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Book Reviews

NOTE: There was an error in the price listed in the review of *Low-Speed Aerodynamics*, 2nd Edition, by Joseph Katz and Allen Plotkin (Cambridge University Press, New York, 2001, 632 pp.) (*AIAA Journal*, Vol. 40, No. 3, 2002, p. 591). The correct price is $54.95.

Inviscid Incompressible Flow

J. S. Marshall, Wiley, New York, 2001, 378 pp., $90.00

This 378-page book is "an introduction to the dynamics of inviscid, incompressible fluids." "It is intended as a text for a beginning graduate-level course on fluid mechanics." According to the back cover, "This one-stop resource for students, instructors, and professionals goes beyond analytical solutions for irrotational fluids to provide practical answers to real-world problems involving complex boundaries." The material is organized into 16 chapters of various lengths. The eight-page introduction is the obligatory defense to the question, "Why study inviscid flow?" In the author's words, "Although inviscid flow theory may not be applicable to all parts of a fluid flow, except in special circumstances, it does apply to most high-Reynolds-number flows."

Chapter 2 (15 pages) is a brief introduction to vectors and tensors using both index and usual vectorial notations. There is no mention of covariant and contravariant tensors and derivatives of tensors. Chapter 3 (19 pages) is on the kinematics of fluid motion. Chapter 4 (19 pages) presents the laws of fluid dynamics, the usual conservation laws, the kinetic energy transport theorem, and the constraint of compressibility. Here, as elsewhere, it would have been preferable to show the full equations of motion (viscosity, compressibility) and then discuss the isochoric character of the incompressible flow and the Boussinesq approximation instead of spending a page to discuss the constraint theory. The discussion of the Navier–Stokes equations (one-half page), based on the constitutive equation for stress (4.4.6) with no explanation whatsoever, is followed by three most elementary examples (plane and rotating Couette flows and plane Poiseuille flow). The constitutive equations for stress are the most fundamental relationships in fluid dynamics, their evolution taking 18 years, from Navier in 1826 to Stokes in 1851–1854. Unless one has had a course on continuum mechanics, one will never forgive their sudden appearance in a book (even if it is on inviscid flows). The students are not likely to read Coleman and Noll[1] or Truesdell and Toupin,[2] as suggested by the author!

Chapter 5 introduces, in 13 pages, the dynamics of discontinuity surfaces, the extended transport theorem, jump conditions across a surface of discontinuity, surface tension, and the boundary conditions for the slip and no-slip at the free surface. There is no mention of the curvature-coincident vorticity at the free surface, nor are any sample solutions offered. Capillary instability of a liquid jet is deferred to Chapter 16. As a whole, this chapter is mainly a collection of equations with little physics woven through them.

Chapter 6 (16 pages) deals with velocity representations and associated theorems in exactly the same manner as the preceding chapter. Chapter 7 (22 pages) introduces vorticity transport theorems. The use of a "columnar vortex confined between two flat plates" (Fig. 7.1) is an unfortunate example that will help to reinforce and perpetuate the often mistaken belief that a vortex can end on a solid boundary. The fact is that the circulation is zero about any closed contour on a nonrotating surface. As noted, for example, by Lighthill,[3] the streamlines become parallel to the wall and the no-slip condition results in the creation of additional vorticity. Thus, the "columnar vortex with core radius σ extending between two infinite parallel planes separated by a distance $L(t)$" is neither an inviscid line vortex nor a viscous vortex.

Chapter 8 (8 pages), on pressure theorems, goes over the well-known general expressions and their counterparts for steady two-dimensional flows. Chapter 9 (44 pages), covers the most common two-dimensional potential flows (assuming familiarity with complex functions), the well-known conformal transformations, Schwarz–Christoffel transformation through the use of simple examples, and free-streamline theory, using two-dimensional flow through an orifice. Chapter 10 (17 pages) deals with forces on bodies in two-dimensional flows and presents the classical problems (Blasius force, circular cylinder with circulation, Lagally's theorem, and two-dimensional airfoils). Chapter 11 (36 pages), on two-dimensional flows with vorticity, briefly discusses the point vortices and vorticity patches and leads to the discrete-vortex method. Obviously fascinated by discrete-vortex or vortex-element methods, the author goes on to state that "Thus for laminar flow past a body, the potential flow field external to the boundary layer and the evolution of vortical structures in the body wake can be efficiently modeled using inviscid flow theory." Even though vortex methods can deal with the creation and convection of vorticity, no one has so far offered a single credible scheme to diffuse vorticity. In fact, the method has become a numerical experiment in perpetuity. It is because of these reasons that Saffman[4] has entirely avoided it by noting that "The accuracy with which a vorticity field is approximated by a set of in general overlapping, non-deforming circular vortex patches is not a problem of vortex dynamics, since they do not constitute an Euler flow, but is a question of numerical analysis."

