ChE book review

Boundary Element Methods in Transport Phenomena

by P. A. Ramachandran

Published by Computational Mechanics, Inc., 25 Bridge Street, Billerica, MA 01821; 424 pages, $160 (1993)

Reviewed by
Bruce A. Finlayson
University of Washington

The boundary element method solves an integral form of a differential equation. This method has the marvelous advantage that for a linear problem the entire solution is determined from the boundary conditions. This changes a three-dimensional problem into a two-dimensional problem, or a two-dimensional problem into a one-dimensional problem; both reductions in order provide significant computational savings. The reduction of dimensionality is useful if one wants only a few features of the solution, such as the value of the function at a few points, or the integrated flux. If one wants the solution everywhere (say, for contour plotting), then the computational cost goes up, and this may be why no contour plots are presented in the book. Multiple equations are also limiting, since the equations must be handled separately, leading to iterations that may not converge.

The disadvantage of the boundary element method is that nonlinear problems still require that the solution be represented everywhere, usually using finite elements throughout the whole domain. This feature destroys the chief advantage of the method, the reduction of dimensionality. The author argues that one does not need to introduce approximations at an early stage, but approximations are finally introduced, and if they affect the result it doesn't matter when they are introduced.

The first chapter carefully develops the differential equations and boundary conditions that are needed to solve transport problems, including fluid flow and mass and heat transfer. This is carefully done, and the treatment is concise.

The second chapter shows how the use of a weighting function plus one integration by parts can lead to a weighted residual method (like Galerkin); with two integration by parts the boundary element method is obtained. The weighting function can be a Green's function, in which case the method is the "Fundamental Solution Method," or the boundary integral method.

The book (which has a total of eleven chapters) is very clearly written, with lots of simple examples. Fundamental Solution Methods and Green's Functions are clearly presented, with lots of details carefully attended to. The Laplacian operator is clearly important, but chapters deal with extensions involving time derivatives, one-, two-, and three-dimensional problems, the Poisson Equation, heat and mass transfer applications, and application to fluid flow. Most of the problems are simple; more complicated solutions are given in tables, which is not a clear way to present material unless it is to be used for checking computer code. A computer diskette is provided, but the reviewer did not review it since it is not in Macintosh format (it also uses the old 5 1/4" format).

There are some minor errors: reference is made to the "Burger" equation; the person's name was Burgers. On page 153 the claim is made that the "quadratic" method for integrating ordinary differential equations does not lead to oscillations regardless of the step size—that is false.

The author makes the claim that the boundary element method will become the most widely used numerical method for engineering analysis in the 21st century. This reviewer believes that won't happen for nonlinear problems, and most problems are nonlinear. In fact, the book is deficient in that hard problems are not presented, even to whet the reader's appetite. The book does not usually demonstrate convergence with mesh refinement, which is a standard required of first-rate numerical journals, and this author believes that is essential. Detailed equations are given for constant, linear, or quadratic elements, but little guidance is given when to use which ones.

Despite these minor defects, overall the book is excellent. The careful, concise treatment of both Green's functions and boundary element methods will make it useful for anyone doing analysis of transport problems, or anyone who wants to learn about Green's functions. This reviewer believes that reviewing a book is only worthwhile if he can learn something. He did. ❐

ChE book review

HAZARDOUS WASTE MANAGEMENT, 2nd ed.

by Charles A. Wentz

Published by McGraw-Hill Book Company, NY (1995)

Reviewed by
Ralph H. Kummler
Wayne State University

At Wayne State University, we used the first edition of *Hazardous Waste Management* by Charles A. Wentz in the developmental stages of our program. We viewed it as an excellent undergraduate and graduate introductory overview to the hazardous waste management (HWM) field. Our civil engineering curriculum also used the text for their environmental engineering course on landfill disposal techniques.

