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REVIEWS

Laser Velocimetry and Particle Sizing. Edited by H. DOYLE THOMPSON & WARREN H. STEVENSON. Hemisphere Publishing Corp., 1979. 566 pp. $49.50.

Professors Thompson and Stevenson of the School of Mechanical Engineering, Purdue University, have taken a praiseworthy lead in the field of laser velocimetry (the use of laser beams to measure velocities of moving macroscopic objects, particularly small seed particles suspended in liquid or gas flows) in organising three International 'Workshops' in 1972, 1974 and 1978, to review progress in the subject. These have been, perhaps, *the* major meetings out of an increasing number and particularly valuable proceedings have been produced in each case. The volume under review is the proceedings of the third of this series. During the first two meetings, a great deal of material was presented on instrumentation, both optical and electronic, and the aim of the organizers for the third was to orient it towards practical applications. In particular, of course, at this stage, difficult ones such as highly turbulent or reacting flows were topical. In addition the increasing use of *in situ* laser scattering to measure aerosol particle sizes, sometimes simultaneously with velocities was recognized by the inclusion of two full sessions devoted to these techniques.

The particle sizing work will be considered first. This is a notoriously difficult and yet industrially important field. We see, in the nine papers recorded, here, approaches which attempt to size particles without removing samples for separate analysis, as has been commonly employed to date by counter-type processors. Four basic methods can be identified in these papers.

(1) Use of the existing signals of a forward-scattering differential Doppler laser velocimeter. A monotonic relationship is sought, by careful calculation of Mie scattering amplitudes for various optical geometries, between particle size and either mean signal strength (Chigier *et al.*) or signal visibility (Farmer and others). The latter method is called particle sizing interferometry.

(2) Measurement of the ratio of scattered amplitude at two different scattering angles. This method can again give the monotonic dependence desired over specified ranges of size and complex refractive index with the advantage of being relatively insensitive to the latter. In an excellent presentation Bachalo describes an instrument combining both this method (0·5–3 μm) and particle sizing interferometry (3–20 μm).

(3) Absolute scattering-intensity measurement from a single focused laser beam at 0° forward scatter. The main difficulty with this method is the variation of scattered signal with the position of the particle in the gaussian beam profile. Holve and Self solve this problem statistically. Each size of particle present will give a distribution of signal strengths of a known form assuming that the trajectories are randomly situated within the beam. The size distribution is found to be a deconvolution of this known form from the total signal strength distribution using a non-negative least-squares fitting procedure.

(4) Use of a laser Doppler velocimeter (LDV) to measure the motion of particles

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suspended in an acoustic field. The single particle aerodynamic relaxation time (SPART) is found in an instrument described by Mazumder *et al.* by measuring the relative phase lag of the LDV signal with respect to that of the acoustic excitation. Up to 10000 particles per minute in the size range 0·1–10 μm can be analysed in a sensing volume of $1{\cdot}3 \times 10^{-7}$ cm^3.

All these methods fail when too many particles are present and I should mention perhaps a method not discussed, which is available in a commercial instrument, namely, that of recording the Fraunhofer diffraction pattern, from an expanded laser beam passing through a particle suspension, with a bank of detectors at different angles. The size distribution is computed as in method 3 above by a least squares deconvolution, assuming a given parametric form.

The increasing interest in so-called 'laser transit velocimetry' (LTV) where the signals from particles passing successively through two highly focused 'spots' gives us a new distinction against the more common differential Doppler (LDV) technique in which the scattered signals from two beams at different angles of incidence on the same particle beat together to form the difference frequency. Much work has been done since this Purdue meeting on the analysis of LTV signals, which perhaps surprisingly is not as simple as it might seem, however. Lars Lading compares LTV with LDV, and in several particular cases recommends the LTV method. Although the debate still rages hotly, there is no doubt of the utility of the LTV method when making measurements close to boundaries due to its high flare rejection. An instrument from the reviewer's laboratory which can be switched between LDV to LTV operation as desired was described.

