Book Review

Finite Element Computational Fluid Mechanics, A. J. Baker
McGraw-Hill Book Company, New York, 1983, 510 pp., list price $39.50.

This work represents a milestone in the author's pioneering efforts to adapt finite-element methods for the solution of fluid mechanics problems. The book is intended as a text for senior and graduate students in engineering, mathematics, and physics who are versed in engineering, fluid mechanics, and mathematics. The author states that the book is a text on fluid mechanics and its computational simulation, with a purpose of providing "a substantive exposition of finite-element solution theory and practice applied to the linear and nonlinear equations governing a wide range of problems in fluid mechanics." The material emphasizes practice over theory and provides an abundance of references for the reader interested in the theory underlying the presentation. The author succeeds handsomely in achieving his goals for the book and has produced a very readable and useful book (text as well as reference) for the computational fluid dynamics community.

Before ushering the readers into the intricacies of the finite-element method, the first chapter provides a succinct review of mathematics focusing on ordinary and partial differential equations, separation of variables and Fourier series, variational calculus, Sturm-Liouville theory and orthogonal functions, and finally matrix algebra. The stage is then set for the chapter introducing the rudiments of the finite-element method. The one-dimensional, steady heat conduction equation is the vehicle for illustrating the applications of the method and for laying the groundwork for extension to higher dimensions, systems of equations, and more complex boundary conditions. The method is cast in the context of a variational formulation for the linear heat conduction equation. This approach is later supplanted, for nonlinear equations, by the penalty function approach, and later still by the more general method of weighted residuals.

After introducing the basics, the remaining chapters address the major problem classes in CFD, with each chapter providing a literature survey. The chapters are entitled Inviscid Potential Flow; Initial-Value Problems, Convection/Diffusion; Viscous Incompressible Two-Dimensional Flow; Two-Dimensional Parabolic Flow; Three-Dimensional Parabolic Flow; and General Three-Dimensional Flow. Solutions are presented to many practical problems arising from the author's industrial and university experience, including such areas as environmental hydrodynamics, external aerodynamics, and propulsion. Each class of problems is analyzed in terms of accuracy, convergence, discretization refinement, and error. Comparisons are made with available analytical solutions, measurements, and finite difference calculations. In comparing with finite difference results one of the few topics not touched upon is the relative cost (computer storage and run time) of finite-element versus finite difference solutions. In each chapter new ideas are translated into the natural FORTRAN equivalents. The related areas of multigrid methods, time-splitting, dissipation (or smoothing), and turbulence modeling are presented, applied and analyzed.

Accepting the prerequisite background of engineering, fluid mechanics, and mathematics, the book is an autonomous exposition of the finite-element method applied to practical fluid dynamics problems and is a worthwhile addition to the library of students or researchers in engineering, mathematics, and physics.

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