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REVIEWS

Numerical Computation of Internal and External Flows. By C. HIRSCH. Wiley. **Vol. 1, Fundamentals of Numerical Discretization.** 1988. 515 pp. £60. **Vol. 2, Computational Methods for Inviscid and Viscous Flows.** 1990, 691 pp. £65.

This book appears in two volumes and the author has been very successful in presenting a unified approach to computational methods for inviscid and viscous flows. Far too often collections of articles from conferences and/or meetings are put together to form one disjointed book. In contrast this book flows easily from one subsection to the next and from one chapter to the next in a most pleasant and natural manner. The author is to be complimented on his clarity of presentation and he should be assured that the time he has devoted to producing a text of almost 1200 pages, along with all the thoughtful examples, is a most welcome contribution to computational fluid dynamics (CFD). I believe that the text will become one which all serious workers in CFD will wish to have on their shelves. Certainly it should be initial reading for all prospective and new researchers in CFD, whether their background be in science or in engineering. The book does have some deficiencies, which will be indicated in the following paragraphs, but these should be interpreted in conjunction with the very positive comments made above.

The author sets out his objectives clearly and because of the vast quantity and variety of work that exists in CFD he recognizes that it is impossible to cover all topics. Several important techniques are indeed not covered. He concentrates on the areas of his own expertise and research activity. Omissions include the spectral method, the solution of the boundary-layer equations, the boundary-element method, detailed mathematical stability analysis, etc. Although the approach is excellent the book would be more complete if it included a short section outlining all these topics with the relevant important references.

The book is divided into seven parts and each part is divided into chapters. The presentation is organized so that the reader may easily find the classical numerical methods as well as their modern developments. Each chapter contains a rich variety of exercises which not only deepen the reader's understanding of the theory but also furnish him with further important details of the subject. The entire material is supported by a carefully selected but complete bibliography at the end of each section. This works well if the book is read consecutively but the absence of a complete bibliography at the end of the book makes it hard to use as a work of reference.

The first volume contains the first four parts and is devoted to the fundamentals of numerical discretization techniques. Much of this material can be found in standard texts on the numerical solution of partial differential equations.

In part I the author considers the mathematical models for fluid flow simulations at various levels of approximation. He systematically presents flow charts, demonstrating the importance of the computational methods employed and indicating where inaccuracies or errors may occur; tables, showing the governing equations under a variety of conditions; clearly defined nomenclature, etc., all of which make the text easy to follow. However, the derivation of the governing equations is rather terse and readers should have a sound background in fluid mechanics before embarking on this book. Another shock to the reader is the rapidity with which the author starts to discuss the numerical solutions of very complex fluid dynamical problems. For example, in chapter 2 he discusses compressible flows around a circular cylinder and gives very detailed numerical results. I feel that this may be off-putting to the novice CFD reader. Further, such examples are intermingled with some highly important principles and as the chapter occupies over 100 pages selective reading is essential. I could not see the purpose of so many detailed numerical solutions so early in the text; much of this material should have been placed in the final part of the second volume.

In part II the basic discretization techniques are discussed. Again a simple but effective table showing the structure of the various numerical schemes is most illuminating. The section includes standard ideas on the finite-difference method, the finite-element method, the finite-volume method and conservative discretizations.

At this stage a set of discretized equations has been obtained and the purpose of part III is to analyse these equations with regard to consistency, accuracy, stability and convergence. Again, all the standard methods are discussed and the advantages and disadvantages of each method are stated objectively and comparisons are made using test examples. Although all the ideas in this part are standard the author successfully achieves his stated aim of giving objective comments and the inclusion of a summary section at the end of each chapter is most effective.

In part IV the resolution of the discretized equations is presented. For time-dependent formulations of initial-value problems a large body of techniques has been developed to define and analyse the numerical schemes and a whole chapter is devoted to solving systems of ordinary differential equations. A further chapter concentrates on boundary-value problems. The multigrid method is introduced briefly but more discussion on this and on the adaptive meshing technique would have been welcome.

Volume 2 contains the remaining three parts. In part V the mathematical formulation of the potential flow model which takes into account the effect of compressibility is presented. As virtually all the computational methods for unsteady potential flows rely on the approaches developed for steady flows, the absence of a discussion on unsteady flows is appropriate. A complete chapter is devoted to describing the well known and classical computations of subsonic potential flows and a variety of techniques are described for solving the resulting nonlinear algebraic system of equations. The chapter on transonic potential flow is at the frontiers of research and an excellent discussion of the observed non-uniqueness of transonic isentropic potential flows which result from the breakdown of the mathematical model with increasing shock strength is interesting and constructive.

