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Book Review

Thierry Poinsot, Denis Veynante, Theoretical and Numerical Combustion, second ed., Edwards, USA, 2005, 520 pp.

The universe of combustion is divided into many overlapping worlds. Combinations of knowledge cumulated in those worlds provide tools for combustion engineering. The scientists who approach the subject must therefore find their way in a large variety of physical problems and techniques available to scrutinize flames. In its first edition, the book by Poinsot and Veynante was of premier importance, because it was the very first monograph simultaneously exposing in detail theoretical and numerical aspects of combustion. This combination of theory and numerics is necessary to really envision the great capabilities of modern numerical tools applied to combustion, and also to understand the drawback of their numerous limitations. At a time where numerical modeling enters many design loops, knowing and controlling those limitations are becoming crucial issues. In its novel edition, this book will continue to be of real help to many working in this direction.

The authors have cumulated remarks from many readers to improve the material of their first edition; in addition, new sections and a chapter have also been added to include more recent findings. The bibliography has been updated (63 references were added) and new indexes are proposed. (Overall, 20 pages of the first edition have been removed and 70 pages are fully new.)

The strength of this book is to address most of the numerous facets of combustion with the same rigorous and systematic approach. For every point discussed, the authors have shown a remarkable and unique ability to seek out the most important and relevant key aspects. This is specifically the case for flame/acoustics interactions and for boundary conditions, which must be applied to fully compressible simulations. Those subjects were not discussed in a comprehensive manner in previous combustion textbooks. One point that is left aside is the subtle details of combustion chemistry and chemical kinetics of flame; they are not deeply explored. The same remark can be made concerning radiative transport.

Chapter 1 presents the balance equations for reacting flows. All the various forms taken by the conservation equations are carefully given and explained. Compared to the first edition, the section "Diffusion velocities: full equations and approximations" has been completely rewritten. Fick's law is discussed versus the Hirschfelder Curtiss approximation of diffusion velocities. Many solvers are based on these formulations and users will find here important information.

Chapter 2 treats a basic model problem, the laminar premixed flame. In addition to the thorough description of those flames already available in the previous version, in this second edition, a new section is devoted to thermodiffusive instabilities of laminar flame fronts; some connections with turbulent flames are also given.

Chapter 3 is devoted to laminar diffusion flames. The various properties of those flames are well explained. Despite its geometrical simplicity, this is a difficult subject to expose with sharpness without generating more puzzling questions than answers. This is beautifully done in this book. There is no major modification in this chapter compared to the first edition (except for some typos that have been corrected).

Chapter 4 is an introduction to turbulent combustion. Some necessary background on turbulence is first given, before summarizing the various modeling approaches used so far to tackle turbulent flames. This second edition contains more details about the physical concepts underlying turbulent combustion modeling. Also, the section devoted to Large Eddy Simulation (LES) has been augmented. The readers will find an interesting discussion on the difficulties raised when comparing LES results with experimental data. A new section deals with the description of chemistry in turbulent combustion modeling; the various methods used to reduce or tabulate detailed chemistry are summarized.

Chapter 5 is on turbulent premixed flames. After a preliminary phenomenological description, the combustion regimes are explained. This paves the way for in-depth discussion of three subsequent topics: Reynolds Average Navier Stokes (RANS) calcula-

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tions, LES, and Direct Numerical Simulation (DNS) of premixed turbulent combustion. This second edition contains new DNS results on V-shape flames stabilized by a hot spot and novel results on scalar dissipation rate modeling.

Chapter 6 covers nonpremixed turbulent combustion. The structure of this chapter is similar to Chapter 5. Important improvements included in this new edition relate to a discussion on swirl flow and precessing vortex cores. The largest simulation of nonpremixed flame available today is also shown.

Chapter 7 summarizes important findings on flame/wall interaction, a subject with many obvious applications, but that is usually not addressed in combustion textbooks. Compared to the previous edition, the authors have removed here DNS results on the influence of thermal boundary conditions at the flame holder to move them in Chapter 5, in the section devoted to flame stabilization.

Chapter 8 explains the basis of flame/acoustics interactions. To my knowledge, some of the formalism and equations presented in this Chapter are only available in this book. They are very useful to understand and progress in this field. This part of the book has been improved (the derivation of the wave equation has been corrected) and augmented. The novel version contains a section on Helmholtz resonators. It is shown that a double duct quarter wave mode is exactly equivalent to a Helmholtz resonator. A section on three-dimensional acoustic tools can be found, and new insights into the Rayleigh criterion are proposed. This Chapter contains important information for those involved in the design of combustion chambers of all kind.

Chapter 9 explains the treatment of boundary conditions, which is essential to high fidelity flame simulations. In this edition, a new classification for boundary condition is proposed. The full range of flow problems is covered from perfect gas to mixture of real gases. New results are also presented on techniques to avoid spurious reflections at outlets of computational domains. This Chapter is essential to those developing or using viscous flow solvers.

Chapter 10 is entirely new; examples of LES simulations are presented. Unsteady simulation of turbulent flames is a very rapidly growing tool, mainly because of the progress of turbulent combustion modeling, numerics, and computer science. It is demonstrated how LES can be utilized to understand flow physics and flame properties of real combustion systems.

This second edition has many interesting moments, which are new compared to the first edition. It will therefore continue to be a reference document for those studying flames using numerical simulations, but also for everyone looking for a well-structured description of the fundamentals of combustion and flames. It constitutes a reference textbook for graduate students. This book can even be used as a handbook, in which all the useful and basic information on flames is readily accessible.

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