BOOK REVIEWS

Finite Element Analysis: From Concepts to Applications

By David S. Burnett, Addison-Wesley Publishing, Reading, MA, 844 pp., 1987

The book describes many of the intricacies needed to write finite element programs. Its primary object (according to the preface) is to provide a solid foundation of the basic concepts, and in this goal the book largely succeeds. Thus, the book will be useful to those who want to write their own codes, who apply the finite element method using an existing code, and who want to understand some fine point. It is too long a book for someone wanting a casual overview. The applications are general science and engineering ones, not just chemical engineering ones, and all problems are linear. While there are linear problems that chemical engineers want to solve, most of the power of the finite element method comes in solving nonlinear problems for which no analytical solution exists. Thus, the reader will be disappointed with that limitation. However, the really hard part of the analysis is the finite element method, not the treatment of nonlinear problems, and in this area the book does an admirable job.

The book is organized in four parts: Introduction, Basic Concepts, One-Dimensional Problems, and Two-Dimensional Problems. While reading the introduction I was immediately struck with the repetitious style. The author says he repeats things because it is a good pedagogical tool, which is true. However, in a book a person can reread and also choose what they want to reread so that it does not have to be repeated. Practically every page of the introduction had a footnote, and the flow of the text was constantly interrupted because I am a conscientious reader of footnotes. The book is based on a class the author gives and needed a good editor to reduce the duplications and sidetracks. Perhaps other readers will prefer the style.

The part on basic concepts explains the Method of Weighted Residuals. The author calls the methods "optimizing" principles, despite the fact that usually nothing is being optimized (although for a few problems minimum or maximum principles do exist). He then gives a set of detailed and useful steps to help the reader learn how to approach each problem. Finally, he describes the element concept, which distinguishes the finite element method from other Methods of Weighted Residuals. He chooses to generate the equations by generating the element equations, and then combining rows and columns for multiple unknowns which really stand for the same quantity. Most books generate the equations by noting that the weighting function overlaps several elements and the global integral is then divided into nonoverlapping integrals over adjoining elements. While I prefer the latter approach, it is a difficult one to teach quickly and the author may have had better experience with his approach.

The part on one-dimensional problems begins with a very good discussion of four sample areas of application: heat conduction, an elastic rod, cable deflection, and electrostatic fields. Each of these problems is solved using the finite element method, and a good discussion is given of all the little things that students struggle with, for example, discontinuities at boundaries. The author wisely shows the reader how to assess the accuracy of the results using estimated errors and reasonableness as guides. Good discussions are given of the Jacobian during element transformations and the need to choose a proper quadrature method depending on the order of the trial function. Reference is made to the patch test, but no details are given (they seldom are). This part discusses high-order elements and compares them as well as treats infinite domains. The treatment of eigenvalue problems is flawed by the fact that the author is apparently unaware that the matrix itself can be used to give upper bounds on the eigenvalues of the matrix; the book gets neither upper nor lower bounds. The theory on stable step sizes is misleading. A rapid change in loading requires a small step size in order to achieve accuracy, but it is the large eigenvalues of the model that require a small step size to maintain stability. Even if a mode is insignificant, if the stability limit involving that eigenvalue is exceeded then the mode will soon be significant!

The final part on two-dimensional problems gives an adequate treatment, but has several flaws. An inviscid fluid is introduced without telling the reader what situations are inviscid; the Navier-Stokes equation, which is more widely applicable, is not discussed. Triangular elements are introduced using the η-ξ coordinates, and triangular coordinates are ignored despite their simplicity. In the discussion of geometric errors, the author is apparently unaware that for the type of problems considered one can have upper/lower bounds if the approximate domain is entirely outside/inside the real domain. Finally, I wondered why the mesh generation section was so out-of-date; it was then that I saw that the book was printed originally in 1987 and mesh generation has advanced significantly since then.

On the whole, the book gives a thorough treatment of the fundamentals of the finite element method. The book takes the reader from knowing only college calculus and differential equations and enables him/her to understand and produce finite element code to solve linear problems. The programs in the back of the book are printed in type too small to be useful, and there are no detailed examples to emphasize the value of the finite element method. Another book is needed to learn the minor remaining step to treat nonlinear problems (by expanding the nonlinear terms in a Taylor series and solving the problem iteratively).

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