Part VI is on the numerical solution of the Euler equations and is by far the largest section in the book. It could easily have been a book in its own right as it consists of about 450 pages. On reflection one is left with the impression that too much emphasis is put into this section at the expense of some of the topics not included in the book and which have already been identified. This subject matter is one in which the author has made important contributions, as is reflected in the depth and detail of the exposition. The first chapter of this part contains a very useful introduction to the mathematical formulation of the system of Euler equations along with the numerical implementation of the boundary conditions. The next chapter gives a clear presentation of the Lax–Wendroff family of space-centred schemes. It indicates the weaknesses of centred second-order-accurate schemes, such as the generation of oscillations at discontinuities, but does not mention the drawbacks of entropy generation. There is a chapter on the explicit and implicit space-centred methods based on separate space (second-order) and time discretizations. The essential element of the approach is the introduction of artificial dissipation in order to maintain stability. A separate chapter is devoted not only to posing the boundary conditions but also to their numerical implementation. Although many research workers appreciate the importance of using mathematics to the full when discretizing the boundary conditions, the need is not always fully appreciated by numerical solvers of the Navier–Stokes equations. Hence it is good to see a whole chapter being devoted to the topic, especially one so well organized and clearly presented. There is a chapter on first-order upwind schemes and one on second-order upwind schemes. Since such schemes generate numerical oscillations in the vicinity of discontinuities these chapters would have been improved by a deeper analysis of the numerical discretizations.

The last part of the book consists of two chapters on the Navier–Stokes equations and represents less than 10 % of the whole work. It is a pity that more emphasis was not put into this part. Too frequently research workers who solve the Euler equations state that 'many of the various schemes developed for the Euler equation can be applied' when referring to the solution of the Navier–Stokes equations. Although this is true there are nevertheless many fundamental complications that arise which require specialised mathematical and numerical investigation. Given the limited space devoted to this section the author has adequately described the essential properties of the system of coupled, compressible Navier–Stokes equations along with a very brief description of the Reynolds-averaged equations and associated turbulence models. Throughout the section the author does refer to other texts where more specialised techniques and up-to-date references may be found, and an excellent bibliography is given at the end of the last chapter.

In conclusion the author has been very successful in introducing the reader to the essential steps involved in the numerical simulation of fluid flows. He has provided a guide all the way from the initial step of selecting a mathematical model to the practical methods for the numerical discretization and resolution of problems in several areas of CFD. Although it is impossible in one text to cover all aspects of CFD he has clearly adopted the correct philosophy in dealing with real problems. All researchers in CFD would benefit from reading this excellent text.

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Fluid Mechanics. By S. M. RICHARDSON. Hemisphere, 1989. 314 pp. £28 or $44.50.
Elementary Fluid Dynamics. By D. J. ACHESON. Clarendon Press Oxford, 1990. 397 pp. £45 (hardback), £15 (paperback).

The publication of an undergraduate fluid mechanics text book is not as remarkable an occasion as it was thirty years ago. These two recent arrivals add to the very long list that have been published over the past three decades.

The first, by Richardson, is aimed at students of engineering and science who wish to undertake a theoretical study of fluid mechanics at a reasonably advanced level. Written by a chemical engineer it is, perhaps inevitably, aimed primarily at engineering students. In its layout the text is fairly traditional, with fundamentals occupying just over one quarter of the book, applications the rest. The fundamentals include kinematics, conservation equations, constitutive equations, boundary conditions and dimensional analysis. For a text at this level there is a brave, if incomplete (since not all of the steps are justified), attempt to derive the constitutive equations from the principles of modern continuum mechanics. Although only

