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Book Review

An Introduction to Combustion

Stephen R. Turns, McGraw–Hill, New York, 1996, 565 pp., $66.00

This is the book for which the undergraduate student in mechanical engineering has been waiting. Combustion is a difficult subject, requiring background in thermodynamics, fluid mechanics, chemical kinetics, and transport theory. A thorough treatment of the subject is best left for a second-year graduate course, following a year of graduate study that includes quantum and statistical mechanics, kinetic theory, turbulence, and variable-density fluid flow, for example. Over the past 30 years, a number of advanced books have become available that treat combustion at a level appropriate for second-year graduate study. Yet, there is a demand in engineering curricula for an undergraduate combustion course, generally to be taken as an elective in one semester. Instructors have continually been frustrated in such courses by having to try to use texts that are too advanced for the students. Turns has taught a course of this kind in mechanical engineering and has designed this book to fill the need for a suitably elementary text. He has succeeded admirably in his objective.

The style is chatty, often employing the first or second person, as a professor might speak to a class. Precise rules of English are not strictly enforced. Each of the 15 chapters seems to reflect what may transpire as a lecturer at an American university addresses undergraduate students. The presentation is strong in engineering motivation. The entire short first chapter is motivational, aside from a few definitions, and it summarizes figures on national usage of fossil fuels and national histories of pollutant emissions, for example. In addition, most of the other chapters begin or end with samples of engineering devices, quite varied when taken in total. All of the chapters, save the first, begin with an overview and end with a summary in which the teacher tells you, succinctly, in no uncertain terms, exactly what you are supposed to have learned. Besides plentiful, fully worked example problems in the text, following each summary are exercises of at least one of three different kinds—questions, in which the student is asked to discuss various things in the chapter; problems, which are like those that have been worked as examples in the chapter; or term projects, which are more open ended and require external reading. The problems are mostly numerical and range from simply plugging numbers into formulas in the text to requiring a little thought. Although some might consider this overkill, an advantage is that even the slowest student in the class will come away with a feeling of having learned something. The course ratings will soar.

The text has been prepared with care, attention is paid to details, and it is entirely self-contained. Besides many necessary tables and graphs that are sprinkled throughout the text, there are appendices including JANNAF-like listings of thermodynamic properties of a dozen of the most common gases encountered in combustion, thermodynamic and transport properties of hydrocarbon and alcohol fuels and air, a short table of binary diffusion coefficients, and a computer code for calculating equilibrium properties of hydrocarbon–air combustion, complete with a user-friendly IBM-compatible disk. At the end of each chapter there are adequate citations of from 5 to about 50 up-to-date references, as well as a thorough list of nomenclature. Handy tables of conversion factors and physical constants are printed inside the front cover. Proofreading was done carefully; I detected only about a dozen misprints throughout the entire volume. A great deal of thought, time, and effort has gone into this book.

The specific topics covered are aimed directly at undergraduates in mechanical engineering, who are assumed to have had a first undergraduate course in thermodynamics. Aspects of thermodynamics related to combustion are introduced first, including ideal gas mixtures, equivalence ratio and mixture fraction, adiabatic flame temperatures, and then chemical equilibria; applications are made to recuperation and to exhaust-gas recirculation. A chapter entitled "Introduction to Mass Transfer" presents rudiments of molecular diffusion and of liquid–gas interface equilibrium and then briefly defines a transfer number and a d^2 law for isothermal droplet evaporation. There are two chapters on chemical kinetics and chemical mechanisms of combustion, including the mechanisms of NO formation. A chapter entitled "Coupling Thermal and Chemical Analyses of Reacting Systems" then details four idealized models: homogeneous chemical kinetics in constant-volume and constant-pressure systems, the well-stirred reactor, and steady plug flow. Except for a brief section on species conservation equations, partial differential equations are not encountered until Chapter 7, aptly named "Simplified Conservation Equations for Reacting Flows" because the development excludes various phenomena such as thermal diffusion and focuses mainly on a few specific geometries; this is the most complicated chapter, and the author indicates that it can be skipped in an undergraduate course.

