Eur. J. Mech. B - Fluids 19 (2000) 317–318

S0997-7546(00)00111-4/BRV

Book review

Efficient Solvers for Incompressible Flow Problems: An Algorithmic and Computational Approach by **S. Turek** (Springer, Berlin, 1999, 352 pp.) DM 149.00, ÖS 1088.00, SFr 136.00, £57.50, US$ 99.00 hardcover ISBN 3 540 65433 X.

This book focuses on Computational Fluid Dynamics. It is an account of the author and his group's experience in computing incompressible viscous flows.

Chapter 1 constitutes an effort to convince the reader that the state of the art in CFD is not as bright as advertisements for commercial codes state it is. To substantiate his claim, the author reports on a benchmark that he co-organized in 1995 under the auspices of the DFG priority Research Programme and this is referred to in the book as the 1995 DFG benchmark. Basically, the assignment consisted in computing flows about circular cylinders in 2D and 3D at Reynolds numbers ranging from 20 to 100. Altogether, 17 research groups contributed to the benchmark. Though in the steady 3D and unsteady 2D cases the lift could be approximated correctly by using heavy computer power, in the 3D unsteady situation the participants computed this quantity within a 20% range or more. The author concludes that for the time being "the GigaFlop supercomputer are not sufficient at all" and "the required improvements must directly concern the algorithmics". Furthermore, the group drew the following technical conclusions:

(1) Use quasi-Newton iterations for stationary solvers.

(2) Use implicit methods for time-dependent situations.

(3) "Flow solvers based on conventional iterative methods... have, on sufficiently fine grids, no chance against those employing suitable multigrid techniques".

(4) "The most efficient and accurate solutions are based either on finite elements or finite volume discretization on contour adapted grids".

(5) "High order treatment of convective term is indispensable" for computing accurately "drag and lift".

In the rest of his book the author comes back to points (1) to (5) and gives rationales for those statements, either from the mathematical point of view or from numerical experiments.

In Chapter 2, the author shows that all possible numerical solution of the time-dependent Navier–Stokes equations boil down to a single tree structure composed of two parts. The first one consists of all the discretization processes that are involved: the meshing, the time-stepping, the discrete representation of the solution (Finite Element, Finite Volumes, etc.), etc. This part covers the difference between the exact solution and the approximate one. It is at this level that adaptivity can be used. The second part of the tree is composed of the solution process: projection, multigrid, nonlinear loops, preconditioning, etc. The author shows that this part always reduces to solving the "pressure Schur complement equation". Finally, the author revisits many standard algorithms and shows how they fit into his classification. Then, he discusses their respective qualities in view of numerical experiments.

In Chapter 3, the author concentrates on some basic mathematical tools that are needed to build a Navier–Stokes solver. Among the items that are discussed in this chapter are the Babuška–Brezzi condition, finite elements, streamline-diffusion techniques, a posteriori error control, fractional step techniques, nonlinear iteration techniques, linear multigrid techniques, and finally considerations on outflow boundary conditions. This chapter constitutes more than half the book (184/352 pp.). It is well written, but the assumed culture of the reader in finite elements is so sharp that it is likely that those who do not have this culture will not benefit fully from the book. At some points, one may regret that the author did not recall some fundamentals. For instance, the concept a posteriori error control, which in my opinion should be made accessible to a wide audience, is presented in a way that only researchers acquainted with the field will be able to understand.

In Chapter 4, the author illustrates some technical points on numerical examples. Chapter 5 to 6 are dedicated to concluding remarks together with a description of the CD that comes with the book.

The book is accompanied by a CD containing FEATFLOW 1.1 and the “Virtual Album of Fluid Motion”. The code needs a Fortran 77 compiler, 32 MB RAM and 100 MB hard disk. It has been tested on UNIX/LINUX platforms and is easy to install. The Virtual Album is very well made and contains very nice pictures and MPEG movies. One gets easily convinced of the performance of FEATFLOW by browsing through the Album.

In summary, I liked the book and many of the ideas it defends. I think it should be mandatory reading for those involved in the development of Finite Element codes in CFD. However, the finite element prerequisite is sometimes so deep that a readership that is used to the more conventional finite difference or finite volume approach will probably shy away from it.

Jean-Luc Guermond
LIMSI
BP 133
91403 Orsay cedex
France