The author emphasizes only the oft-repeated virtues of the method. It is a well-known fact that a vorticity patch is not a solution of either the Euler or the Navier–Stokes equations, the inviscid vortices cannot be diffused (otherwise, they would not be inviscid), and turbulence cannot be simulated. Thus, the author's exaltation of the so-called approximate vortex methods throughout the book is not quite in keeping with the intended purpose of a book on the classical theory of inviscid incompressible fluids containing, at times, regions of finite vorticity. As Hoyle[5] noted long ago, "Correlations after experiment's done is bloody bad. Only prediction is science."

Chapter 12 (41 pages) deals with three-dimensional flows (uniform flow and the point versions of sources and doublets), flow about a sphere, Rankine bodies, axisymmetric flows, source, doublet, vortex sheet boundary-integral methods, and forces induced by singularities. This is followed by a brief discussion of the added mass and buoyancy forces. The usual added mass coefficient is obtained for the sphere. It is stated that "the added mass M is a constant for a rigid body with translation velocity in a fixed direction, and it is independent of the speed of translation of the body through the fluid." It should have been emphasized, even in a book on inviscid flows, that this is not what happens in viscous flows. Some of the most important facts should have been pointed out regarding this much-used and much-confused mass. As shown by Sir Charles Darwin,[6] the motion of a body through inviscid fluid media is always accompanied by a fluid-mass transport and this mass is the added mass that unveils itself only when the body is accelerated. In real fluids, the added mass varies with the instantaneous shape and volume of the wake or cavity and their rates of change, as well as with the time history of the motion. It is not uniformly distributed and does not look like the author's Fig. 12.15.

Chapter 13 (36 pages) covers axisymmetric vortex flows: vortex rings, Hill's spherical vortex, axisymmetric contour dynamics, steady axisymmetric flows, waves of variable core area, the plug-flow model, and a detailed argument on the shocklike discontinuity model of vortex breakdown, which appears to be completely out of place. The chapter ends with a discussion of the axisymmetric discrete vortex method. Chapter 14 (18 pages) deals with vortex tubes, the cutoff model, and the local-induction approximation. Chapter 15 (16 pages) is devoted to the discussion of interfacial wave motion and Chapter 16 (34 pages) to the stability of flows, elliptical vortex patches, stability of two-dimensional point vortex arrays (where all of the vortices in Figs. 16.5b–c happen to rotate counterclockwise!). Other instabilities discussed are Rayleigh–Taylor instability, Kelvin–Helmholtz instability, capillary instability, centrifugal instability, stability of parallel shear flows, and the so-called Crow instability of a vortex pair. The book ends with an appendix of common expressions in orthogonal curvilinear coordinate systems. There is a subject index, but no author index.

In summary, the book is an assembly of equations for inviscid fluid motions. Little effort has been made to impart deep insight and to make connections with nature's behavior. The references are very limited even on the author's favorite topics. The examples chosen are far too simple and intended to impart passing familiarity rather than profound understanding of the strengths and weaknesses of the inviscid-flow assumption. The book imparts neither the wisdom of Saffman[4] nor the insight of Batchelor.[7] Without these, "a beginning graduate-level" student is not expected to be sufficiently inspired to go forward to enjoy the rewarding experiences of dealing with and often working around the yet un-understood physics of engineering problems. Thus, contrary to the claims of the publisher, the book is not the "one-stop resource for students, instructors, and professionals."

References

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[3]Lighthill, M. J., "I. Introduction, Real and Ideal Fluids," *Laminar Boundary Layers*, edited by L. Rosenhead, Clarendon, Oxford, 1963, p. 50.

[4]Saffman, P. G., *Vortex Dynamics*, Cambridge Univ. Press, Cambridge, England, U.K., 1992.

[5]Hoyle, F., *The Black Cloud*, Harper, New York, 1957, p. 125.

[6]Darwin, C., "Notes on Hydrodynamics," *Proceedings of the Cambridge Philosophical Society*, Vol. 49, No. 2, 1953, pp. 342–354.

