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REVIEWS

Advances in Fluid Mechanics Measurements. Edited by M. Gad-el-Hak. Springer-Verlag, 1989. 608 pp. £53

Frontiers in Experimental Fluid Mechanics. Edited by M. Gad-el-Hak. Springer-Verlag, 1989. 532 pp. DM 120.

The editor of these two volumes in the Springer series of Lecture Notes in Engineering is a well-known experimentalist in fluid mechanics, a senior member of the research staff of Flow Research, Inc. and presently Professor in the Department of Aerospace and Mechanical Engineering, University of Notre Dame, USA. Each volume is a collection of independent review articles. But it is noteworthy that many of the papers are closely related, as indeed are the two volumes.

We begin with *Advances in Fluid Mechanics Measurements*, the table of contents of which is as follows:

The papers by Freymuth, Miles & Nosenchuck, Gharib & Willert, Lourenco, Krothapalli & Smith and in part the papers by Simpson and Weidman have much in common and describe a great variety of conventional and novel visualization techniques and optical methods including image processing. The most comprehensive exposition of modern methods for three-dimensional diagnostics of fluid volumes is given in the paper by Miles & Nosenchuck. Their paper contains a review of the physical processes involved, methods of volume imaging (lightsheet, stereo-imaging and schlieren techniques), holographic particle imaging, optical tomography, acoustic and magnetic resonance imaging, and a review of visualization methods of space-filling three-dimensional data. The papers of Gharib & Willert and Lourenco *et al.* deal with two-dimensional particle image velocimetry – the first article describes the recent advances in solving drawbacks of conventional particle tracing, while the second one deals with the modern state of laser speckle velocimetry. The papers by Simpson and Weidman present in addition to visualization and optical methods a large number of other experimental methods for specific applications in separated flows and laboratory rotating flows with the emphasis on problems of probe interference. The paper by Leehey on dynamic wall pressure measurements in turbulent boundary layers is concerned primarily with specific problems of resolution of large-wavenumber components, interpretation of cross-spectral measurements and scaling of the small-wavenumber components. Haritonidis puts the emphasis 'on how to approach wall shear stress measurement and the inherent problems in the most common techniques' with particular attention to those methods which are 'most useful for calibration purposes and either the most reliable or holding the greatest promise for future development'. The second part of the article by Diller & Telionis overlaps considerably with that of Haritonidis, while the first part of their paper contains an updated review of methods of heat transfer measurements with particular attention to measurements in unsteady flows. Perhaps all known methods of vorticity measurements are reviewed in the paper by Foss & Wallace. In fact the scope of their paper is broader and includes measurements of velocity gradients as well. The modern state of the experimental methods for turbulent flows of drag-reducing polymer solutions is reviewed in the article by Hendricks *et al.* The final paper of this volume by Dunn, Novick & Schlenger is devoted to a rather special problem – measurement techniques used for aerosol measurements in nuclear test facilities.

Frontiers in Experimental Fluid Mechanics is a collection of rather different papers, the titles and authors of which are as follows:

The influence of developments in dynamical systems theory on experimental fluid mechanics, by M. Sen;

Low speed, indraft wind tunnels, by S. M. Batill & R. C. Nelson;

High-Reynolds number liquid flow measurements, by G. C. Lauchle, M. L. Billet & S. Deutsch;

The turbulent boundary layer, by K. R. Sreenivasan;

The art and science of flow control, by M. Gad-el-Hak;

Microbubble drag reduction, by C. L. Merkle & S. Deutsch;

Unsteady pulsing of cylinder wakes, by D. R. Williams & C. A. Amato;

Vortex dynamics of delta wings, by M. Lee & C.-M. Ho;

Accomplished insect fliers, by M. W. Luttges;

The aeroacoustics of trailing edges, by W. K. Blake & J. L. Gershfeld.