On the conventional LDV method one can classify the contributions into two main groups, namely, problems in data analysis and applications to particular flow problems. Apart from one mention of the Fabry Perot interferometer (Self) four signal-processing methods were used or discussed in the various contributions. Spectrum analysis (Simpson and Chew) is still used rarely, here in a fast scanning arrangement. Frequency tracking (Schefer *et al.* and Humphrey) continues to be useful in certain circumstances. Burst counting (in many forms) is the most popular technique represented here although there is much discussion in various contributions of the effects of photomultiplier noise, digitization of time measurement, particle bias errors and polar response on the measured output. Whiffen, for example, in a sobering burst-counter study of turbulence in a subsonic jet shows errors in turbulence measurement over those recorded with a hot wire of up to 500 % in some circumstances. The problem is not unknown to your reviewer which is one reason why he counsels this book as essential reading for discriminating would-be users of these methods. Photon correlation is the fourth method and here if the first person may be excused for a moment, I have some difficulty in being objective since this method was developed in our own laboratories at Malvern. It seems to be agreed that photon correlation, as was intended by its proponents, keeps going when all other methods give up either for lack of signal or of signal to noise ratio. In a personal contribution to the volume I showed that, using this method, 100 detected photons from a scattering particle could be considered to be a strong signal. Other contributions from Smart and from Mayo discussed photon correlation and photon noise limitations on performance. Erdmann and Gellert's recurrence rate correlation method for direct measurement of the velocity autocorrelation function (*App. Phys. Lett.* **29**, 408,

1976) also had a mention by Stevenson in his introductory review. This will surely be of invaluable use in the topical 'hunt the strange attractor' game.

Particular flow problems considered included combustion measurements, turbulent boundary layers, internal combustion engines, RF plasma and two phase flows, but space forbids singling out any of these areas of research for detailed comment. It is clear that the LV method is not yet (and perhaps never will be) reduced to the simplicity of pointing the beams and reading a meter. One might also comment that if a hot wire is applicable to the problem than it should be applied! Nevertheless, as this workshop has shown, LV is a tool of considerable power and versatility and without doubt will make more and more contributions of significance to the subject of fluid mechanics.

E. R. PIKE

Transfer Processes: An Introduction to Diffusion, Convection, and Radiation. By D. K. EDWARDS, V. E. DENNY and A. F. MILLS. 2nd Edition. Hemisphere, 1979, 421 pp. $21.50.

In this second edition of an introductory level text, published originally in 1973, emphasis is placed on a phenomenological approach to transfer processes. The student is encouraged to develop a basic understanding of the physical phenomena occurring in the systems under consideration, while employing elementary mathematical tools to solve engineering problems. Formal mathematical modelling methods, discussed in abbreviated form, are relegated to the appendices. This de-emphasis of the consideration of partial differential equations seems to be traditional among many heat-transfer educators. The authors reinforce this viewpoint by imploring the instructor to consider the importance of student experience with engineering practice when overcome with the urge to solve differential equations. In operation, this approach to instruction can lead to the development of heat transfer engineers with significant skills in using reference texts and handbooks who have little ability to be quantitatively innovative with novel systems. In this sense the book ignores contemporary mathematical modelling efforts which are aimed at developing an integrated approach to solution development and physical interpretation. The student exposed to such an instructional process finds the motivation for the introduction of mathematical skills contained in the immediate physical application.

The authors have combined material for an introductory course in transfer processes with more detailed subject matter appropriate for advanced courses. In either case the emphasis is on engineering solutions to systems of practical interest. The practising engineer, as well as the student, can make excellent use of the book as a resource base. One finds a significant collection of useful data. Both British engineering and Systéme International (S.I.) units have been employed.

Once the, perhaps excessively complex, examples of transfer processes in the first chapter are overcome one finds a nicely written text with many illustrative examples, an extensive collection of interesting problems and many citations presented for further education. There is a gradual transition from discussions of transfer processes in elementary situations to those occurring in real engineering systems. The student with an opportunity for a several course sequence, in which the text was employed in a comprehensive manner, would have an enlightening experience!

D. R. KASSOY

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Studies in Heat Transfer, A Festschrift for E. R. G. Eckert. Edited by J. P. Hartnett, T. F. Irvine, E. Pfender and E. M. Sparrow. Hemisphere, 1979. 516 pp. $42.50.

Studies in Heat Transfer is a compendium of invited articles dedicated to Professor E. R. G. Eckert in honour of his seventy-fifth birthday. The eclectic nature of the collected papers reflects the extensive impact that Eckert's work has had on the development of heat-transfer analysis. In particular one finds the application of basic scientific principles and contemporary mathematical modelling techniques to complex systems in order to obtain usable engineering results.

