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Book review

Introduction to Computational Fluid Dynamics, by Anil W. Date. Cambridge University Press, New York (2005) ($80.00, Hardcover, ISBN:13978-0-521-85326-2 and ISBN:10-0-521-85326-5).

The author states that his book "is intended to serve as a textbook for a student uninitiated in CFD" but with exposure to undergraduate thermal science courses. He then proceeds to present a sophisticated and detailed treatment of CFD, which, in the opinion of this reviewer, is beyond the scope of the intended audience. The material seems more suited for a course, which would follow a traditional numerical methods course in which students would learn to solve elliptic and parabolic PDEs. This traditional course could be taught from G.D. Smith's "Numerical Solution of Partial Differential Equations", Oxford University Press, or a similar book. Then the student would be prepared for a venture into the book which is the subject of this review.

Having made these observations, I will now attempt to provide a review of the book, assuming an appropriate audience.

The author begins by presenting the appropriate equations to represent a general flow problem and outlines a sequence of steps necessary to solve these equations. The derivation of the equations is appropriately relegated to the Appendix although it is the reviewer's opinion that these derivations are not necessary in a CFD book.

In Chapter 2, the author develops the finite-difference and finite-volume versions of the heat-conduction equation. However, he does not refer to them as such. The concepts of explicit, partially implicit, and implicit representation of the discretizations are introduced. Some standard solution techniques such as Under-relaxation, Gauss–Seidel, and the Tridiagonal Matrix Algorithm (normally known as the Thomas Algorithm) are introduced. Examples illustrate the use of the Gauss–Seidel method, but the other two methods are not illustrated here. A turbulent flow example is included, but seems out of place.

Also in Chapter 2, the author introduces his own notation for various descriptions. He refers to the finite-difference method as the TSE (Taylor series expansion) method and the finite-volume method as the IOCV (integrated over a control volume) method. The new terminology is awkward because it does not relate to the standard descriptions used in comparable literature.

In Chapter 3, the author introduces, for example, Upwind Difference Schemes (UDS). The concept is discussed, but the shortcomings of the first-order UDS are not mentioned. Even though UDS is a section topic in Chapter 3, it is not listed as an item in the index. The author continues to develop his own notation regarding the terminology of CFD. This technique does not provide continuity when this book is read and compared to other CFD literature, which use conventional notation.

In Chapter 4, the author generalizes the form of the boundary layer equation as an introduction to 2-D boundary layers. Personally, the reviewer would rather see a simple example solution to the boundary layer equations and then a generalization to cover the six situations listed in Table 4.1.

An example of several nomenclature anomalies is the use of e–ε instead of k–ε for the turbulent kinetic energy—turbulent energy dissipation. Again, this is inconvenient when other relevant literature is consulted.

In Chapter 5, the same pattern as in Chapter 4 of generalizing initially is followed. Again, the reviewer's preference is to generalize only after providing a simple solution to the problem at hand. The reviewer feels that this suggested approach is more effective. On page 117, the author discusses the determination of the pressure at a solid boundary by a linear extrapolation of the pressure at two adjacent points to the boundary. In the reviewer's experience, this is not adequate; values from five to six points adjacent to the wall are necessary for an accurate extrapolation to obtain the boundary pressure, especially in a separated flow.

In Chapter 5, the author discusses the matter of an outflow boundary where the values of the dependent variables are not known. One suggested technique is to move the downstream boundary further downstream. In a complex problem, such as separated flow past a body, this is not practical due to the increased size of the computational grid. Another suggested technique is to use the assumption of a fully developed state at the outflow boundary. For a time-dependent flow, again such as separated flow past a body, this is not a realistic technique because there is no fully developed state.

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The prevalent methods in the literature for an outflow boundary are the zero vorticity gradient technique (i.e., letting the vortices cross the outflow boundary undisturbed by the presence of the boundary) and the unsteady convective condition as discussed by Ferziger and Perić in their book "Computational Methods for Fluid Dynamics", Springer-Verlag.

Chapter 6 is a continuation of Chapter 5, but for complex domains. The concept of the mapping function (coordinate transformation) is introduced to facilitate the solution of the flow field. Unstructured grids are also discussed with a grid generator, such as ANSYS, being suggested as the method to be used for grid generation. It might also be mentioned that there are several very good commercial codes available for structured grids as well.

Chapter 7 deals with phase change, which is not within the experience realm of this reviewer and will not be discussed in this review.

Numerical grid generation is presented in Chapter 8. It seems to this reviewer that this material could have been presented prior to the grid-generation discussions of Chapter 5 and 6. This earlier presentation would have provided more insight on the grid-generation concepts in Chapters 5 and 6.

Chapter 8 has a discussion of convergence enhancement techniques. These show that the Gauss–Seidel and ADI solutions can be accelerated by slightly modifying the solution methods. Stone's Strongly Implicit Procedure (SIP) is used as one of the enhancement methods, but the author does not refer to it as the "SIP method" by which it is very widely known. The multi-grid method could also have been briefly mentioned here.

There are several items that could have been discussed, but are omitted: a brief mention of spectral methods leading to Direct Numerical Simulation of flow problems; compact differencing to improve accuracy; and other turbulence modeling techniques, such as large eddy simulation (LES). For separated flow problems, LES has been found to provide better solutions than the k–ε (or e–ε, as the author calls it) method. Another topic that could have been given greater coverage is time stepping. The beginning CFD student needs to be made aware of concepts such as the Euler Forward and Backward Methods and the Adams–Bashforth and Adams–Moulton Methods and the shortcomings of the upwind method.

Regarding the exercises at the end of each chapter, the author has provided an adequate number of challenging problems.

In summary, in the opinion of this reviewer, the author has written a book, which seems to have been developed for an audience other than that for which he says it is intended. As an introductory book to CFD, it would not satisfy the perceived needs of this reviewer. The notation and terminology in the book are not conventional and required the reviewer to consistently return to earlier parts of the book for clarification. As mentioned earlier, in the opinion of this reviewer, the book is not recommended for a first CFD course, but could be considered for a second course.

C. Dalton
Department of Mechanical Engineering, University of Houston, N207, Engineering Building 1, Houston, TX 77204-4792, USA
E-mail address: Dalton@uh.edu