Journal of Vibration, Acoustics, Stress, and Reliability in Design

Book Reviews

Probabilistic Methods in the Mechanics of Solids and Structures, S. Eggwertz and N. C. Lind, Eds., Springer-Verlag, Berlin, Heidelberg, New York, 1985, 610 pages, $51.00.

Reviewed by H. Saunders

Structural engineering makes a giant stride forward with this symposium. This book represents an international symposium held in Stockholm honoring Prof. W. Weibull. It drew participants from 21 countries with a total of 55 invited papers. There were 7 scientific sessions. Most of our studies in school revolved about deterministic happenings. Random loading becomes more and more important when we equate events in our world with physical and mathematical reasoning. Probabilistic failure model and stochastic fatigue crack growth play important roles in the safety of nuclear structures, random loading due to wind turbulence, earthquake spectra, offshore structural design, and aircraft design.

The initial paper summarizes Prof. Weibull's life and accomplishments including a mention of Weibull distribution used in fatigue studies. The initial session deals with extreme value theory (EVT). The first paper reviewed applications of extreme value theory to material behavior and indicates the importance of the accompanying statistical theory. The next paper generalizes Weibull distribution in matrix form. The following papers proclaim (*a*) extreme value theory as compatible to random field theory, (*b*) incomplete samples can be transformed to a mixed-exponential survival for a more comprehensive Weibull distribution, (*c*) EVT in endurance testing of ball and roller bearings, (*d*) use of the Slepian model identifying the behavior of Gaussian noise near or between its zero crossing, (*e*) plastic movement of SDOF elastic plastic oscillator subjected to stationary Gaussian process excitation, and (*f*) generalized Hermitian polynomial used in the perturbation method for nonlinear random vibrations. The final paper reports on Weibull distribution in large earthquake modelling.

Session 2 reports on fatigue crack growth. Beginning with an analysis of stochastic equation models of crack growth, it continues with stochastic models of fatigue crack growth and propagation, prediction of crack growth under spectrum loading employing a cycle-by-cycle technique and fatigue life distribution in a random loading sense with interacting failures. The final paper considers a new approach to fatigue crack propagation under random loading and the use of Monte Carlo simulation in correlating micro fracture process and fatigue crack propagation. This session indicates that more experimental work is required in crack propagation to reach the same level as crack initiation.

Session 3 comprises a total of 13 papers and dwells upon probabilistic failure models. The initial paper proposes a generalized probabilistic model for the fatigue life and reliability prediction of a structure containing noninteracting cracks and employs Poisson random sets. The next group of papers focuses upon (*a*) structural reliability treated as a single stochastic model, (*b*) fatigue life and reliability estimates of mineral pipe lines using probability theory, (*c*) Weibull-based equation employed in predicting the failure of a stressed brittle material, (*d*) a preliminary suggestion that specimens failed in proof tests may be used to estimate the parameters of the reliability function for the survivors, and (*e*) brittle material design using three parametric Weibull distributions. The next set of papers considers ring-in-ring tests on strength of cladded glass using the three-parameter Weibull distribution, probabilistic analysis of plastic plates utilizing yield-line theory plus lower bound reliability analysis of plastic plates evaluated by inclusion-exclusion theory. The final set of papers questions the possibility of flaws in the present probabilistic models for unidirectional fibrous composites, strength relations for cracks in unidirectional long fiber composites employing Weibull distribution and a stochastic approach in studying the fracture and fatigue of concrete.

Session 4 delves into probabilistic fracture mechanics. The initial paper estimates the probable failure of PWR pressure vessels employing Weibull distribution and updates the well-known Marshall A(a) and B(a) functions. The final set of papers covers probabilistic assessment of structures with weld defects, probability of fracture in main coolant pipes of PWR, and statistical modelling of shaft predictions (as measured by Charpy impact curve) in the reference temperature of pressure vessel welds. The authors suggested that U.S. Nuclear Regulatory Guide 1.99 be updated to remove excessive conservatism.

Session 5 covers reliability analysis. The first paper recommends a Bayessian approach to assessing the system reliability with obtained failure data. A new algorithm for bounds based upon the inclusion-exclusion principle is proposed. The final set of papers considers closed form solutions for cost optimized reliability using Weibull distribution plus use of time transformation techniques in updating the accuracy of cumulative damage models based on service data.

Session 6 discusses structural response to random loads. The initial paper reviews the latest development in random vibration of inelastic structures. It outlines the modelling and analysis of hysteretic structural systems. The following papers address (*a*) peak response of a simple oscillator subject to a nonstationary student's t model, (*b*) time-dependent failure probability of multicomponent systems under random loading, (*c*) random vibration of Timoshenko beam employing classical and higher order theories, and (*d*) reliability assessment of frames characterized by nonlinear mechanics. The next set of papers reports on (*a*) method of conservative evaluation of cumulative damage from maximum stress due to seismic excitation, (*b*) emphasis and review of new response spectra in seismic structural design, (*c*) the employment of tuned and damped vibration damper in reducing stress resulting from wind induced random vibrations on a structure, and (*d*) evaluation of failure probability of a structure and parameter estimations of a structure with Weibull distribution strength.

The last session recounts the design philosophy, codes, and applications applied to structures. The first paper recommends that civil and military aircraft authorities adopt a reliability procedure applicable to fatigue safety of aircraft structures. The following papers expound upon fatigue reliability analysis of components having critically located fastener holes under a scheduled inspection and repair maintenance in service plus reliability analysis of landing gear fatigue life considering runway unevenness. The next set of papers recounts the various problems of time, aspects of failure reliability, vectorial value analysis, and the "importance factor" relevant to human life. The concluding set of papers reviews and selects various load combination factors in design of structures plus a data pooling analysis of fatigue data employing data base or fatigue strength from files of the Society of Materials Science in Japan.

