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BOOK REVIEWS

Boundary-Element Analysis. By J. H. KANE. Prentice Hall, 1994. 676 pp. ISBN 0130869279.

Authors of books on applied numerical methods in science in engineering are faced with two important decisions: How lengthy should the mathematical introduction to the physical phenomena considered be? And what is the appropriate balance between the mathematical formulation, the analysis of the numerical methods, and the presentation of the numerical examples? The answers to these questions can form a basis for classifying such books and understanding their intended usage.

In the case of boundary-integral methods, books have had a broad spectrum of styles, ranging from 'how to' recipe-like texts, to rigorous mathematical monographs on integral equations. Each category is intended for distinctly different audiences: the former for practising engineers whose main interest is in generating rough answers, and the latter for researchers who pay more attention to accuracy and require a good understanding of the intermediate steps.

This voluminous book by Kane finds a good balance between theory and practice, which makes it attractive to a broad audience and a starting point for learning how to solve the integral equations of mathematical and engineering physics using boundary-element methods. I personally would have liked a more rigorous introduction to the theory of integral equations, one that emphasizes even more that the boundary-element method is simply a technique for solving integral equations, but I understand this omission in the light of the intended usefulness.

Chapter 1 contains mathematical preliminaries: identities of integral calculus, and the delta function. Chapters 2 and 3 introduce the boundary-element method in the context of steady heat transport. Chapter 4 discusses numerical integration with regular and singular integrands, including useful tips for boundary-element implementation. Chapters 5, 6 and 7 introduce the equations of linear elastostatics in two and three dimensions and their boundary-integral formulations. Chapter 8 discusses the implementation of the boundary-element method for elastostatics in two dimensions. Chapter 9 presents efficient methods for solving large linear systems of algebraic equations that arise from the boundary-element formulation, including the interesting multi-zone method. Chapter 10 introduces the boundary-element method for problems of heat conduction in three dimensions. Chapter 11 discusses elastostatics with distributed body forces of special forms. Chapters 12, 13 and 14 address nonlinear problems in heat transfer and elastostatics. Chapter 16 presents numerical examples of selected applications. Chapter 17 discusses boundary-element methods in acoustics. The last two chapters, 17 and 18, are reserved for advanced and peripheral topics.

The book focuses on the integral equations of linear and nonlinear elasticity, with heat transfer serving as a preamble, and fluid mechanics restricted to acoustics. Low-Reynolds-number fluid dynamics enjoys a broader phenomenology and a wider range of applicability than elastostatics, primarily because of the diversity of multiphase and particulate flow. But a thorough discussion of the associated boundary-integral methods would probably double the size of the book, and it is better that it has been left aside. Moreover, the book highlights several aspects of boundary-element research that have received little or no attention in fluid mechanics: multi-zone decomposition (chapter 9), numerical integration on triangles and quadrilaterals (chapter 10), methods for inhomogeneous and nonlinear equations with analogies to non-Newtonian flow and flow at non-zero Reynolds numbers (chapters 12–14), and advanced topics (chapter 17).

Points of criticism are superficial rather than fundamental. I would have preferred a smaller book with some peripheral topics omitted. The production was obviously based on a camera-ready copy prepared on a Macintosh, which inevitably compromised the quality. Several sections are lengthy without subsections or break points, and this makes for intense reading; a more accessible presentation would have been desirable.

Overall, this is a useful book for beginners in the field of boundary-element methods and experts alike. It is perhaps one of the few available books that can be used as a text in an advanced undergraduate or graduate class on boundary-element methods.

C. Pozrikidis

Essays on Aerodynamics. Edited by P. G. Bakker, R. Coene & J. L. van Ingen. Delft University Press, 1992. ISBN 90-6275-763-4. 412 pp. 100 Dgl.

Professor Jaap Steketee was appointed to the newly created chair of theoretical aerodynamics at Delft University of Technology in 1960. On his retirement over thirty years later he was presented with the volume under review. It is in two parts: the first and most substantial contains the essays of the title, the second consists of personal recollections and impressions. Most, but not all, of the essays are written by colleagues and the volume therefore, to some extent, represents a showcase for Delft aero-/fluid-dynamics. Unsurprisingly, flow separation, turbulence and aero-acoustics feature prominently.

The first essay, by Bakker, develops a mathematical model for three-dimensional ‘open’ separation from a smooth surface, in the neighbourhood of the boundary. The model results in a nonlinear dynamical system whose wall singularities provide the topology of separation and attachment structures. Separation from the leading edge of a swept wing differs from that from a smooth surface, not least in that the vorticity content of the resulting free shear layers is primarily determined by the shear of the velocity vector at the separation line, rather than the vorticity contained within the viscous layers that meet there. Bannink describes experiments on the flow past a delta wing in the high subsonic Mach number range. Oil flow visualizations and surface pressure measurements reveal the presence of the leading-edge vortex and secondary separation; but particular attention is paid to the presence of embedded shocks, vortex breakdown and the interaction between them. In a complementary essay, the longest, Hoeijmakers describes modern computational techniques for such flows based on Euler’s equations. Earlier potential-flow methods relied upon embedding vortex sheets within the flow, consequent upon satisfying a Kutta condition at the leading edge. No such condition need be applied with the Euler equations for reasons that are not fully understood, although it is believed that numerical dissipation mimics the effects of true viscous flow at and near the sharp edge. Secondary separation cannot, of course, result from such an inviscid model.

