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Book Reviews

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Springer Handbook of Experimental Fluid Mechanics

Edited by Cameron Tropea, Alexander Yarin, and John Foss, Springer–Verlag, Berlin, Heidelberg, 2007, 1556 pp., $249.00

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WHEN asked to review this handbook, I wanted to read the entire book as quickly as possible, but ended up taking 3 months to study and digest sections on topics of which I had some prior knowledge and many which I did not. I was able to have a peer's viewpoint on some of the work and that of a student on other parts. Both types of person will be users of this Handbook.

The editors, Cameron Tropea, John Foss, and Alexander Yarin, are distinguished experimental fluid dynamicists, active researchers, and professors, who have made many contributions of their own to the development, use, and improvement of a number of the techniques described in this handbook. The editors selected 89 other noted and accomplished experimentalists to collaborate in developing this work. These 92 authors represent all parts of the globe and include not only very experienced persons, but many who received their advanced degrees developing and using the latest techniques within the past 10 years. A photo and short biography of each person with mention of their handbook contributions introduces the reader to these authors and some of their accomplishments.

The stated purpose of this 1500 page handbook is to provide comprehensive information to the experimental fluid mechanics community for planning, executing, and interpreting experiments. To achieve these goals, the handbook has been organized into four logical parts: Part A (Chapters 1 and 2), which addresses the need and motivation for experiments and presents the rigorous governing equations and boundary and initial conditions that form the foundation of experimental work; Part B (Chapters 3–8), which is devoted to the measurement of all primary quantities that are in these equations; Part C (Chapters 9–21), which presents topics related to specific applications or techniques; and Part D (Chapters 22–25), which is devoted to signal and data acquisition and processing. The thread of development of information in the various parts and chapters follows a logical order, so that if one reads the book starting from the beginning, they will have covered everything needed to understand the later portions.

Chapter 1 also includes two-phase interfacial conditions and constitutive relations for the nonlinear rheology of polymer melts. Chapter 2 presents similitude, dimensional analysis, and some similarity solutions for now classical fluid mechanics problems. This treatment is both a thorough reference for the experienced fluid dynamicist and a lucid introduction for a student researcher. Chapter 3 not only covers the measurement of density, viscosity, thermal, and mass diffusion properties, but a rather thorough treatment on the measurement of surface tension, contact angle, and electric and magnetic properties. Experimental uncertainties for most of the methods are discussed too. Although classical methods of measuring static pressure are well covered, the discussion of the use of modern pressure sensitive paints in Chapter 4 captured my attention.

The 258 page Chapter 5 provides a comprehensive treatment of the measurement of velocity, vorticity, and Mach number, and could be a book by itself. Pitot tubes, hot-wire and laser-Doppler velocimetry (LDV), particle image velocimetry (PIV) and other particle based methods, molecular tagging methods, thermal transient anemometry, and sonic anemometry are discussed and related to 865 references.

The graphics are particularly informative for the Chapter 6 discussion of density-based techniques, such as shadowgraphy, schlieren method, Moiré deflectometry, interferometry, and optical tomography. Chapter 7 contains discussion of modern methods for measuring temperature and heat flux of surfaces using thermochromic liquid crystals, infrared cameras and imaging, absorption and fluorescence methods, and temperature sensitive paint. Flowfield temperature measurements using methods using thermochromic liquid crystals with tracers is also included. When I first thought that thermocouples had been left out, I quickly discovered through the index that high-response thermocouples were discussed in Chapter 16. The treatment of force and moment measurements in Chapter 8 is a typical example of how this handbook is written for both the professional and the student. The description of strain gauge and load cell principles is clear and concise for the beginner, while still providing room for much discussion of many of the detailed issues that affect low uncertainty results.

As mentioned toward the beginning of this review, Part C (Chapters 9–21) presents topics related to specific applications or techniques. This is important because generic measurement techniques often have to be modified to produce useful results for specific applications. Chapter 9 on non-Newtonian flows was entirely new material to me. A very understandable discussion of the equations in Chapter 1 and the concepts and theory of some non-Newtonian flows permitted me to quickly understand the methods that were used to measure features of these flows. Likewise, Chapter 10 describes the nature and features of turbulent flows before discussing single point and global flowfield methods that can be used to provide information for improved modeling, such as large-eddy simulations.

