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Book Review

Computation of Unsteady Internal Flows

Paul G. Tucker, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2001, 355 pages, $160.00

Unsteady Navier–Stokes flow computations are increasingly necessary and are becoming more frequently conducted in engineering analyses. For the momentum equation, the unsteady form differs from the steady-state form by a single, time-dependent term, causing the governing partial differential equations to change from elliptic to parabolic type. To perform unsteady simulations successfully and economically, one has to address the time-stepping procedure required by the type of the equation, as well as extended issues relevant to the coupled, nonlinear equations, such as effective open boundary treatments, performance of convection operators under the influence of temporal operators, time-dependent geometry, and numerical stability.

In this book, Dr. Tucker presents basic information on the numerical techniques for unsteady computations as well as comments and comparison tables to help readers appreciate the main features of selected commercial computational fluid dynamics (CFD) codes. With the fast-growing trend of adopting commercial software in engineering practice, it is helpful for users to gain overall ideas about these tools. Naturally, this type of information requires frequent revision to stay accurate. Direct comparison of these codes presented in the context of case studies as well as relevant numerical techniques would also be helpful.

Throughout the book, the author blends basic concepts, specific numerical techniques, case studies, and practical advice. On p. 30, he states that "Unless there are obvious reasons, an effective strategy is to model all flows as unsteady. This is consistent with reality, where generally most flows are of this nature. Such an approach can avoid frequent fruitless attempts to gain converged solutions that, due to unsteadiness, cannot be supported by the governing equations." More discussion is needed here because there are numerical uncertainties (such as dispersion and dissipation) associated with any finite-digit computing. A time-dependent computation may fail to yield a steady-state solution due to its own characteristics, not the underlying physics. Conversely, a time-dependent computation may reach a steady state due to excessive numerical damping. The existence and uniqueness of the fluid dynamics equations remain very difficult issues and should be treated with caution.

The computational techniques covered in this book include algorithms for combined pressure–velocity computation, convection schemes, time-stepping strategies, multilevel/multigrid methods, turbulence modeling, moving boundaries, parallel processing, solution adaptation schemes, and case studies. A chapter is devoted to the solution-adapted time-stepping strategy. On the other hand, there is little information on grid generation (structured or unstructured) for complex geometric configurations. The interface treatment in multiblock computing is mentioned in Chapter 5 and Appendix C; however, little discussion about the nominal order of accuracy, conservative properties, and stability is offered. For unsteady flows involving moving boundaries and variable geometries, appropriate grid redistributions are often needed to maintain desirable grid quality. The author has restricted focus largely on the space (or geometry) conservation law and free surface tracking. The impact of the space-time combination on the convection operator is briefly mentioned but not elaborated upon. For turbulence modeling, a main question is what, if any, modifications in turbulence closures are needed when considering nonstationary flows where the mean flow variables are time dependent. A more comprehensive evaluation of these alternative closures would be helpful.

The author offers personal advice to help readers gain insight into some practical issues. Examples include the statement of a "very rough" ratio of 2 in computing efforts between central-based and "hybrid" convection schemes (p. 52) and square rate of increase in the number of iterations vs the number of grid points in "most solvers" (p. 115). Needless to say, the applicability of such rules depends strongly on the physical as well as numerical contexts, such as the Reynolds number, grid size and distribution, and solution techniques. The case studies and appendices detailing the specific computer program information can be put into the CD-ROM, which contains computer programs. This way, the book can be expanded to cover more technical details without being lengthy.

In spite of the tremendous progress made during the past three decades, we still lack comprehensive tools to analyze numerical methods for the Navier–Stokes equations, especially when the geometry is complicated and the nonlinearity is strong. Many aspects of code design and execution are hard to document in the archival literature, and yet they can substantially affect the outcome of a computation. In this context, this book has recorded the experience of an active CFD researcher and is useful for others to study.

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