Nieuwstadt’s essay on turbulence addresses the problem of the decay of isotropic homogenous turbulence by means of large-eddy simulation. For this a two-part spectral model is adopted. This is modified by the introduction of a filter which then results in good agreement with the large-eddy simulation. Turbulent non-premixed combustion is discussed by van Esch. Laminar diffusion flames are well understood, but turbulent diffusion flame models based on averaging lack the modelling of turbulence–combustion interaction. An alternative is the laminar flamelet concept of a turbulent diffusion flame in which the latter is described as an ensemble of laminar diffusion flamelets. This essay reviews the flamelet concept theory, and its implementation. Reacting gas mixtures for flow past a catalytic wall are studied by Kurotaki *et al.* by asymptotic methods based on the Boltzmann–Krook equations. And an essay by Vos on hypersonic flow, that is flows for which air dissociation or radiative heat transfer are important, includes calculation results for flow about a sphere and a space shuttle.

Aeroacoustics is represented by Schulten's essay. In it he seeks an alternative to the Ffowcs Williams–Hawkings equation for very thin highly swept propfan blades at small angles of attack, in which the influence of the quadrupole field is still correctly represented. The proposed alternative is a generalized Kelvin–Helmholtz approach in which a surface S is defined to enclose all quadrupole strength adjacent to the body. A monopole/dipole distribution is distributed over S, enclosing the nonlinear flow field. Also contained in the essay is a demonstration of the analogy between lifting surface theory and aeroacoustics, in which the integral equation of the lifting surface approximation may be derived from an aeroacoustic formulation. With a different emphasis Bruggeman's essay presents a theoretical and experimental description for the low-frequency acoustic behaviour of a cavity in a plane wall covered by a louvered grid. The motivation is associated with the noise and vibration caused by self-excited flow oscillations in open cavities of ship hulls.

There are nineteen essays in all. In addition to the above we find essays on incompressible aerodynamics embracing the drift past an airfoil, classical boundary layers, propeller performance and unsteady airfoil wakes; computational fluid dynamics is represented by a discussion of the conceptual design of codes for the calculation of flows around transport aircraft, computer algebra, and an essay on the relation between computing and fluid dynamics; in non-aerodynamic areas we find essays on the role of surfactant in the mechanical behaviour of the lung, and the construction of a lung model to establish a relation between ventilation efficiency and frequency in a human lung, and essays on magnetohydrodynamics associated with open cycle, disk and linear generators, and Hall current effects in rotating flows.

It is clear from the above that the essays contributed to this volume are wide ranging, and should whet the appetite of many of the readers of this journal.

N. Riley

Biological Flows. Edited by M. Y. Jaffrin & C. G. Caro. Plenum Press, 1996. 367 pp. ISBN 0 306 45206 5 £76.

This book is a collection of papers presented at the Second World Congress of Biomechanics in Amsterdam in 1994, each intended to be a 'didactic' review of an area of biological fluid mechanics. Although the title promises a broad range of topics, the subjects considered are almost exclusively biomedical: thirteen of the seventeen contributions are concerned with various aspects of the cardiovascular system, and the remainder are largely restricted to respiratory or lymphatic flows. It is perhaps inevitable that such a collection is something of a mixed bag, both in terms of subject matter and presentation, but throughout there is a clear focus on applications, a healthy mixture of theory and experiment, and plenty of interesting fluid mechanics.

The apparent link between atherosclerosis, heart disease and the distribution of arterial wall shear stress has motivated innumerable studies of the fluid mechanics of veins and arteries. This now classical area of biomechanics is represented by four articles on flows in large arteries at high Reynolds numbers (by Giddens, Tang & Loth; Caro, Doorly, Tarnawski *et al.*; Perktold & Rappitsch; Yamaguchi) and two on the coronary circulation (Kajiya, Goto, Yada *et al.*; Spaan); other areas of haemodynamics are represented by one chapter on wave propagation and the effectiveness of the heart as a pump (Westerhof), two in the microcirculation (Skalak; Secomb, Pries & Gaehtgens) and four on the arterial wall and membrane transport (Fung & Liu; Stergiopulos & Meister; Lever; Jaffrin).

