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BOOK REVIEW

Computational Fluid Dynamics. By T. J. Chung. Cambridge University Press, 2002. 1012 pp. ISBN 0 521 59416 2. £65.

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This book aims to provide elementary concepts for the beginner and state-of-the-art CFD for the practitioner, thus covering an extraordinarily wide range of Computational Fluid Dynamics. Some of the topics, such as chemical reaction and combustion, electromagnetic flows and relativistic astrophysical flows, are rarely seen in a general CFD book. In this sense this book has a rich content and could be very informative for a beginner.

However, elementary concepts for the beginner and state-of-the-art knowledge for the practitioner are two opposite ends of a research field, and it is not easy to make the two ends meet in a single book. In particular, CFD covers a vast area, and many of its aspects could constitute a single book in their own right. Thus, though this is a very thick book (1012 pages), it cannot devote substantial space to any single aspect of CFD, which has an impact on the clarity and the style. For example, Chapter 6 discusses finite difference methods for compressible flows. This is a rich subject with much subtlety. Hirsh's (1992) book devotes almost 700 pages to explaining the theoretical background, and describing the interpretation and performance of each scheme. Most of Hirsch's book is repeated here in about 45 pages. We see many pages of lengthy mathematical formulae, while the companion texts are too short to explain the underlying ideas. This makes it very difficult to understand and heavy reading if one does not already have some solid understanding of the topic. Another example is the finite difference method for incompressible flow. When the SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) method is introduced, we suddenly meet the following relations (equations (5.3.4a) and (5.3.4b)) between the correction terms of velocity u', v' and pressure p':

$$u' = -\frac{\Delta t}{\rho}\frac{\partial p'}{\partial x}, \quad v' = -\frac{\Delta t}{\rho}\frac{\partial p'}{\partial y}.$$

A beginner would wonder where this comes from, and why it works. One would need to look at other books (e.g. Patankar 1980; Ferziger & Peric 1966) to understand how the above equations are derived and what terms are neglected from the complete relation between u', v' and p', and hence the motivation to improve the SIMPLE method by the SIMPLEC scheme which approximates the neglected terms. The relation between the SIMPLE scheme and the PISO (Pressure Implicit with Splitting of Operators) method (which has one more correction step than the SIMPLE method) is not explained here either. In my judgment, the connections between different schemes are crucial for the understanding of the subject. It is regrettable that some explicit methods for incompressible flow are not introduced here. Explicit methods are easy to construct and make the pressure-correction equation, one of the most crucial for many incompressible flow schemes, more accessible to the beginner.

This book reflects to a large extent the author's own research interests. Chapter 5 discusses finite difference methods for incompressible flow, comprising the SIMPLE, SIMPLER, SIMPLEC and PISO methods, as already mentioned above. These schemes are implicit methods and are efficient when a large time-step is needed for a flow problem, in particular for finding a steady solution. But this is not the whole story. When the time evolution of the flow is important, we often resort to some kind of fractional-step (projection) method, see Kim & Moin (1985) and Zang, Street & Koseff (1994) for example. For the incompressible scheme based on primitive variables, the issue of where to define the variables is crucial: the staggered-grid method defines the velocity components and the pressure at different locations while the colocated-grid method defines them at the same location. The book shows that for a Cartesian grid the staggered-grid method is preferable to the colocated-grid one, because the latter produces spurious oscillations in the pressure field, i.e. the ‘checkerboard’ pattern. However, the book does not mention that there is a cure for this problem, which is to employ special interpolations to obtain a compact stencil for the pressure equation to avoid pressure-velocity decoupling (see Rhie & Chow 1983; Zang *et al.* 1994; Ferziger & Peric 1966). This cure makes the colocated-grid method more convenient for dealing with complex geometry problems, for which the staggered-grid method loses its advantage because of the inefficient representation of the momentum equation through contravariant velocity components. On the other hand, the new colocated-grid method is slightly more complicated than in a Cartesian grid. It is more efficient than the staggered-grid method, and therefore preferable.

Finally, a comment on the volume of fluid (VOF) method discussed in this book: though the concept is introduced here, it is not presented in its state-of-the-art form. The modern VOF method is based on a two-stage approach: interface reconstruction and interface evolution. The best interface reconstruction algorithm is still the one introduced by Debar (1974), namely the piecewise linear interface calculation (PLIC). To solve the evolution of the volume fraction, one uses a geometric approach rather than an algebraic approach such as in a shock capturing scheme. This geometric approach can reduce the smearing of interfaces.

In summary, although this book covers almost all areas of CFD, from elementary numerical methods (finite difference and finite element methods) to mesh generation, from special techniques (adaptive methods and computing techniques) to large numbers of applications, it is not easy to understand if one does not have a significant amount of previous knowledge of the subject.

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