Though some of these articles are perhaps not close to the frontiers of experimental fluid mechanics, all of them contain updated and useful information. We first review groups of related papers. The articles by Batill & Nelson and by Lauchle, Billet & Deutsch describe two groups of basic laboratory facilities. The first paper is a comprehensive account on indraft wind tunnels describing all the aspects of the question including a fascinating historical overview, description of types of indraft tunnels, their components and modern design. The second article concentrates on liquid flow facilities, mostly water tunnels, their operation and a variety of areas of measurement: body force, boundary layer, multiphase flow (cavitation), hydro-acoustic and internal flow measurements. In this last respect this paper is closely related to the previous volume. Another group of related papers are those by Gad-el-Hak, Merkle & Deutsch and Williams & Amato. The article by Gad-el-Hak is a broad exposition of approaches and techniques of flow control for various purposes with the emphasis on boundary-layer flows. Two other papers from this group review particular aspects of the flow control problem, namely drag reduction via injection of gas microtubules into a liquid turbulent boundary layer and the influence of unsteady forcing on wakes past cylinders. Three last papers, by Lee & Ho, Luttges and Blake & Gershfeld though very different in contents and theme have vorticity as a common basis. The first article in this group is a review of experimental research on steady and unsteady flows past delta wings in the framework of dynamics of vorticity and the vorticity balance. The paper by Luttges deals with flight characteristics of dragonflies and hawk moths. These include wing kinematics, aerodynamic force generation and flow–wing interactions, with the emphasis and particular attention on the role of vorticity production and several ways of shedding it. The third paper in this group is a survey of the physics of aerodynamic noise generation of trailing-edge flows including the importance of the geometry of a lifting surface, the upstream boundary layer and trailing-edge wake. The article by Sreenivasan is a brief review of the present state of research on the turbulent boundary layer on a smooth flat wall. Finally, the paper by Sen outlines the impact that some developments in dynamical system theory have had on particular aspects of experimental fluid dynamics.

Summarizing, both volumes are collections of valuable updated information which will be useful not only for experimentalists, but also for theoreticians who want to have an impression of what experimental fluid dynamics is about. For those who think of an experimentalist as a superior kind of professional fixer knowing how to turn nuts and bolts into a confirmation of their theories, these volumes will be especially instructive. It would perhaps help to make these two volumes an outstanding exposition of advances and frontiers in experimental fluid dynamics if the editor could add a paper (or even a volume) containing along with current methods of experimental research an explicit presentation of problematics and future prospects for experimentation in turbulence – one of the greatest frontiers of fluid mechanics.

A. Tsinober

Mathematical Modelling in Combustion and Related Topics. Edited by C.-M. Brauner and C. Schmidt-Lainé. Martinus Nijhoff, 1988. 592 pp. $99 or £59.

Instrumentation for Combustion and Flow in Engines. Edited by D. F. G. Durão, J. H. Whitelaw and P. O. Witze. Kluwer Academic, 1989. 395 pp. $99 or £64.50.

Combustion, the science and technology of chemically reacting fluids and solids, is an interdisciplinary field combining essential aspects of fluid mechanics, thermodynamics and chemistry, each of these disciplines representing an important field in its own right. Owing to the remarkable progress in the development of both experimental and numerical techniques in recent years, means have become available which allow combustion phenomena to be studied in a depth previously unknown. A characteristic of many of the new techniques is their ability to produce high spatial and temporal resolution of flame structures and evolutions, and it is this ability that has provided enhanced insight into many modes and ingredients of combustion processes. This progress in the understanding of combustion is reflected not only in the fast growth of the literature on the subject, but also in the rapidly increasing number of conferences and workshops being held all over the world with the aim of keeping up with the emerging trends in experimental techniques, numerical methods and computational facilities.

Since the advent of computers, and with the steady improvement of their speed and memory size, the theoretical development of combustion has been complemented by a new branch termed 'computational combustion'. Nowadays combustion theory and computational combustion collectively are known as 'mathematical modelling of combustion', which is the main topic of the first of the two proceedings under review. The many different timescales introduced by chemical reactions and the heat released in any combustion process add both challenges and difficulties to the dynamics of non-reacting flows. As a consequence, although great progress has been made in recent years, the mathematical modelling of combusting fluids and solids is at a less advanced level than that of non-reactive fluid mechanics. This is reflected by the proceedings of this NATO Advanced Research Workshop held in Lyon, France, in April 1987. The book, which is dedicated to the memory of Geoffrey S. S. Ludford and his many contributions to combustion theory, is divided into two parts. Part I comprises the papers associated with invited lectures, and part II consists of shorter contributions. The invited lectures were given by H. Berestycki *et al.*, J. D. Buckmaster, J. F. Clarke, P. Clavin, P. C. Fife, B. P. Gerasimov, G. Joulin, M. Lesieur, A. Liñán, M. Marion & R. Temam, N. Peters, T. Poinsot & S. M. Candel, A. A. Samarskii, S. Sivasegaram & J. H. Whitelaw, M. D. Smooke *et al.*, D. S. Stewart and F. A. Williams. In general, the papers of the invited lectures, as well as those of the shorter contributions, represent the results of recent works and are both original and of high quality.

