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REVIEWS

Vortex Element Methods for Fluid Dynamic Analysis of Engineering Systems.

By R. I. Lewis. Cambridge University Press, 1991. 566 pp. £75 or $125.

The appearance of this volume is to be welcomed, since it draws together a large body of work carried out by the author, his students and his associates since the 1960s, and presents it in a unified way, setting it in the context of parallel efforts elsewhere. Much of this work has previously been available only in theses, internal reports and conference proceedings. Workers in the field will now be able to assess its relevance to their own problems.

The vortex elements of the title are the rectilinear and circular line vortices of incompressible potential flow, giving rise to velocity fields which are calculated from the Biot–Savart relation, and the whole evolves in a natural way from Martensen's method for aerofoils. The first half of the book, comprising six chapters, deals with attached flows in the inviscid approximation, covering aerofoils, linear cascades, mixed-flow cascades, radial cascades, axisymmetric bodies, ducts and annuli, ducted propellers, and three-dimensional flows in turbomachinery. In this part the vortex elements are confined to the surfaces of the configurations, and the flows calculated are steady. In the second half, chapters 7 to 12, vortices also appear in the interior of the fluid, either by convection from specified points of separation to yield an inviscid approximation to separated flow, or by a combination of diffusion and convection to yield an approximation to real viscous flow. Diffusion is simulated by random walks, while convection and vortex formation are treated in distinct steps of a multi-step approach in time. Flows are entirely two-dimensional and, in principle, time-dependent, although steady-state conditions are often approached. The method is tested against analytical solutions of the Navier–Stokes equations for the diffusing vortex and the plane shear layer, and against accurate numerical solutions of the Falkner–Skan equations for laminar boundary layers. It is applied to separated flows past aerofoils, both clean and with spoilers, cascades and bluff bodies, and to rotating stall in compressors. There is even a strikingly successful prediction of the mean velocity profile in a turbulent flat-plate boundary layer. Comparisons are made with experimental results and plausible explanations are provided for discrepancies. Attention is paid throughout to considerations of computational economy, many of the schemes having been devised for very modest resources. Some seventeen programs in Pascal are reproduced as an appendix, allowing the diligent student to investigate in detail many aspects of the performance of the methods.

Not surprisingly, in order to achieve so much from an approach that is essentially elementary, a number of rules have to be followed, appropriate choices of parameters have to be made, apparently arbitrary procedures are introduced, and results have to be averaged in some cases. The author is agreeably open about all this, providing what justification is possible and quoting the values of the parameters chosen for the calculations that he describes. Some of the listed programs allow other options to be explored.

Since the methods are elementary, with a strong intuitive basis, the author has been able to present them with little mathematical sophistication, thereby widening his potential readership. An unfortunate consequence is that many mathematicians will be unhappy with the presentation and may find difficulty in following the argument in some places. Frequently the result obtained is of a familiar form, or the derivation can readily be tightened up, but this is not always the case. In particular, I found the arguments leading to the formulae for the surface pressure gradient in chapter 10 unconvincing, owing to the simultaneous appeal to the Navier–Stokes equations representing the continuous flow and to the properties of the potential flow model, which is discontinuous in space and time. A subsequent difficulty arises in relating the pressure to its undisturbed value, where the method involves an assumption that the maximum pressure on the body is the stagnation pressure of the undisturbed flow, in what is an unsteady situation. The reader should be warned that formulae quoted for 'generalized curvilinear coordinates' in chapters 1 and 6 are actually for orthogonal systems. The only application to use a non-orthogonal system is for a swept cascade between sidewalls and does not rely on the formulae. However, the detail provided is not sufficient to allow an assessment of its validity. Chapter 7 includes a section on the design of aerofoils, cascades and bodies of revolution for specified pressure distributions. This seems to envisage the arbitrary prescription of pressure, with no reference to Lighthill's conclusion in 1945 that the pressure distribution on an aerofoil in inviscid incompressible flow must satisfy certain integral relations.

It is not clear from the book how far the methods described represent the state of the art for the configurations and flow regimes considered. For the external aerodynamic problems of aircraft at low speeds, its discussion of the relative merits of source and vortex elements is now of historical interest, since the advantages of using appropriate combinations of these have been familiar for many years. The absence of any representation of the effects of compressibility presumably excludes applications to aeroengine design, but this leaves a wide range of pumps, turbines and compressors operating with liquids and with gases at low speeds. Here the simplicity of the basic modelling and the flexibility of the approaches used will encourage the use of the methods and their extension to other configurations. The application to large-scale separated flows depends crucially on how well the processes of laminar and turbulent separation can be represented, and on how adequate the two-dimensional wake model turns out to be. The explicit representation of the unsteadiness of large-scale separated flow past two-dimensional shapes at least provides an essential ingredient for success.

The book is attractively laid out, clearly printed, and well illustrated with over 200 figures. Typographical errors are few, and those found are readily recognizable. Its appearance provides an opportunity for all those concerned with the development of computational methods for fluid dynamics to reconsider the reliance on body-conforming grids which has dominated the development of the subject.

J. H. B. Smith

Free-Surface Hydraulics. By J. M. Townson. Unwin Hyman, 1991. 228 pp. £45 (hardback) or £17.95 (paperback).

