
Reviewed by H. Saunders

Have you ever attempted to write a program using a numerical procedure in your finite element (FE), finite difference (FD), or response programs and reached an impasse? Either the information was wrong, insufficient, and/or the convergence was poor. This is a different type of text on numerical methods. It is slanted toward the numerical procedures used in current FE, FD, and response analysis. It covers a number of procedures which are barely covered or deleted in texts on numerical methods. As stated by the author, "The objective of this text is to introduce the science and engineering student to the methods, tools, and ideas of numerical computation...The objective of this text...is to present scientific problem solving using standard mathematical software...". The text discusses numerous programs and software packages. The IMSL library and ACM algorithms are the software that the author discusses extensively in his text. They are widely available to the general public and contain high-quality mathematical software. In addition, the book explains a number of the procedures which are used in current FE and FD programs.

The book consists of 14 chapters.

Chapter 1 introduces the basic essentials of differential equations, linear algebra for matrices, and basic sequence of calculus in a very concise form.

Chapter 2 focuses on numerical software. It details the use of a library of software suited for certain computer programs and mentions the individual programs in the major software library (IMSL, NAG, SL/MATH, BMD). The author further introduces PROTRAN which is an extension of FORTRAN. Developed at Purdue University, PROTRAN brings many of the IMSL library programs into a language which is simple to use.

The next chapter discusses errors, round-off, and stability. In numerical approximations, truncation errors and order of convergence are important. Round-off errors may occur because of floating arithmetic, propagation of round-off errors and stability, and the condition of the problem. A number of examples are given to explain the aforementioned statements.

Chapter 4 contains models and formulas for numerical computation. Beginning with polynomials, this chapter extends to piecewise polynomials. The chapter concludes with the methods for deriving formulas: use of undetermined coefficients, models for analytical substitution, and Taylor series method.

Chapter 5 reports on interpolation as a tool in deriving formulas as well as solving problems. It can be viewed as a special case of the approximations of functions and data. Interpolation permits the solution of linear equation solving and its conditioned effects. The most prominent interpolation schemes are Lagrange polynomial, Newton interpolating polynomials, B-spline as a divided difference, osculatory interpolation, piecewise polynomials, and cubic spline interpolation. The chapter continues with software application to Hermite cubic interpolation and Chebychev points. The choice of interpolation points and forms depends on the previously mentioned interpolation schemes. The chapter includes an assessment and selection of points for piecewise interpolation plus error analysis involved in interpolation. This is an excellent chapter and should be read by all who are interested in numerical methods.

Chapter 6 covers the various types of matrices and methods of computations. Gauss elimination and its pivoting aspects are described. This continues with iteration schemes for linear equations plus considerations of the use of iteration schemes. Progressing ahead, the author refers to three important software packages (LINPACK, IPACK, YALEPACK), IMSL library software, and the use of a band matrix software in solving a differential equation. Case studies are employed as demonstration models in solving linear equations. The final subject in this chapter is the solution of eigen system problems and their eigenvalues, plus associated software.

Chapter 7 speaks about differentiation and integration. Methods for estimating derivatives and finite differences are introduced. Accompanying this are some available software packages. Estimation of integrals are next on the agenda. This includes piecewise polynomials, weighted functions, adaptive quadrature, and IMSL software for integration. Forging ahead, we encounter performance evaluations of four integration methods (trapezoidal, Simpson, three-point Gauss, and D CADRE). Error analysis formulas conclude the chapter.

Chapter 8 relates the problem areas in the solution of nonlinear equations. The seven most prominent methods are (a) bisection, (b) Regula Falsi, (c) Newton, (d) secant, (e) fixed point, (f) Muller, and (g) higher-order Newton. Convergence tests are important, and the author shows their application when a troublesome iteration could "foul" up a solution. The effect of multiple roots and special methods for polynomials are next brought into focus. As in previous chapters, references are made to available software packages, i.e. IMSL library and ACM algorithms.

Chapter 9 covers ordinary differential and difference equations. Beginning with the stability of differential and difference equations, we progress into the various well-known methods: Euler, Taylor series, Runge-Kutta, Adams-Bashford (explicit), Adams-Moulton (implicit), and polyalgorithms for differential equations as stated in the IMSL library and ACM algorithms software. Analyzing differential equations, the most common are the instep and multistep methods.

The next chapter continues with the solution of partial differential (pde) equations. The most common are finite differences, finite elements, and method of lines (initial value time-dependent problems). The two best methods are explicit and Crank-Nicholson (implicit). The most popular FE
methods are collocation, Galerkin, the bicubic Hermite. The author applies the previous three methods to the solution of elliptical problems. The author refers to the IMSL library and FLPACK system.