This is an excellent symposium and worthy as a tribute to Prof. Weibull. It covers most of the facets in probabilistic methods. The reviewer would have preferred papers on data processing and its reduction applied to the stochastic endeavors as well as a paper on stress derived from the experimental stress in an S/N random curve. To the best of the reviewer's knowledge, there is a semi-empirical equation derived by Frost and Pook. The reviewer has applied this with success in a Rayleigh distribution experimental S/N curve. However, good intuition is required to use this equation. Other experimental works must be performed to put these equations on a firm footing. This book is a must for those interested in probability and random vibration analysis of structures.

Advanced Dynamics For Engineers, B. J. Torby, Holt, Rinehart & Winston, Division of CBS College Publishing Co., N.Y., 1984, 426 pages.

The study of the dynamics involved in engineering problems has been greatly altered in the past three decades. The introduction of analog and digital computers has wrought great changes. Engineering problems thought to be difficult two decades ago can now be solved by modern computer systems. As stated by the author, "This text in advanced dynamics introduces the use of computer analysis and numerical methods in the solution of dynamics problems. . . . Too often the engineering student takes an isolated service area course covering the fundamentals of programming and numerical analysis and then is never required to use this knowledge in his or her major area of study. The student never integrates what has been learned and rarely experiences how a computer is put to use in his or her chosen field."

The book consists of 2 parts, 10 chapters, and 2 appendices on elementary dynamics and mass moments of inertia and common shapes. It contains an excellent section on symbols.

Part 1 is a review of Newtonian mechanics. The initial chapter presents Newton's law, gravitational laws, various symbols and their common SI and American units and initial axis of reference, i.e., absolute frame of reference for measurement. Chapter 2 introduces the subject of particle dynamics or kinematics. Cartesian coordinates are accompanied by uniformly accelerated rectilinear motions. This proceeds into free and forced single degree of freedom vibration with and without damping. The next topics are normal and tangential coordinates, cylindrical and spherical coordinates with accompanying illustrative equations. The important relative motion is considered next. This progresses into the important numerical solutions of ordinary differential equations with initial conditions. The methods considered and accompanied by computer programs are (*a*) Euler's method, (*b*) Euler's trapezoidal method, (*c*) Runge-Kutta's 4th order method, and (*d*) Newton-Raphson's method. Chapter 3 reports on kinetics. Starting off with the equations of motion via Newton's second law, we forge ahead into integrals of motion, i.e., principles of work and kinetic energy, conservative forces, closed vector path integrals, principles of angular impulse and momentum. Chapter 4 considers systems of particles. Inaugurating this chapter are the definitions and equations describing center of mass. This leads into equations of motion for a system of particles and a continuation of the integrals of motion. A brief description of impact is presented with a more elaborate discussion of angular impulse and momentum.

The next chapter focuses on kinematics or rigid body dynamics. The important topics considered are degree of freedom, translation, rotation about a fixed point, two and three degrees of freedom, and rotational freedom. We next consider Chasle's theorem which is an extension of Euler's work. This reduces the most general displacement of a rigid body which in turn is reduced to translation followed by rotation. The author introduces the subject of general plane motion (velocity and acceleration analysis) and methods of instantaneous centers. Looking ahead, we encounter the topic of derivative of a vector referenced to a rotating frame velocity analysis in two coordinate systems, acceleration analysis with respect to rotating reference plane plus orthogonal matrix and transformation. The chapter concludes with a short section on motion relative to the rotating earth. Chapter 6 concludes Part I and reports on rigid body plane motion. Continuing the equation of motion studied in Chapter 4, the definition of mass and products of inertia, mass moments of inertia matrix transformation (parallel axis theorem, coordinate rotation), we next meet the topics of eigenvalues and eigenvectors and moment equation about an arbitrary point which are solved by Jacobi's method. The final topics in this chapter are (*a*) principle of work and kinetic energy for a rigid body, and (*b*) principle of impulse and momentum for a rigid body.

With the review of elementary dynamics under our belt, we venture forth into advanced dynamics. Chapter 6 delves into rigid body dynamics and space motion. This encompasses the application of Euler's and Euler's modified equation plus Eulerian angles. Continuing we next meet the subject of general force-free motion of a rigid body with discussion of (*a*) Poinset ellipsoid, (*b*) force-free motion of axially symmetric shapes, and (*c*) motion of a symmetrical top. The chapter ends with an illluminating discourse on gyroscopic instruments. Chapter 8 covers energy methods. This includes the derivation of Lagrangian equations, Lagrangian multipliers, Routhian equations (eliminating the associated coordinate velocities of the cyclic coordinates from the Lagrangian), Hamilton's principle, the associated Hamiltonian equation and canonical transformation.

Chapter 9 speaks about the theory of small oscillations of m degrees of freedom. Beginning with the Lagrangian equations, one derives the equations of motion. This follows with normal modes of vibration plus the dynamically coupled system where the mass matrix is not diagonal. This leads to forced vibration with damping set in matrix form. The numerical methods employed in solving the matrix for natural frequencies are Householder's method, matrix iteration, Gauss-Jordan reduction method including its computer program. The chapter concludes with an interesting account of small oscillations