Often, flow visualization can provide important global flowfield insights relatively quickly early in an investigation. Chapter 11 provides the fundamentals and details for well-developed methods. I was particularly impressed with the section titled "The Addition of Tracer Materials as Initial Condition," which alerts the user to the proper interpretation of flow visualization data, particularly in unsteady flows. Building on earlier discussions in Chapters 5 and 10, Chapter 12 on "Wall Bounded Flows" focuses on methods used to conduct laminar-turbulent transition studies, to determine the surface skin friction, and to resolve issues related to the close proximity of a wall in measurements. The surface also constrains the possible flow patterns, which are discussed in Chapter 13 on topological considerations. Although no discussion of the surface oil-flow visualization method is given, the same caution given in Chapter 11 on the influence of initial conditions applies on the patterns and interpretation, especially for highly separated unsteady and three-dimensional flows.

Measurements in turbomachinery are particularly difficult because the flows are unsteady and highly three-dimensional and there is limited access for instruments. Chapter 14 contains a review of many issues and efforts using various types of techniques introduced in Chapters 4 and 5. Measurements in cavitating flows, wave height measurements, and sediment transport measurements are the subjects of Chapter 15 on hydraulics. Although aerodynamics is the subject of Chapter 16, it is really devoted to the timely specialty subjects of ground vehicle aerodynamic wind-tunnel testing, short duration high-enthalpy high-pressure hypersonic flows, and bluff body aerodynamics.

Unlike any of the earlier discussed techniques, Chapter 17 deals with atmospheric flows, where there is no practical limit on the size of the instruments. The local measurement of wind velocity, temperature, pressure, humidity, heat flux, and dispersion of pollutants is addressed. Typical information that can be obtained from remote sensing and satellite data is also included. Oceanographic measurements (Chapter 18) are also not limited by instrument size and use saltwater devices for ocean currents, salinity, temperature, density, speed of sound, and dispersion on measurement platforms like towed vehicles and autonomous underwater vehicles, as well as remote sensing systems.

At the other end of the length scale spectrum, Chapter 19 (Microfluidics: The No-Slip Boundary Condition) addresses the wall no-slip condition and the methods used to examine this nearest wall region. One may first think that assuming the no-slip condition within a few nanometers uncertainty is adequate, but with the potential for modifying the slip by means of new nanotechnologies, these methods and techniques will be valuable in evaluating fluid–surface interactions.

The combustion diagnostics in Chapter 20 are mainly spectroscopic in nature, because laser-based methods are preferred, and LDV and PIV methods are discussed earlier. The relation between combustion experiments and numerical simulation is also addressed. When hydrodynamic systems are subjected to electric fields (Chapter 21, Electrohydrodynamic Systems), the electrical force term plays a crucial role in the Navier–Stokes equations. Electrical heating affects the temperature and the flow. The behavior of particles used in LDV or PIV is affected. The discussion addresses all of these issues.

Of course, all useful information should be extracted from these experiments, and so Chapter 22 deals with data processing by transforms, correlations, and proper orthogonal decomposition, whereas Chapter 23 is devoted to statistical principles and discussion of the Cramer–Rao lower bound for signal-to-noise ratios that produce low uncertainties. (Few other books even discuss this important topic.) Because of the importance of optical imaging data, Chapter 24 (Data Acquisition by Imaging Detectors) is devoted to the principles and limitations of these technologies. Finally, Chapter 25 is devoted to image processing and motion analysis.

The hundreds of references at the end of each chapter generally seem to satisfy the requirement that the most definitive and useful sources be cited for the reader's further study. Citations are not just from recent work, but also from some time-tested sources from nearly a century ago. References to review articles and books for some topics will lead the reader to many more sources for greater detail. The authors have distilled the considerable literature and present the issues and the essence for each subtopic, for the most part. However, in some few instances for topics that I know something about, I believe that more useful articles and books or later editions of books could have been cited, but were not.

A DVD-ROM PDF version of the handbook accompanies the hardback book. The universally available Adobe Reader allows the user to read, search, navigate, and zoom throughout the text in quickly searching through the subject index. A click on a listed subtopic in the table of contents jumps to that material. A click on a cited reference within the text leads to the end-of-chapter reference list.

The book is excellent for a user who wants to obtain some information on a given topic without reading and digesting many papers. At this price, it will likely be a

library book, although having the DVD-ROM makes it easily worth the money for a fluid mechanics professional. The book production quality is excellent too, although the binding on my copy was weak. (This drawback is not significant because most will use the DVD-ROM.) The high-quality drawings, photos, and figures are clearly labeled and captioned.

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