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REVIEWS

Computational Fluid Dynamics: An Introduction. Edited by J. F. WENDT. Springer, 1992. 291 pp. DM128.

Numerical Solutions of the Euler Equations for Steady Flow Problems. By A. EBERLE, A. RIZZI and E. H. HIRSCHEL. Vieweg, 1992. 449 pp. DM148.

The first of these books results from a lecture series given at the von Kármán Institute each year since 1985. It consists of seven introductory chapters by J. D. Anderson followed by four chapters on more specific topics by R. Grundmann, G. Degrez and E. Dick. It is meant as an introduction to the subject rather than an up-to-date account; and, though continuously revised, there are only two references to original material after 1987.

The second book, on the other hand, gives a state-of-the-art account of aeronautical computations for steady inviscid compressible flow, concentrating on the three authors' own work up to 1990. The emphasis is on finite volume methods, using both central differencing and upwinding, and a quarter of the book (three out of the ten main chapters) is devoted to describing practical applications, the modelling of vortex flows and coupling to viscous models.

Anderson's introduction to the VKI book makes it clear that the target readership consists of engineers with little or no previous knowledge of CFD, and that it is overwhelmingly aerodynamical CFD that is the book's business. Within these limitations he gives an excellent historical perspective and motivation from the 1950s onwards, before deriving a fairly general formulation of the governing equations and describing their mathematical properties. Sandwiched between these two topics is a chapter on panel methods, which brought the first major successes for CFD in aeronautics; the explanation here is clear, and is followed by a very good practical example, but the more mathematical reader could wish for more derivation, e.g. of the quoted results for the kernel singularities. Similarly, the short chapter introducing finite difference methods and that on mesh transformations are insufficiently rigorous to form main texts for mathematics students; while the following chapter which describes the application of explicit difference schemes to typical inviscid and viscous flow problems is not very illuminating.

Chapter 8 by Grundmann on boundary layers describes a hierarchy of boundary-layer equations but considers only the θ-method of approximation. The next chapter, by Degrez, is devoted to the second major success in aeronautical CFD – the use of time-marching iterations to solve steady subsonic, transonic and supersonic flows in a unified way. It includes a useful introduction to implicit and semi-implicit methods as well as to the use of numerical dissipation.

In the final pair of chapters, Dick provides a simple, integrated presentation of finite element and finite volume methods. He has deliberately risked the charge of naiveté to make his main points and has succeeded admirably. There is no attempt at error analysis so that, for instance, the idea of 'lumping' appears in a very ad hoc way; but this is not a major criticism since the error analysis for finite element methods is limited to fairly simple problems and for finite volume methods has hardly been started.

The use of steady inviscid flow models for aerodynamical flows, and the development of accurate numerical approximations to them, is clearly fraught with difficulties; there are no inviscid experiments that can be used for validation, for example. Thus the first chapter of the book on the Euler equations is devoted to an extensive historical survey of the subject, from Aristotle through Newton, D'Alembert, Euler, Lagrange and Helmholtz to the 20th century; and in the later chapters there is much discussion on the use of the inviscid theory to model wakes, vortex sheets etc. and the future role of Euler equation computations. Chapter 2 presents the Euler equations and their elementary properties, in non-vector notation; while a lengthy chapter 3 introduces the ideas of characteristics, Riemann invariants, weak solutions, and shocks before going on to the concepts of consistency, convergence and stability for difference approximations. The presentation seems to be directed towards neither engineers nor mathematicians, it is wordy and rather imprecise, and the examples are generally not well chosen – see e.g. the examples of non-existence and non-uniqueness of solution on p. 60.

The meat of the book starts with chapters 4 and 5 on the finite volume method and specifically its cell centre form; there is a brief (14 lines!) but correct description of the rival cell vertex form which, however, gives no indication of its rapid development since 1985. As many of the practical computations presented in chapter 11 use the cell centre method, these are key chapters for their understanding; and most of the details of the formulation regarding generation and choice of meshes, boundary conditions, artificial viscosity models and time-stepping procedures are all fully described. But there is no attempt at analyzing the method, even on simple model problems, apart from a rather unhelpful section on the truncation error. The final sentence aptly sums up this approach – 'Artificial viscosity is an essential feature of the numerical model for inviscid transonic flow'.

The 110-page sixth chapter is on 'principles of upwinding', which is an alternative approach. It is a very long-winded and not very structured account of Riemann solvers, flux and flux-difference splitting, flux limiters and non-oscillating interpolation which this reviewer did not find at all illuminating. For example, on p. 216 it is concluded that 'the von Neumann stability test is a useless tool for upwind schemes', when the real phenomenon considered is not stability but convergence to steady state. Yet chapter 7 is wholly devoted to the latter topic, without contributing much to the material of other chapters – as another example, there is no reference to the 'matrix method' of chapter 3 which could have been used to show why it is that the simple upwind scheme can be convergent to steady state for CFL numbers up to 2 but stable only up to 1.

In conclusion, then, the first book is much more successful in achieving its objectives, is well produced and can be recommended as an introduction to aeronautical CFD for engineers. But, after its very promising first chapter and despite its wealth of practical test-case computations, the second book is a disappointment. It suffers from poor coordination and selection of material and is not helped by the old-fashioned typed format, many typos in key places, and often messy choice of notation.

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