The initial article, an elucidating review of turbine-blade cooling, is followed by several fundamental studies of boundary-layer cooling by wall mass addition and liquid-film evaporation. Additional articles concerning external boundary-layer phenomena deal with the stability of heated laminar flow, the nature of compressible turbulence and the influence of surface roughness. Internal natural-convection processes, including the effects of phase transition at a free boundary, are the subject of several papers. The interaction of fluid mechanics and heat transfer is observed in a study of a melting solid. Investigations of confined systems are found in papers dealing with complex duct flows, convection in a rotating system and heat transfer in a confined jet. Several papers deal with the fluid mechanical process in the vicinity of a solid surface. A triad of papers discuss heat-transfer processes in solar-energy engineering systems. We are transported to the Moon for measurement of lunar soil conductivity and returned gently to the Earth's surface to consider the atmospheric boundary layer. And yet there is more!

The diversity of the subject matter makes the book of interest to the engineer, to the scientist, to the educator and the student. There is an inviting mixture of engineering studies and more fundamental investigations. A perusal of the article abstracts, collected just before the Index, provides the reader with perspective on the extraordinary expanse of subjects in which heat transfer processes are significant. In this sense the volume contents provide a terrific justification for providing engineering students with fundamental courses in fluid mechanics and heat transfer: the knowledge obtained can be used in subsequent courses which deal with complex engineering systems. The book could be used as a text in an advanced graduate level course on contemporary heat-transfer problems.

D. R. Kassoy

Shorter Notices

Energy Methods in Finite Element Analysis. Edited by R. Glowinski, E. Y. Rodin and O. C. Zienkiewicz. Wiley, 1979. 361 pp. £17.50.

This book is a collection of 19 papers and is dedicated to the memory of Professor de Veubeke. The theme of the book, from the point of view of finite elements, is the use of variational or energy methods, as the title suggests. Thus the first paper, by J. T. Oden, is 'The classical variational principles of mechanics.' This paper also shows another common feature of the papers, which is their interest in mechanics, particularly continuum mechanics. Readers of this journal should be warned, however,

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that the papers are presented in the language of algebraic spaces (Hilbert, Sobolev, etc.) and consequently may be a little abstract for the taste of the average reader.

Elementary Finite Element Method. By C. S. DESAI. Prentice-Hall, 1979. 434 pp. £16.20.

This book aims at teaching the method of finite elements to undergraduates. It opens with a description of the author's division of a finite-element analysis into 8 steps. These steps are then referred to when tackling specific problems later in the book. The physical problems that the book uses as examples include fluid flow, wave propagation and stress-deformation problems; the first 10 chapters deal with one-dimensional versions of these problems, and the remaining four chapters two-dimensional problems. As an additional aid to undergraduate teaching, the author includes actual computer codes, written in Fortran, for implementing many of the solutions to problems studied in the book.

Water and Steam, Their Properties and Current Industrial Applications. Edited by J. STRAUB and K. SCHEFFLER. Pergamon, 1980. 684 pp. $75.00

This volume is the proceedings of the 9th international conference on the properties of steam, held at the Technische Universität, München, in September 1979. There are 30 papers grouped under the heading *Equilibrium Properties*, 16 papers under *Transport Properties*, 9 papers under *Other Properties* and 15 papers under *Power Cycle Chemistry*. The papers of the first section include experimental ones providing compilations of data on the properties of water and heavy water over a wide range of conditions (temperature and pressure), and theoretical ones on equations of state suitable for various regimes. The second section repeats the pattern with viscosity and thermal conductivity being the objects of study. The third section includes papers on refractive index, surface tension, contact angle and other properties, while the fourth closes the book, with papers on more chemical aspects – interaction between iron and water, electrolytic solutions, etc.

Heat and Fluid Flow in Power System Components. Edited by A. M. A. REZK. Pergamon, 1979. 308 pp. £21.00.

This volume consists of twenty papers selected from those presented at the second conference on Mechanical Power Engineering held at the Faculty of Engineering, Ain-Shams University, Cairo, in September 1978, together with a subject-index at the end of the book. The papers are grouped into three parts: Part I is 'Heat Transfer in Power Elements' and contains 9 papers; part II is 'Non-reactive Flows' and contains 8 papers; part III is 'Reactive Flows' and contains 3 papers. There are experimental, numerical and analytical contributions. The book is a reproduction of the authors' typescripts, including hand-written symbols. The affiliations of the authors are not given.

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