[7]Batchelor, G. K., *An Introduction to Fluid Dynamics*, Cambridge Univ. Press, Cambridge, England, U.K., 1967.

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An Engineering Approach to the Calculation of Aerodynamic Flows

Tuncer Cebeci, Horizons Publishing, Long Beach, CA, 1999, 416 pp., $96.00

At the Douglas Aircraft Company A.M.O. Smith was one of the first to recognize the need to complement wind-tunnel testing by rapid and accurate computational predictions of an aircraft's aerodynamic characteristics in order to reduce its design and development costs and risks. This led at first to the well-known Douglas Neumann Program or Panel Method developed by John Hess and A.M.O. Smith for the prediction of the inviscid incompressible flow characteristics. The author of this book was another member of A.M.O. Smith's group who concentrated on the development of an efficient boundary-layer code using Keller's finite difference box method. The systematic merging of the boundary-layer and the panel codes, first in the direct and later in the interactive mode, showed the growing potential of this approach to predict viscous flow effects on practical aircraft configurations. Having succeeded A.M.O. Smith as head of aerodynamics research, Tuncer Cebeci extended the interactive boundary-layer approach to increasingly more complex flow situations. This book contains a compilation of his most important approaches and results.

In the first chapter Cebeci introduces the reader to the possible viscous–inviscid interaction models for the analysis of two-dimensional airfoil flows. He explains his preference for the approach, first suggested by Veldman, where the external velocity and the displacement thickness are treated as unknown quantities and the equations are solved in the inverse mode in successive sweeps over the airfoil surface. Furthermore, he stresses the importance of accounting for the transition from laminar to turbulent boundary-layer flow. To this end, he recommends the use of the Granville–Michel correlations or the e^n-method, due to A.M.O. Smith and van Ingen, to predict the transition onset, and the Chen–Thyson formula to predict the length of the transition region. In the following chapters, this viscous–inviscid interaction approach is first elaborated in detail for steady incompressible airfoil flows with a description of the Hess–Smith panel method, the boundary-layer analysis in conjunction with several turbulence models (the widely used algebraic Cebeci–Smith model, the k–ϵ model, and Reynolds stress models), and the transition computations. The author then proceeds to demonstrate this method by assessing it against the experimental data available for the NACA 66-018, ONERA-D, NACA 65-213, Eppler, and Liebeck airfoils. He shows how this approach can be extended to the prediction of ice shapes on airfoils and of the flow over airfoil–flap combinations. In the remaining chapters he describes how the interactive method can be extended to the analysis of steady subsonic/transonic airfoil flows, unsteady incompressible airfoil flows, and steady three-dimensional incompressible and compressible flows over aircraft wings. These extensions lead to the discussion of flow separation near the leading edge of oscillating airfoils and of the question of whether there occurs a singularity. He describes the panel method for steady three-dimensional flow, the three-dimensional boundary-layer analysis, and the calculation of transition in three-dimensional flows. He concludes the book with an assessment of the effects of sweep angle, curvature, and Reynolds number on transition and a comparison of the computations with experiments available for a SAAB and RAE wing as well as wing–flap and slat–wing–flap combinations. He also shows comparisons with icing experiments on a Twin Otter aircraft and transonic test results for the ONERA-M6 wing and the Douglas LB-488 wing–body configuration.

Tuncer Cebeci is an internationally recognized pioneer of the viscous–inviscid interaction approach. In this book, he shows that this approach provides a very efficient and powerful tool for the analysis of attached or mildly separated viscous flows over practical aircraft configurations at subsonic and transonic flight speeds. This type of flow is unlikely to be computed competitively with Navier–Stokes codes in the near future. Indeed, the Navier–Stokes computation of transitional flows with separation bubbles still presents great challenges. Hence practicing aerodynamicists in need of practical tools for the prediction of this class of aerodynamic flows will find this book a welcome and indispensible means of familiarizing themselves with their analysis and practical computation. This is facilitated by the listing of the computer programs and the availability of the codes from the author. Consistent with the book's title, the author restricted himself to a discussion of his own methods and results. However, he refers to the major publications in this field, including the proceedings of symposia on numerical and physical aspects of aerodynamic flows that he organized over the past 20 years and that provide a comprehensive review of the work of other contributors. Therefore, teachers of advanced aerodynamics courses and aeronautical engineering students will find that this book gives them convenient access to the understanding and use of viscous–inviscid interaction methods.

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