The remainder of the book, with the exception of a short chapter introducing turbulence in constant-density fluids, is devoted specifically to topics in combustion. Premixed laminar flames, laminar-jet diffusion flames, droplet burning, turbulent premixed flames, turbulent diffusion flames, burning of single carbon particles, and pollutant emission are all treated in different chapters. Many of these chapters are among the most unique and most interesting of the book; for example, in the chapter on premixed laminar flames, a good basis for designing burners for home gas ranges is given. A great deal of up-to-date knowledge about various combustion processes and devices is imparted in these chapters. Remarkable measures are taken to make the entire book palatable to the beginner. There are strong efforts to keep each chapter self-contained, even to the extent of repeating material from earlier chapters, usually calling the reader's attention to the earlier presentation. For example, an appendix is added to Chapter 6 that restates information from Chapter 2. Repetition of statements can be found even within the same chapter, in different sections. Detailed explanations are given of the simplest phenomena, but when somewhat more complicated phenomena are introduced, only brief statements of facts usually are offered, without an attempt at explanation. Things often are merely said to be quite complicated. In this respect, to the mature reader the book appears in a number of places to be short on explanation and long on exclamation. It is not beyond the author to offer a somewhat flawed argument, if it is simple and gives the right answer. A case in point is the mean-free-path treatment of molecular diffusion; there is no mention of why the molecules are assumed to come from one mean free path away, of the idea that for heat transfer this is because of the tendency to equalize energy in the last collision, or of the fact that for molecular diffusion there is nothing to equalize. There are instances, such as those concerning measured dependences of NO emissions on dilution in turbulent jet diffusion flames, in which explanations are offered, without indicating that there are at least equally tenable alternative explanations that are contradictory to what is said. These instances, however, are rare, and one is more likely to read simply that the reasons (if mentioned at all) are complicated or controversial or unknown. It seems to me that, since many younger undergraduates are content to merely absorb facts, the book could work well even at the junior level, although it is designed for seniors.

It is interesting to compare prefaces of books on combustion that try to target undergraduates. Murty Kanury[1] writes, "...this work finds its origin in the days of my teaching a senior level undergraduate combustion course...." In the 1984 revision of his 1968 book, Roger Strehlow[2] again begins, "This book is intended to be an introductory textbook on combustion for advanced undergraduates or beginning graduate students in combustion." Ken Kuo[3] states that "The level of this book is suitable for either senior or graduate courses in combustion." In his preface for J. C. Jones,[4] Alan Williams writes, "This book is suitable for undergraduate and postgraduate students in Departments of Chemistry, Energy, and Environmental Science as well as in part for students in Mechanical Engineering." Only Irv Glassman[5] refrains from calling out a level at which the text may be employed. Where does the book by Steve Turns fall in this spectrum? For many years, Murty Kanury[1] could lay claim to the most elementary book, but now Jones[4] and Turns have surpassed him in that respect. The Jones book is more of a survey for students not in engineering, and while its terse style allows broader coverage, it lacks all of the numerous pedagogic aids described above for the Turns volume. The Turns book can be recommended not only for undergraduate teaching but also for quite a bit of useful and up-do-date judiciously selected information on combustion that is not available in any other book and that will be of interest to engineers.

References

[1]Murty Kanury, A., *Introduction to Combustion Phenomena*, Gordon and Breach, New York, 1975.

[2]Strehlow, R. A., *Combustion Fundamentals*, McGraw–Hill, New York, 1984.

[3]Kuo, K. K., *Principles of Combustion*, Wiley, New York, 1986.

[4]Jones, J. C., *Combustion Science Principles and Practice*, Millennium Books, Newtown, NSW, Australia, 1993.

[5]Glassman, I., *Combustion*, 2nd ed., Academic, Orlando, FL, 1987.

Forman A. Williams
University of California, San Diego