The contents of the book clearly reflect two important trends in the mathematical modelling of combustion. Firstly, the oversimplifying assumption that combustion chemistry can be described by a one-step reaction, i.e. by a single global reaction step in which the reactants are converted into products without forming reaction intermediates, appears to have become redundant from both the theoretical and numerical viewpoint; it remains justified only for problems in which either geometry or physics, or both, are extremely complicated. There is a strong trend towards chemistry models called '(systematically) reduced mechanisms', which comprise several global reaction steps, say 4 to 8, whose rates depend in an algebraically complicated fashion on the rates of individual elementary steps of a detailed kinetic mechanism of elementary reactions. For instance, a reduced mechanism for premixed methane–air flames comprises seven reacting species and four global steps, and the rate expressions of these steps contain explicitly the rates of 15 elementary reactions.

Systematically reduced mechanisms provide new perspectives for modelling both laminar and turbulent reacting flows. For instance, until recently in the majority of theoretical approaches to solutions of laminar combustion problems asymptotic expansions have been based on the large Damköhler (Damköhler-number asymptotics) or Zel'dovich number (large activation-energy asymptotics) of a single overall one-step reaction. Both Damköhler-number asymptotics and large activation-energy asymptotics are now being displaced by the so-called 'rate-ratio asymptotics' in which the ratios of the rates of two or more elementary-reaction steps provide expansion parameters for asymptotic analysis. In rate-ratio asymptotics the combustion chemistry is described by a systematically reduced kinetic mechanism. Owing to the moderate number of chemical species and reaction steps involved in systematically reduced mechanisms, these mechanisms open the avenue for the detailed modelling of turbulence-chemistry interactions in reacting flows. The breakthrough here is the fact that reduced mechanisms allow realistic chemistry to be taken into account in a manner not restricted to particular modes of turbulent combustion.

The second important trend in the mathematical modelling of combustion is concerned with computational aspects of laminar reacting flows. Difficulties in the numerical simulation of such flows arise from an undesirable mathematical property of the governing equations, called stiffness, which is a consequence of the strongly nonlinear chemical-source terms which appear in the energy and species-mass conservation equations. Only recently have the knowledge of numerical methods and the speed and capacity of computers advanced to a point where numerical simulations of laminar reacting flows in two space dimensions are becoming feasible with somewhat detailed chemistry, i.e. with up to twenty chemical species, say. However, despite this remarkable progress, the state of the art of computational combustion lags far behind that of computational fluid dynamics, a field in which a few years ago numerical simulations had already become feasible for laminar and turbulent flows in complicated three-dimensional geometries.

Certainly, the present book is not suitable for newcomers to the field, but it is likely that anyone already acquainted with either theoretical or numerical approaches to combustion problems and wishing for more information on current developments in his or her particular area will find something useful in it. In particular, the book will be useful for researchers active in the area of mathematical modelling of combustion.

Combustion experiments have played an important role in validating and delineating the limits of various approximations to the equations governing chemically reacting flows, and great progress has been made in developing new or extending existing experimental methods. Examples are quantitative measurement techniques, such as Mie, Rayleigh and Raman scattering or laser-induced fluorescence, and various flow-visualization techniques such as laser-Doppler and particle-tracking velocimetry. In particular, a recent major breakthrough was the extension of quantitative point-measurement techniques using laser sheets and multi-dimensional detectors to two and three dimensions. These techniques allow quantitative instantaneous field measurements as well as qualitative visualization of chemically reacting flows with high temporal and spatial resolution. The second book under review, which is the proceedings of a NATO Advanced Study Institute held in Vimeira, Portugal, in September 1987, is concerned with recent advances in these areas, although focusing on the application of the experimental techniques to two practical devices, viz. gas turbine combustors and internal-combustion engines. The book contains selected conference papers only, the authors of which are M. V. Heitor, S. Sivasegaram & J. H. Whitelaw, K. C. Hopkins *et al.*, A. C. Eckbreth, A. Leipertz, J. Haumann *et al.*, D. F. G. Durao & J. M. C. Mendes-Lopez, J. Labbe & A. Jerot, A. Cadiou, C. F. Old, C. Arcoumanis, P. O. Witze & T. A. Baritaud, J. C. F. Pereira, F. Durst & T. Börner, R. P. Lucht, C. G. W. Sheppard & E.-S. A. A. Ibrahim, M. Haghgoodie & J. C. Kent, and M. Parsi & H. Daneshyar.

Like the book discussed first, these proceedings are not suitable for newcomers to the field; rather they represent a book containing information provided by specialists for specialists working in the same specific area. In the preface it is said that the motivation for the conference was 'to narrow the gap between current industrial practice and the acquisition and implementation of improved (experimental) techniques', and, therefore, about one third of the articles in the book originate from industry, national laboratories and other non-university institutions. Whether or not the book does fulfil the declared aim of the conference appears questionable. Nevertheless, the book provides information on the current status of the experimental techniques discussed above and, therefore, can be recommended to experimental researchers not only in gas turbines and internal combustion engines but in all areas of combustion.

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