Newtonian fluids are pursued, this framework does allow a glimpse of the approach which is necessary if non-Newtonian fluids are to be accommodated and such, of course, are of great interest to the chemical engineer. An appendix to underpin the fundamentals is devoted to the 'algebra and calculus of scalar, vector and tensor fields'. However, a serious omission from this appendix is Stokes' theorem, which compromises the author in his discussions of vorticity and irrotational flows. In particular the existence of a velocity potential for, and the persistence of, irrotational flow are inadequately demonstrated. Similarly inadequate is the discussion of the contribution of the bending and stretching of vortex lines to the local rate of change of vorticity. For the vorticity itself the author claims to have shown that it is a measure of the local rotation in the flow, but this he has not done. In the applications area there is a chapter on slow flow problems which include extension of a fluid cylinder, a digression on flow in porous media, as well as the familiar flows past spheres, cylinders and bubbles. The discussion of the flow past a sphere and cylinder, with their attendant difficulties, is carefully presented, marred only by a misleading statement about the closed form solution of Oséen's equations for flow past a circular cylinder. The next chapter, at the other end of the scale, discusses inviscid flows. Here the author misses an opportunity to introduce the idea that pressure may be interpreted as an internal potential energy in the fluid. The comment that 'There is an essential difference between flows for which the Reynolds number is very large, and flows for which the Reynolds number is infinite' may be true for bluff bodies, but misses the point as far as streamline shapes are concerned. Chapter 10 follows, and is entitled '(Nearly) nonaccelerating flows' which is a mysterious choice for a discussion which includes fully developed pipe and channel flows, lubrication theory and the impulsive motion of a flat plate! The chapter on boundary layers is devoted largely to the flat-plate boundary layer, entry flow in a pipe and the two-dimensional jet. There is a discussion of flow separation, but the role attributed physically to the pressure would result in separation even in an inviscid flow. A penultimate chapter on turbulence introduces the Reynolds equations and the closure problem. The turbulent boundary layer on a flat plate, and the flow in a pipe are discussed via an eddy-viscosity model. There is a final one and a half page chapter entitled 'Postlude'. In it the opinion is offered that 'the more difficult the problem, the less fastidious we must usually be about how we solve it', a view which is, thankfully, not shared by all engineers. The book concludes with a range of problems to be solved and a useful, annotated, list of books suitable for further reading. Unfortunately this book has a superficial air about it and is not one that can be recommended with confidence to newcomers in the field.

Acheson's book is altogether more satisfactory and interesting. Written by a mathematician for students of applied mathematics, physics and engineering it is aimed primarily at the first category. The author's approach is somewhat unconventional, at least as far as the ordering of his material is concerned. The introductory chapter uses the two-dimensional aerofoil as a vehicle for presenting basic ideas including vorticity and circulation, although Kelvin's theorem does not make its appearance until chapter 5. Euler's equations are developed and an interpretation of vorticity in two-dimensional flows as local rotation rate allows the notion of irrotational flow and its persistence in two-dimensional inviscid flow. Illustrative excursions embrace the Kutta–Joukowsky condition and wing-tip vortices. In chapter 2 we are thrown into viscous flow theory including the notion of a boundary layer and separation. The Navier–Stokes equations are *presented*, although any formal discussion of their derivation is deferred to chapter 6, and simple exact solutions are given. Chapters 3 and 4 are devoted to wave motion and two-dimensional aerofoil theory respectively. The first few pages of the former introduce a bewildering array of concepts and phenomena ranging from group velocity to the solitary wave. But in the remaining part of the chapter each of the topics, and the author does not restrict himself to surface waves, is picked up and developed in detail. Chapter 4 is used to introduce complex variable techniques into two-dimensional irrotational flows. As indicated, Kelvin's circulation theorem and its consequences are the starting point for chapter 5, which also includes Helmholtz's vorticity equation and theorems. The chapter discusses the role of circulation in lift creation, including the Weis–Fogh 'clap and fling' mechanism. But the discussion is not confined to inviscid flows, viscous vortices also make their appearance. The author squares up to the Navier–Stokes equations in chapter 6, and essentially defines the Newtonian fluid via the stress–rate-of-strain relation, justified by arguments originally advanced by Stokes. With the equations in place traditional chapters on inertialess flows, and the author offers plenty, and boundary layers follow with a concluding chapter on stability theory. An important feature of the book is the set of exercises associated with each chapter. These serve not only to illustrate the theory but to develop it further. A comment about the ordering of material has been made above; whilst the trained eye can appreciate the author's intent, a newcomer to the subject may well flounder without some help and the book may well best serve its introductory purpose as an adjunct to a lecture course. A very valuable aspect of the book is the historical perspective which the author weaves into it, and which serves to remind us of the heroic contributions made by 19th and early 20th century scientists to the subject which, on the whole, we now take for granted. Throughout, the author demonstrates his awareness of the relevance of his material, and conveys his enthusiasm for it. His book has its own particular flavour, contains a wealth of information and is mathematically secure. It can be confidently recommended, subject to the reservations outlined above and the comment that the term 'elementary' in the title may be misleading, as the discussion of triple decks and deterministic chaos reveals.

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