In his introduction Dr Townson states that this book was written to fill a perceived gap; it was to provide the young civil engineer with a volume to which he or she could turn, with varying degrees of despair, when faced with design problems that made demands beyond the normal level of undergraduate coverage – or should it be comprehension? – of this subject. The selection of subject matter for the book is also such that it could be adopted as a postgraduate course text.

As the title suggests, the book deals with a wide range of water-flow problems in which a free surface is the governing factor. The material is arranged conventionally in chapters entitled: (1) The free surface at rest; (2) Steady flows in channels; (3) Unsteady but largely kinematic flows; (4) Shallow-water transients; (5) Oscillatory water waves; (6) The partially free surface.

Chapter 1 starts off very gently. The reader is expected to have missed those first-year lectures (or lecture) which dealt with hydrostatic forces and floating stability. Chapter 2 is mostly about non-uniform and uniform flow in channels, based upon the principles of the specific energy and the specific force terms, which are clearly explained. However, the treatment is wider than is common in most textbooks, which is a good thing, but the correspondingly complicated diagrams (often several elements combined in one) are not always easy to follow without starting at the beginning of the chapter, something which a busy practitioner might be reluctant to do. The latter part of Chapter 2 deals with friction and includes a discussion of the relative merits of the friction-coefficient-based methods (Darcy/Weisbach, Manning) and those derived from boundary-layer theory using a grain roughness size k. The section on the gradually varied-flow equation is strong on the analysis which forms the basis for numerical solution techniques but rather short on the descriptive material which might make it easier for the reader to get going.

Chapter 3 covers level-pool and kinematic-channel routeing techniques. The author rather surprisingly includes an exact solution method for level-pool routeing which must have very limited uses when compared with the widely used and much more flexible numerical methods which are also covered. Chapter 4 covers other aspects of unsteady flow in open channels. It commences with a clear definition of the kinematic and dynamic wave approaches and the zone of validity of each. In establishing the equations of motion the author introduces the method of characteristics which forms the basis of many of the techniques which follow. Cases considered include channel waves generated by the operation of sluice gates, their propagation in non-rectangular channels and the problem of attenuation. Other topics covered in this chapter are bores, dam-break flows and roll waves on spillways.

Chapter 5 covers oscillatory water waves, both the short-wavelength variety, which are mostly wind-driven, and long-wavelength tidal waves. Harbour seiches are also covered. Standing and progressive waves are defined. A linearized wave equation is derived and the classical wave theory of Airy summarized. The limitations set on Airy's theory by wave height and water depth are set out and lead on to a treatment of refraction, reflection and diffraction. The limits of wave height are discussed, as is also wave-height prediction from wind. The treatment of ocean tides includes both harmonic behaviour and the dynamic theory of the tides. The effect of estuaries is included and illustrated with simulation results from both the Severn and the Thames.

Chapter 6 deals with a number of problems all involving the free surface as an air/water interface. The relationship between fluid turbulence and the air entrainment mechanism is first set out, next the behaviour of free jets, hydraulic jumps and spillway flows, and then enclosed air-entraining flows associated with bellmouths and shaft inlets. The inclusion of large quantities of air in culverts and syphons is covered as is also the behaviour of large air bubbles in near-horizontal pipes. Finally the theoretical relationship between circulation, vorticity and air-entraining vortices is set out.

The book is illustrated with a gratifyingly large number of photographs of variable quality. The diagrams are numerous, large and usually clear and well labelled. There is a list of notation and references at the end of each chapter. The number of typographical errors did not appear to this reviewer to be large, but some unfortunately involved either the misprinting or omission of physical symbols.

In conclusion, this book will find a useful place on the shelves of civil engineers involved in the design of hydraulic engineering works and it will also be of value to research workers in this area. It does not set out to be a textbook on river engineering as it makes no mention of sediment behaviour or natural river channels. Similarly it does not deal with the design of hydraulic structures, although much of its content has a clear use in that direction. Its style is such that a fairly experienced and capable engineer should be able to follow it, but students might have difficulties.

R. H. J. SELLIN

The following volumes of conference proceedings have also been received:

Of Fluid Mechanics and Related Matters: Proc. Symp. Honoring John Miles on his Seventieth Birthday. Edited by R. SALMON and D. BETTS. Scripps Institution of Oceanography Ref. Series 91-24, 1991. 248 pp. Copy available on request to editors (SIO 0225, La Jolla, CA 92093, USA).

Spontaneous Formation of Space-Time Constructures and Criticality. Edited by T. RISTE and D. SHERRINGTON. Kluwer, 1991. 446 pp. Dfl 225 or $125.

Physical Acoustics. Fundamentals and Applications. Edited by Q. LEROY and M. A. BREAZEALE. Plenum, 1991. 737 pp. $139.50.

Recent Developments in Turbulence Management. Edited by K.-S. CHOI. Kluwer, 1991. 337 pp. $99 or £64.

Computational Fluid Dynamics for the Petrochemical Process Industry. Edited by R. V. A. OLIEMANS. Kluwer, 1991. 445 pp. $97 or £61.

Combusting Flow Diagnostics. Edited by D. F. G. DURAO, M. V. HEITOR, J. H. WHITELAW and P. O. WITZE. Kluwer, 1991. 568 pp. $158 or £95.

Innovations in Flotation Technology. Edited by P. MAVROS and K. A. MATIS. Kluwer 1991. 538 pp. $155 or £92.