Chapter 11, the lengthiest, encompasses the subject of approximation and data. This chapter covers some of the topics which are employed in data processing, the measure of “closeness and goodness” of data in which approximations are important. The most prominent are (a) Chebychev norm, (b) least deviation, and (c) least squares. The author introduces the Gram–Schmidt orthogonalization and the modified Gram–Schmidt applied to the approximation scheme. The available software would be PPPACE which contains a number of subprograms for piecewise polynomials and splines; IMSL library for least-square approximation (RFOTH, RFOTW, RLFOR), and IMSL least-square spline approximations (ICSERV, ICSCWC, ICSPRU); IMSL discrete $L_2$ approximation (RLLAV); IMSL Chebychev approximation (RLLMV, IRATCU); and IMSL spline data smoothing programs (ICSSU, ICSSCU, ICS MDU). He then furnishes a number of case studies where these programs are utilized. The next topic is smoothing of data which may contain uniformly distributed random errors, namely distributed random normal errors via varying errors or wild points. The data can be smoothed using least squares with polynomials or smoothing cubic splines. The author goes to great length in his case studies by employing the various IMSL programs. The chapter concludes with approximation of mathematical functions by means of orthogonal polynomials. An excellent chapter!

Chapter 12 is a most informative chapter. It describes software tools and engineering. Many neophyte programmers fail to realize that programming is a high-level intellectual activity. Depending upon the motif, reason, and extent of the program, many unwanted pitfalls occur. The principal stages of a large software project are (a) specification, (b) design, (c) coding, (d) testing, (e) integration, (f) documentation, and (g) maintenance. Each plays an important role that one should not neglect. Programming should follow tools which are useful in developing debugging other programs. The author details cost per line of program based on 1980 costs. These should be modified to conform with present-day costs.

The next chapter reports on software performance and evaluation. A major problem associated with software performance is the utter disregard of good experimental techniques in measuring. Another important aspect is software efficiency. This utilizes the computing resources, i.e. time, memory, and input/output (I/O). Another important phase is software reliability which measures how well the software performs its intended functions. An additional feature is the portability of software. All of the above are important characteristics of software performance. The validation of models employed in numerical computation requires certainty of numerical data, round-off for single and double precision, employment of different methods to certify correctness of FE and FD calculations, plus some modification of model used in software.

The last chapter covers PROTRAN. Its prime purpose is to act as a preprocessor for FORTRAN. It issues diagnostic messages and warnings plus run time diagnostics. It is a very powerful tool and the author details how it may be employed in a FORTRAN program. PROTRAN contains general purpose statements, problem solving, and simple statements.

In summary, this is an excellent book. The book contains a vast number of computer programs which supplement the various phases. Although it does not make one an excellent programmer, it provides enough information that permits one to be wary in their programming efforts. There are a number of topics that the reviewer would have liked to see included in the text, such as the use of Newton interpolation and Lagrangian interpolation in three-dimensional problems and divided differences for unequal increments. No mention is made of WAVEFRONT and subspace iteration for solution of matrix equations; nor are the Houholt, Wilson and Newmark methods in the solution of transient equations covered. Nevertheless, the reviewer does recommend this book to those interested in programming of FE and FD problems. Congratulations to the author for his prodigious work!

### Probabilistic Fracture Mechanics and Fatigue Methods - Applications for Structural Design of Maintenance


The development of increasingly complex structures requires high reliability and availability which then become exceedingly more difficult to attain. To counter this demand with regard to structures, satisfactory safety and reliability have been accomplished over a period of time by altering design criteria founded on service experience. Damage tolerance design criteria require the growth rate of the damage which is compatible with a detailed inspection program. Probabilistic methods have tended to supplant deterministic methods due to the latter’s conservatism. However, progress is slow. Probabilistic or risk analysis methods demand enough data to characterize in a statistical manner the number of variables which pertain to structural reliability and safety. The important methodology required to develop the stress and strength parameters must be factored into the damage estimates of the structure. In addition, the rates of damage growth and inspection must be determined to discover damage before it reaches catastrophic proportions. The papers in this volume point toward some aspect of probabilistic methodology. This book consists of 11 papers divided into two sections. The first section is on probabilistic fracture mechanics, and the second is on statistical aspects of fatigue.

The initial paper on probabilistic methods emphasizes failure probabilities compared to deterministic ASME Code Margins of Safety. By employing linear elastic fracture mechanics and probability density functions, the authors conclude that Appendix G vessels of section III are designed too conservatively.

The next paper discusses the influence of the desired important aspect of in-service inspection on structural reliability. Employing probabilistic fracture mechanics, the authors calculate the probability of failure of a large-diameter nuclear vessel due to fatigue crack growth of initial cracklike defects. Using a computer program which incorporates Monte Carlo techniques, the authors conclude that the relative benefits of in-service inspection do not hinge upon the exact knowledge of initial crack distribution.

The third paper uses the material toughness and fatigue crack growth ratio employed in evaluating structural reliability. The author does predict $K_c$, from small-scale Charpy data. He further shows that the $c$ in the “Paris Power Law” fatigue crack growth rate is lognormally distributed. An illustrative example furnishes a change in failure probability with the number of accumulated cycles.

Paper No. 4, combines the FELM and fatigue $S/N$ curve approaches in estimating the initial defect size which can progress to structural failure. The scatter in fatigue life is based upon the Weibull weakest-link concept. Cycle crack growth, fatigue data, and initial defect sizes are used, and any two can determine the third one. The authors conclude that the distribution of the critical size defect in components can be distinguished, i.e., inspection criteria and material processing can be founded upon the required component life. This approach is only appropriate for cast materials and high-strength alloys.