As our HWM program developed, we began taking in

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ε^2 :

$$-\frac{1}{a^2}\frac{\partial^2 F_2}{\partial \zeta^2} = \frac{\partial^2 F_2}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_2}{\partial \xi} \tag{36}$$

$$\frac{\partial F_2(0,\xi)}{\partial \zeta} = 0 \tag{37}$$

$$\frac{\partial F_2(\zeta,0)}{\partial \xi} = 0 \tag{38}$$

$$F_2(\zeta,1) = 0 \tag{39}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\frac{\partial F_2}{\partial \zeta} = k_0 C_{Ab_i}\left(F_0^2 + F_1\right) \tag{40}$$

The continuation of this process is possible up to any desired power of ε. Note that by this process, an otherwise nonlinear system is reduced to a set of linear problems. Solving each of the above linear systems, we obtain

$$F_0 = 1 - \frac{2\delta k_0}{aD_{AB}}\sum_{n=0}^{\infty}\frac{J_0(\alpha_n\xi)\cosh(a\alpha_n\zeta)}{\alpha_n^2 \sinh(a\alpha_n)J_1(\alpha_n)} \tag{41}$$

$$J_0(\alpha_n) = 0 \tag{42}$$

$$F_1 = \frac{2\delta k_0}{a^2 D_{AB}}\sum_{n=0}^{\infty}\frac{\frac{\delta k_0}{D_{AB}}\cosh(a\alpha_n) - a\alpha_n \sinh(a\alpha_n)J_0(\alpha_n\xi)\cosh(a\alpha_n\zeta)}{\alpha_n^3 \sinh^2(a\alpha_n)J_1(\alpha_n)} \tag{43}$$

$$F_2 = \sum_{n=0}^{\infty} Q_n J_0(\alpha_n\xi)\cosh(a\alpha_n\zeta) \tag{44}$$

with

$$Q_n = \frac{-2\frac{\delta k_0}{D_{AB}}\int_0^1 F_0^2 \xi J_0(\alpha_n\xi)d\xi}{a\alpha_n \sinh(a\alpha_n)J_1^2(\alpha_n)} - \frac{4\left(\frac{\delta k_0}{aD_{AB}}\right)^2\int_0^1 F_1\xi J_0(\alpha_n\xi)d\xi}{a\alpha_n \sinh(a\alpha_n)J_1^2(\alpha_n)} \tag{45}$$

where J_0 and J_1 are Bessel functions of the first kind of order zero and one respectively.

The first order approximation F_0 is sufficient to describe the concentration profile of interest. Also note that Eq. (18) expresses a general form of the two possible power series expansions of Eq. (2).

Equation (41) was tested in the prediction of silicon nitride deposition data with reasonable results.[6]

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100-200 new students in the introductory course each year, and as a result we eventually introduced a full MS in HWM, with over thirty required and elective courses. We developed a separate, in-depth course in each of the Wentz chapters and subtopics, outgrowing much of the text. Moreover, the text's data and examples had become dated. So we switched texts, despite the excellent material contained in many chapters and the presentation from the chemical engineer's perspective. We therefore looked forward to the second edition.

Clearly, most students will take only a single course in this field; hence, there is a need for a broad-based text covering the entire subject. The second edition of *Hazardous Waste Management* fits that need well. Wentz provides an overview of all the major topics that should be addressed in HWM.

A major strength of the revised text is its comprehensive coverage within a reasonable number of pages. Another strength is its hard-hitting chemical engineering approach to the technical treatment and remediation subject areas. A major asset is the case studies of many of the major chemical tragedies that have driven federal law development, allowing the student to gain a sense of the field's history as well as its technical requirements. The second edition also groups topics in a more logical order, such as merging toxicology with risk assessment, landfills with injection well disposal, while giving other areas, such as biological treatment, a separate chapter.

The new material in environmental auditing and site assessment and the enhanced technical material in site remediation are major positive additions to the second edition. Likewise, the addition of problems to the technical chapters improves the text significantly as a teaching tool.

Weaknesses of the text include the aged data in Chapter 1, the brevity of the toxicology and environmental auditing sections, and the absence of the OSHA perspective and statistical considerations of data, none of which are serious drawbacks for the student who will take several courses in the field. The international environmental examples provided will increase the students' global awareness, but are largely out of context as they follow discussions of US law.

In summary, the Wentz text led the field since it was first published in 1989; the revised second edition is greatly improved and is a sound choice for a course to round out the background of most chemical engineers. It is also a good choice for an introductory course for a wide range of disciplines with interest in the field. ❐