Giddens *et al.* provide a fine review of some thorough experiments with laser-Doppler-velocimetry (LDV) investigating flows in rigid casts of some arterial bifurcations. They emphasize the extreme sensitivity of such flows to their geometry, the inherent difficulty of generalizing from a few model studies, and the potential importance of a Lagrangian description of blood-borne particle paths. Caro *et al.* describe experiments using magnetic-resonance techniques, including some *in vivo* angiography of flows in arterial bifurcations with non-planar geometry (where vessels have both curvature and torsion); their helical structure appears to suppress circumferential variations in wall shear stress. Complementing these two experimental papers are a pair of computational studies: Perktold & Rappitsch describe finite-element calculations of flows in some widely studied arterial geometries, and Yamaguchi tackles the major problem of visualizing unsteady-three-dimensional flows in complex geometries. While the former chapter contains some sophisticated technical material and some impressive Navier–Stokes solutions (although the account is let down by numerous typographical errors), the latter is by comparison lightweight, giving a glossy view for non-engineers of CFD technology, and results are presented without the supporting evidence one would have expected in a volume such as this.

Kajiya *et al.* describe some technically impressive experiments in which LDV is used to measure blood flow in the coronary arteries of a beating heart; they show that there may be slow retrograde flow during systole, and are able to investigate the effects on this 'coronary slosh' phenomenon of either stenosis or pharmacological intervention, giving a direct fluid-mechanical view of the effects of some of the vasodilators used to treat angina, for example. In an accompanying chapter, Spaan gives a thorough account of the development of relatively simple models of the fluid mechanics of the coronary circulation, and a critical comparison of their effectiveness when compared with experiment. Westerhof's contribution is concerned with the whole arterial system, using electrical circuit language to describe wave propagation, and showing (with lumped models) how the heart works at optimum power output by minimizing its volume. At very much smaller scales, Skalak's chapter starts the book with a short but interesting history of the study of the mechanics of red blood cells. He wisely highlights the importance of understanding cellular biomechanics in terms of the underlying molecular substructure. The review of the architecture and haemodynamics of microvascular networks by Secomb *et al.* is an excellent, authoritative survey, starting from the basics but swiftly moving into challenging and open areas, such as the difficulties of characterizing a heterogeneous network and of understanding how such networks 'remodel' themselves in response to flow conditions.

The fluid-mechanical content of the contributions concerned with the arterial wall is limited, since the flow can generally be represented just by an imposed wall shear stress or pressure. Fung & Liu describe simple models for the mechanics of the endothelium in blood flow, and provide some preliminary answers to the question of which constitutive relation might be appropriate for an endothelial cell. Sadly the editing (and spelling) standards fall to inexcusable depths in this chapter; the material is largely lifted directly from two published papers, with little attention given to their new context. The active and the passive interact in the chapter by Stergiopulos & Meister on arterial vasomotion, in which they describe both experimental and theoretical accounts (in particular the model due to Gonzalez-Fernandez & Ermentrout) of spontaneous oscillations in arterial smooth muscle, considering the possible response of the arterial wall to the induced flow via signals stimulated by the wall shear stress; also mentioned briefly are the efforts by Griffith and coworkers to interpret these oscillations using dynamical systems theory. In his review of the transport of materials through the walls of veins and arteries, Lever gives a physiologist's account of the various transmural pathways and the implications for atherosclerosis, but strangely he avoids citing any of his figures. Finally, in a practical review of plasma separation using blood cross-flow filtration through artificial membranes, Jaffrin tackles the complexities of flows of concentrated suspensions of deformable particles with some simple theory and correlations; most interesting from a fluid-mechanical point of view is the use of Taylor vortices and of unsteady flow over furrowed membranes to enhance mixing.

Two chapters are devoted to respiration. Shin, Elad & Kamm describe a well-developed whole-lung model of forced expiration and cough, which although one-dimensional is an effective means of simulating lung function and assessing the effects of asthma and other obstructive airway diseases. This is followed by an account (by Isabey, Brochard & Harf) of respiratory mechanics and mechanical ventilation; this is a thorough, practical review, providing plenty of physiological background and a useful survey of up-to-date clinical techniques (which ideally demand an understanding of, for example, internal high-frequency oscillatory flows and confined turbulent jets). This chapter serves as a reminder of the enormous gap between the often empirical clinical approach to ventilation and the primitive state of existing theoretical models.

This leaves two remaining chapters. Schmid-Schönbein & Ikomi describe briefly the biomechanics of lymph transport, a novel and interesting area in which flows are driven either by peristalsis or by external squeezing motions, with reflux being prevented by both intramural and intraluminal valves. The one chapter which lives up to the title of the book is by Pedley, who gives a broad review of a range of topics in biological fluid dynamics, including flows that are both internal (e.g. pressure drop and gas mixing in lung airways, peristaltic pumping in the ureter) and external (fish swimming and bioconvection). Once again an important theme, which will no doubt be developed more fully in the future, is the linking of the active and passive, coupling fluid flow (around a fish, say, or within a ureter) to muscle mechanics.

Overall, the quality of typesetting in this book is fairly high, although the editing is patchy; one would have expected better at this price. However this is a valuable survey text for biomedical engineers with interests in fluid mechanics. Readers should find several articles that provide stimulating introductions to new fields of research.

O. E. Jensen