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Book Reviews

Dynamics of Slender Vortices

Edited by E. Krause and K. Gersten, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1998, 458 pp., $205.00

As part of its series "Fluid Mechanics and Its Applications," Kluwer publishes International Union of Theoretical and Applied Mechanics (IUTAM) symposia on topics that fit under the umbrella of the series title. The present volume is one of the most recent, recording the papers presented at the IUTAM Symposium on the Dynamics of Slender Vortices held at the Rheinisch–Westfälische Technische Hochschule (RWTH), Aachen, Germany, Aug. 31–Sept. 3, 1997. Fittingly, the sessions were held in the RWTH's von Kármán Auditorium, named after Theodore von Kármán, who worked there decades ago on related problems, modern versions of which Aachen continues to explore so vigorously today. The symposium was broken into session topics: asymptotic theories, numerical methods, vortices in shear layers, interaction of vortices, vortex breakdown, vortex sound, and aircraft and helicopter vortices. Like most IUTAM symposia, this one consisted of a judicious blend of fundamental investigations and engineering applications. The topics of the first two sessions give the reader an idea of the present state and capabilities of asymptotic theories and numerical methods, which, although presented here often in the context of specific problems, are applicable to more general flows where slender vortices play the dominant role. The remaining topics show the progress in the wide spectrum of fluid dynamical problems in which the concept of slender vortices, broadly conceived, arises as a significant part of the problem. The reader might be impressed by this, were it not that the past few decades have acclimated research workers in fluid mechanics, and the students they have mentored, to the enormous power of vorticity and vortices as organizing principles in so many areas of fluid dynamics. The person new to the subject could do worse than to consult two recent texts, *Fluid Vortices* [S. I. Green (ed.), Kluwer, 1995; reviewed in *AIAA Journal*, Vol. 34, No. 4, 1996, pp. 875, 876] and *Introduction to Vortex Theory* (H. J. Lugt, Vortex Flow Press, 1996; reviewed in *AIAA Journal*, Vol. 36, No. 6, 1998, p. 1120), to gain a comprehensive in-depth knowledge of the subject and its multiple applications. The present volume could then serve to show some of the new directions of research in this area plus the most recent work in older areas. The specialist will undoubtedly find much of interest in his or her specific area, while all readers will find that the individual contributions in this volume are not of the kind we routinely find in symposium proceedings. The authors generally begin with succinct but thorough surveys of work on their problem, followed by their particular most recent contribution. Also, unlike in so many recent "photo-ready" volumes, the papers are not so different in typography and format as to make the transition from one to another disconcerting. Were the world more perfect, on the other hand, the price of the book would not be so dispiritingly consistent with the recent prices of such volumes.

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Propulsion Combustion: Fuels to Emissions

Edited by G. D. Roy, Taylor & Francis Publishers, Bristol, PA, 1998, 429 pp., $89.95

Evolving from studies spanning the past decade under the framework of the Office of Naval Research, where the editor, G. D. Roy, manages the Energy Conversion–Propulsion Program, the topics presented in this book cover, as the title suggests, broad aspects of the physical and chemical processes that we generically call combustion. Included are analyses of i) newly synthesized hydrocarbons of high-energy content, including their oxidative decomposition and combustion characteristics; ii) new reduced kinetic mechanisms; iii) current understanding of the mechanisms responsible for combustion instabilities; iv) modeling and simulation of multiphase chemically reacting flows; v) combustion diagnostics; vi) propulsion systems for underwater propulsion; vii) jet plume characterization; and viii) pollutant emissions.

Contributors to this volume have included updated information that, in many cases, is still part of open topics of research. For this reason, as the editor makes clear in his introduction, the authors present current advances and formulate opinions for needed future research in several areas.

Following the editor's overview, Chapter 2 describes a number of synthetic hydrocarbon systems with high-energy-density (HED) content. The authors, S. L. Anderson and S. R. Davis, include measured and calculated properties of HED hydrocarbons and certain oxidizing reaction paths. Some of these materials owe their elevated energy content to strained bonds, whereas others have a large, compact molecular structure. Although some of these formulations were synthesized over three decades ago (for example, cubane), only recently has progress been made in characterizing them for combustion applications. The difficulties, the authors point out, are derived from complicated syntheses that result in a low yield, producing in general subgram quantities, thus precluding extensive combustion-type experiments. Recently, however, some laboratories have produced larger quantities of HED materials, exceeding 100 g of certain compounds, which have thus become more amenable to experimental evaluations. Anderson and Davis focus in their paper on evaluations of dihydrobenzevalene (DHBV) using Fourier transform infrared spectroscopy, matrix photolysis, and a micro-flow-tube spectrometer to obtain the infrared spectrum and identify the decomposition products. From this information, a reaction scheme for the decomposition of DHBV has been suggested. Additional HED compounds have been evaluated by the authors, among them methylcubane, a liquid formulation, and dinitrocubane, a compound expected to decompose rapidly due to the presence of the NO_2 groups. Further, computational chemistry methods have been developed to expand the theoretical analyses of energetic materials.

