



Book Reviews

An Introduction to the Design and Behaviour of Bolted Joints. by J. H. Bickford, Marcel Dekker Inc., New York, 1981, 442 pages.

Reviewed by H. Saunders¹

Joints are the weakest element in most structures. The product can leak, wear, slip, or tear apart. Improper use of joints (fasteners) results in the largest cause of warranty claims faced by U.S. automobile manufacturers. An unofficial empirical rule states that a modern military plane has a linear relationship to the number of fasteners used in its construction. Considering its importance, bolted joints still possess some mystery and are not well understood. Specialists who design equipment and structures (nuclear reactors, airplanes, and heavy machinery) which should not fail and which cost large sums of money are required to understand and know everything about the design and workings of bolted joints. Nonspecialists glean their information by guesswork, experience, and handbooks. Nevertheless, problems still emerge.

Bolted joints entertain a large number of variables which are difficult and at times impossible to control and/or predict. An innumerable number of equations and design theories are, in most cases, approximations and gross simplifications. They tend to be insufficient for critical joints. The demands placed on critical designs, i.e., higher operating temperatures and pressures, new materials, increased requirements, better strength to weight ratios and more precise environmental and safety protection play the role of the devil. A number of the present codes fail to keep pace with the designer's needs. At present, extensive experimental and analytical studies are being funded in order to remedy this situation. This requires time but we must function within the state of the art even though we can't eliminate the codes.

This book consists of 20 chapters plus 13 appendices.

Section 1 (Chapters 1-4) introduces the basic concepts of stress and strain, stiffness, and strain consideration of bolted joints. Chapter 5 considers the tightening of the joint. This includes the importance of preload, torque control, and adequate tools for torque control. Equations are presented for torque in terms of preload, pitch of threads, coefficient of friction between nut and bolt threads, effective radius of contact between nut and joint surfaces and half angle of threads. A well put-together chapter that merits thought and consideration, this should be read by all joint designers.

Chapter 6 focuses on basic concepts of preload and friction effects. Equations accompany these thoughts. Included is a section on turn-preload case history involving a heat exchanger in an oil refinery.

Chapter 7 continues with torque and turn equations. The simultaneous measurement of torque and turn provides better control over preload and furnishes more information on how to detect gross problems. The author concludes this chapter with various computer-controlled systems in regulating the proper tension or joint control.

Chapter 8 states the concept of stretch control in the bolt and enumerates the associated variables, i.e., elastic modulus, dimensional problems, preload scatter, and variations in stress loads within the fastener.

Chapter 9 treats the ultrasonic measurement of bolt stretch by detailing the various instruments used in this procedure. Included is an excellent section on practical considerations, i.e., need for calibration, acoustic coupling, transducer selection, correction for velocity, dimensional and temperature changes. An illustrative example discusses the bolt tension and temperature in a bolted joint. This is a most practical chapter and should be read without hesitation.

Chapter 10 introduces the methods of obtaining preload control. The most prevalent are strain-gaged bolts, washers, and ultrasonic measurements of stress. This is accompanied by theoretical considerations of vibrating wire gage, acoustic emission, and hydraulic tensioners. Although the latter has the disadvantage of involving only a portion of the fastener during the operation, it does furnish accuracy in determining the scatter in magnitude of the loads in the fasteners. A lot more must be accomplished in propelling this method in obtaining better and more accurate information.

Chapter 11 is very informative. The joint diagrams usually stated in books on mechanical design are elaborated by including their various constituents. This entails the external loads which are a function of the compressive and tensile forces in a joint. The accompanying equations, although simple in nature, contain a lot of "meat" and should be read carefully.

Chapter 12 treats shear loads in joints. These include friction-type joints, bearing type joints, combined bending-tension and eccentrically loaded shear joints. Chapter 13 continues with effect of prying action in bolts. As stated by the author, "Multiple bolts on an eccentrically loaded joint doesn't help much since most of the load is absorbed by the first (innermost) row." Usually, designers neglect this condition. Joints can behave nonlinearly and possess higher preloads than those suggested by linear analysis. They, in turn, are required to prevent joint separation, reduce prying effects, and, in general, increase the service life of a joint.

Chapter 14 treats short- and long-term relaxation of the bolts and methods of measuring joint relaxation. Chapter 15 explains the type of joint slip and separation. Contributing factors influence failure rates, and increases in stress levels are stated in tabular form. The chapter concludes with static failure of bolt or nut under tensile loads. Elaborate equations describe the static strength of threads. Again, a very meaningful chapter which should be read by all designers.

¹ General Electric Co., Schenectady, N.Y. 12345

Chapter 16, the lengthiest and most important, faces the reader with the vibration loosening of bolts. Beginning with the loosening of the nut by vibration, we progress to the loosening sequence testing for vibration resistance (Alma and Junker tests) and ways in resisting vibration. This translates to maintenance of friction, prevention of relative slip between surfaces, reduction of back-off torque. With this under our belt, fatigue failure occupies the podium. The author proceeds from the various types of fatigue failure through *S/N* diagrams, influence of preload and joint stiffness and, finally, the minimization of the fatigue problem. The reviewer considers the latter two chapters to be read with a clear and open mind.

