attest, having spent pleasant days visiting with them at their summer home in Saint-Tropez. Previously, I had collaborated with Marcel in Paris, writing an AGARDograph on fundamental aspects of solid propellant rockets while he was at ONERA, and it was there that I discovered how unusually kind and considerate the gentleman was. The volume under review is thus, in a sense, a tribute to the far-reaching favorable influences that Marcel had.

The subject matter here of chemically reacting flows is presented in a uniquely personalized manner. With a strong grounding in continuum mechanics and fundamental fluid mechanics, complemented by a keen interest in applied mathematics, Roger Prud'homme has now addressed a wide range of problems in this general area. The book has evolved from graduate-level courses that he has given at his university, Pierre et Marie Curie, as well as advanced-level lecture series that he has given elsewhere. The material thus resides very much at an advanced level; although it is softened by a number of photographs, many of major researchers (including one of Marcel), as well as by a few exercises followed by solutions. Efforts at pedagogy are thus evident.

The personalized presentation complicates the task of exposing the contents in a clear and concise manner. For example, the same topic may appear in more than one place, from different viewpoints, sometimes quite unexpected; although the author does generally say where a topic will appear again in the presentation. Moreover, the writing is quite comprehensible. The English is very good, there being only a few examples where the most common English terminology is not used. Coupled with the fact that there are relatively few errors or misprints, this care in composition contributes favorably to the readability of the volume, as does a very useful complete list of symbols at the beginning. A reader interested in a fresh perspective may therefore enjoy the book.

Much of the development exhibits a focus on entropy. For example, already in the second of the 12 chapters, the first (following a six-page introductory chapter) to present technical material (a chapter entitled "Equations of State" but also covering the thermodynamics of ideal and real gases, both single component and multicomponent, reacting and nonreacting, as well as liquids, reacting solutions, and separately, solids), there is a discussion of entropy production in homogeneous reacting mixtures and a treatment of thermodynamic stability from an entropy viewpoint. Information in this chapter extends to thermal expansion (called dilatation) coefficients, sound speeds, surface tension, and a number of other things illustrative of the variety to be encountered throughout.

The entropy focus continues in Chapters 3 and 4, which complete the development of the fundamental information: the first on transport phenomena and chemical kinetics and the second on the conservation equations. While there is a brief discussion of elementary kinetic theory of gases, transport processes are approached mainly from general irreversible thermodynamics, emphasizing entropy. The reader will not find detailed chemical–kinetic descriptions in this volume, since the author prefers to give only the general formulation and simplified model examples to which mathematical methods can readily be applied. The conservation laws are followed by examples of determining entropy production, and probabilistic approaches common in chemical-reactor theory are exposed here.

Before moving on to applications, the author interjects a brief chapter discussing similarity concepts and giving most of the relevant nondimensional parameters, following a statement of the Buckingham pi theorem. The first application addressed (also briefly) is chemical-reactor theory, with a discussion of multiplicity, stability of steady states, and residence-time distributions. It is in the subsequent applications, beginning with Chapter 7, that the arrangement becomes especially unique and personalized.

An exception is Chapter 8 on turbulent flow concepts, a general area in which the author has not done as much original research himself as he has on the other topics. Here, he has done a remarkably excellent job of reviewing the literature, beginning with classical nonreacting flows and laminar-flow instabilities, proceeding to laminar-flame instabilities, vortices, turbulent statistics,

Reynolds-average modeling, and up-to-date turbulent-combustion modeling, including regime diagrams for turbulent combustion. These relatively concise (yet reasonably complete) discussions, along with the significant literature citations, provide a very useful entry into the area of turbulent combustion.

The other application chapters, "Coupled Phenomena" (Chapter 7), "Boundary Layers and Fluid Layers," "Reactive and Nonreactive Waves," "Interface Phenomena," and "Multiphase Flow Concepts," each form separate collections of material that most readers would not normally expect to find grouped together. The presentations in these chapters range from detailed analyses to brief comments or quotations of results. The chapter titled, "Coupled Phenomena," meaning that more than one physical process is involved, includes nozzle flow, osmosis, Burke–Schumann diffusion flames, premixed flames, the G equation, Rayleigh–Benard instability, and Marangoni convection, for example. In the chapter titled, "Boundary Layers and Fluid Layers" may be found Couette flow, the Emmons problem, von K rm n swirling flows, and classical turbulent flow over a flat plate, among other topics. The final chapter, somewhat more like the turbulence chapter, is a wide-ranging discussion of two-phase systems, including liquid-jet instabilities, the combustion of spherical droplets, simplified conservation equations, and spray combustion, for example, with a good set of literature references.

"Interface Phenomena," Chapter 11, is especially illustrative of a unique viewpoint. Who would ever think of grouping constitutive relations for surface stresses, results for Marangoni instability at different crispation numbers, heterogeneous catalysis, and premixed laminar flames, including their Markstein lengths and jump conditions for larger deflections, in the same category? Yet, a reasoning for doing this, which cannot be dismissed entirely, is put forward here. Interface concepts, emanating from asymptotic ideas that collapse phenomena into surfaces, pervade this volume, from thermodynamic equations for interfaces in Chapter 2 to jump-condition balance laws at discontinuities in Chapter 4, and so on, culminating in the grouping in Chapter 11. If you want to experience a new outlook on the subject, read this book.

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