An appropriate tool to evaluate the combustion characteristics of quantity-limited, HED fuels is droplet combustion. Chapter 3, authored by C. K. Law, presents results of droplet combustion of energetic materials obtained either through synthesis of HED hydrocarbons or by mixing metal powders in existing fuel formulations. The author points out that the HED content must be accompanied by the requirement of fast burning rate, as the mixing rate-controlling effects can prevent the realization of the high-energy potential. The gasification and burning rates for a number of compounds are presented, including azido-organic compounds individually and in stable mixtures with organic halides and hydrocarbons. It is shown that mixtures of less than 50% did not increase substantially the burning rate of dodecane, which leads to the conclusion that diazides are not effective as fuel additives. However, other recently synthesized HED hydrocarbons have indicated a significant increase in the burning rate, as described by the d^2 law, when compared with current fuel formulations, such as JP-10. Metallized slurries are treated next, identifying the stages of metal droplet combustion: evaporation, formation of a solid shell surrounding the molten material, internal vaporization, and finally microexplosion. It is shown that, because the burning rate is linearly dependent on mass conservation, the d^3 law describes the metal droplet combustion. Finally, it is pointed out that HED hydrocarbons have a propensity to soot, in particular when the highly energetic content results from a low hydrogen/hydrocarbon ratio in the structure.

In Chapter 4, F. A. Williams presents reduced kinetic schemes in combustion. Detailed kinetic mechanisms involve hundreds of chemical reactions even for low-order hydrocarbons. Despite significant developments in computational power in recent years, it is still practically impossible to include detailed chemistry in current theoretical analyses. The author shows through several examples how reduced kinetic schemes can be used to solve a number of combustion problems relevant to propulsion, including ignition and soot formation.

Although the subject of research for many years, combustion instability control is an issue that has yet to find a solution for practical propulsion systems. In Chapter 5, K. Kailasanath and E. J. Gutmark present the current theoretical understanding of combustion instabilities and results of theoretical and experimental studies of combustion instability control. In view of the broad range of relevant topics related to combustion instability systems, the authors limit their paper to the effects of large-scale flow structures applied to gaseous systems. Methods are indicated that have the potential to increase combustion efficiencies by a factor of 2 to 5 and reduce pollutants emission over three times.

Chapter 6, by G. D. Roy, complements the preceding chapter with a description of additional advances in combustion enhancement and control. This analysis is dedicated, in particular, to the effect of mixing as a limiting factor in chemically reacting flows and presents progress made in theoretical analysis of the large-scale structure formation, jet structure developments, entrainment and mixing due to axially generated vorticity, and practical methods to enhance mixing. Among them, lobed surfaces and countercurrent mixing layers are identified. Included are the effects of heat release on the mixing processes and the ability to control the combustion processes through mixing mechanisms, such as countercurrent mixing layers.

A particular combustion application is underwater propulsion that can be achieved with open or closed systems. S. H. Chan, L. A. Parnell, and E. W. Hendricks present in Chapter 7 a stored chemical power system specifically designed for underwater propulsion. This system uses as a heat source the combustion of a submerged gaseous oxidizer jet in a liquid metal bath. Theoretical and experimental analyses are developed for this multiphase, chemically reacting system. A conserved scalar approach has been used for the theoretical analysis, and new nonintrusive experimental methods have been developed to offer penetrating radiation imaging of the flowfield in real time.

One of the most challenging problems in the effort to model and predict processes in propulsion systems is the theoretical description and simulation of multiphase turbulent flows. This issue is presented in Chapter 8 by F. Mashayek, D. B. Taulbee, and P. Givi. The problem of multiphase flows is compounded by the need to capture the dispersion, and sometimes coalescence, of the condensed phase, liquid or solid particles. The authors present both statistical and stochastic modeling and direct numerical simulations (DNS). The chapter discusses the advances made in this area by the authors in recent years under U.S. Navy sponsorship, rather than a comprehensive review of the state of the art in the field. Some suggestions for future development are made based on these and other researchers' results. In this regard, DNS appears to play an increasingly significant role, as the increased computer capability will permit simulations of increasingly complex flows, including evaporating droplet dispersion and two-way condensed phase-fluid coupling.

Experimentally, recent years have seen a continuing development of nonintrusive, optically based measuring techniques. Some of the most promising are described in Chapter 9, authored by T. P. Parr and R. Hanson. Nonresonant techniques (Rayleigh and Mie scattering) and resonant techniques (absorption and fluorescence) are included. In recent years, absorption techniques using tunable diode lasers have reached the level of development that allows diagnostics of a large number of gaseous species (listed in the chapter) for concentration, temperature, and velocity measurements. Multidiode systems allow simultaneous measurements of multiple-species concentration and temperature. Planar laser-induced fluorescence (PLIF) techniques, developed for concentration, temperature, and velocity measurements in two dimensions, are presented as well. A three-dimensional PLIF technique emerges by use of either scanning mirrors or electronic scanning.

For practical propulsion systems, understanding the plume structure is significant from the point of view of signature and pollutants emission. Chapter 10, authored by K. C. Schadow, K. H. Yu, and D. W. Netzer, treats the issue of rocket propulsion exhaust plume characteristics. The signature can be caused by several factors, such as UV and visual radiation, particle thermal radiation, and radar cross section. Recent flow-control techniques capable of reducing plume signatures are presented along with their impact on performance.

Further combustion emission and control issues are the subjects of Chapter 11, which is authored by G. M. Faeth, G. Roth, and M. Gundersen. These topics include soot formation, growth and control, effects of oxides of nitrogen on the environment, and control technologies via mixing and plasma techniques. Emphasized are recent advances made in the description of the chemical mechanisms leading to pollutant formation and control.

Clearly, this book covers a broad range of recent advances in propulsion research, mostly within the U.S. Navy-sponsored research framework. The book appears to be too advanced for undergraduate students, but it may be of interest for advanced industrial applications. The papers are at a uniformly high level, and the book is attractive for potential and active researchers in the field.

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