Chapter 18 discusses gasketed joints. The well known *m* and *y* factors stated in the ASME Boiler and Pressure Vessel Code is next on the agenda. The author presents the more recent information on the subject and describes a number of suggestions for reducing the possibility of leaks in the field. An accompanying example explains the design of a gasketed joint elucidating the factors plus an interesting case history.

Chapter 19 describes in simple terms the corrosion mechanism affecting joints and ways of minimizing this problem. Chapter 20 concludes the book by summarizing the various equations from the previous chapters on bolt tension and preload decisions, the proper bolted joint design procedure, and torque and elongation means.

The appendices consider the nomenclature and the various units employed in bolt design, glossary of bolted joint terms, English and metric conversion, proof strengths, and bolt and nut materials.

In summary, this is an excellent book. The reviewer would have preferred seeing a section on finite elements applied to design and multiple plate bearing loads on bolts. The book is a must for all designers involved in joint and bolt design. The author unravels a number of mysteries of bolt design but does not promise a "Garden of Eden" in solving all bolt designs. The reviewer highly recommends this book.

Modern Automotive Structural Analysis. by M. M. Kamal and J. A. Wolf, Jr., Eds., Van Nostrand Reinhold Co., New York, 1982, 458 pages. Price \$34.50

Reviewed by H. Saunders

Modern computational methods have revolutionized automotive structural design. Fifteen years ago automotive structural design was based on experience, extensive laboratory testing, and finally proving ground evaluation and development. Modern stringent requirements placed on new vehicles require large reduction in consumed fuel and no pollutants. This necessitates the resizing of automobiles with an accompanying command: "Reduce the size and weight of the automobile without sacrificing interior roominess and passenger safety." Additional requirements include isolation from internal and exterior noise sources. The body structure must satisfy all requirements for life expectancy of the automobile and associated environments. Factors included are heat, cold, corrosive action, and a host of other uncomfortable conditions. The bottom line requires that the overall cost must be sufficiently low so that millions of people can afford the automobile. This places the structural engineer in an unenviable position. He must accommodate these mandates without exceeding the stipulated product development cycle. This incorporates the alternatives of full-scale testing which is required to determine areas in need of redesign. The advent of the digital computer plus its accompanying software has come charging in to greatly assist the designer.

This book consists of twelve chapters, each packed with a great deal of information.

Chapter 1 relates historically the automobile and its structure, including the horseless carriage to modern automotive structure.

Chapter 2 establishes automobile structural design criteria. Beginning with the external load applied to the vehicle, the chapter continues on to dynamic load analysis. We reside in a random world rather than a textbook deterministic one. Spectrum analysis using random vibration techniques dictates the applied resultant loading and vehicle dynamic response stresses. The usual predominant frequencies are bounce and pitch, wheel hop, first body mode and elastic body mode. Another important criterion is passenger acceptance which includes human response to vibration, ride quality, internal noise environment, and safety requirements.

Chapter 3 introduces matrix structural analysis which is the heart of the FE method. The structure is idealized in the form of beams, plates, and different types of joint constraints. This is a good chapter but the reviewer would like to see an additional section on the elements required in manipulating the equations.

Chapter 4 continues with the FE modeling of automotive structures. This includes the basic scalar and line elements, area elements (used in plate and membrane modeling), and volume elements (3D isoparametric elements.) Modeling examples include open and closed section, roof panel and roof rail floor sections, house and classic frame models. Load compliances must be included since they influence the general global response of structures.

Chapter 5 continues with automotive, structural system models used in study of vibration. Since the automobile is a complicated multifacet structure, the computer costs would be exorbitant if one were to model all elements in one program. The advent of dynamic synthesis of structures via component mode analysis reduces the dynamic model to a comprehensible method of analysis. The large structure is broken down to substructures and they are then incorporated into the total modeling. In many cases, only one part of the dynamic response is of interest. This reduces the calculation time and expense to a manageable effort. The author employs examples utilizing the component method in determining the separate response of frame, front sheet metal, engine and transmission, different types of body and engine mounts and local compliances. Based on the extensive computational exercises, body mounts must be modeled with care. This is important in the case of the first torsional mode which is sensitive to shear stiffness. Extensive care is required when one incorporates the substructures into the response of the automotive structure.

Chapter 6 explains the solution methods for vehicle structural models. Since matrix analysis is the "name of the game," various methods of equation solutions are discussed. They include the Gaussian elimination method, decomposition method, Cholesky method and Guyan reduction procedure in static analysis of structures. Bandwidth plays an important role. The author treats the minimization of the bandwidth in reducing the cost of analysis. Employing the previous considerations of modal superposition, the author addresses himself to methods in reducing this extensive consumption and time in dynamic analysis. Among these reduction methods is inertia relief. Calculating eigenvalues requires different schemes. The most predominant methods are iterative techniques, Jacobian method, kinematic condensation and subspace iteration. The latter assumes a role of great importance in reducing the size of the problem. An illustrative example explains the inner workings of the subiteration scheme. The reviewer believes that incorporating a computer program would provide a great insight into the workings of the method.