is impossible to predict fatigue crack growth data from results of constant amplitude tests. This extends to empirical methods of the prediction of fatigue crack growth under variable amplitude loadings. The most prominent are Wheeler's equation and the rainflow method.

Chapter 7 involves the consideration of the direction taken by fatigue crack growing in an isotropic material under essentially elastic conditions. The crack tip stress field can be characterized by stress intensity factors. This follows with slant crack growth in thin sheets and the mixed mode threshold behavior, i.e., growth in mode I. The crack then angles to a mode II. This intimates that the transition to state II crack growth is controlled by directional stability of stage I crack, not solely by threshold phenomena. In biaxial stress, an applied tensile stress parallel to a crack greater than the tensile stress perpendicular to the crack, the crack becomes directionally unstable and the crack trajectory becomes a random walk. The precise path cannot be predicted with certainty. Although fracture mechanics is regarded as two-dimensional, this is not so. The crack front is usually curved with both the stress intensity factor and the fatigue crack growth rate varying along the crack front. The chapter concludes with a short but informative discourse on fretting fatigue. If the latter occurs during fatigue loading, this usually results in a large reduction on the fatigue strength. The reviewer has observed this fretting effect from tests. Usually under the loading conditions, only Modes II and III crack surface displacements can be present. This is a mixed mode problem.

The last chapter describes the present standing of metal fatigue. There is considerable research and development efforts but still a larger understanding is required. Continuing research does reveal new guidelines for the design of fatigue-resistant structures. More effort is required in investigating the 10-mm range.

In summary, this is an excellent volume. The reviewer would have preferred seeing an expanded section on random fatigue and its relationship to crack growth, a more detailed section on rainflow method plus an extension of the equations for crack growth in biaxial mode. The reviewer does recommend this book to the neophyte as well as the experienced engineer and scientist. It is well worth reading!

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Piping Stress Handbook, 2nd Edition, Victor Helguero M., Gulf Publishing Co. Book Division, Houston, Tex. 77001, 1986, 375 pp., $67.00.

This book contains a wealth of material which should aid the piping designer or pipe stress analyst. Pipe stress analysis has undergone a vast number of changes during the last few decades. Stress analysts require a definite guide in making the piping stronger, more useful and economical. The ramification involved in proper piping design forces one to pay particular attention to the fundamentals of good piping design. As stated by the author, "This reference book provides formulas, technical data and other pertinent design information not readily available in a single source for the pipe stress analyst in the petrochemical industry who has difficulty collecting the required data and solutions to complete a piping stress analysis. . . The author's aim is to bring together in a single reference all of the above material and present it in a convenient form." Starting from the basic equations stated in the various codes, he progresses through a number of stages by referencing various tables, illustrations, flexibility and stress intensification factors, design criteria and pipe properties. The book consists of 14 chapters, an excellent glossary descibing various terms used in piping and metals.

Chapter 1 presents the formulas for the basic theory of pipe stress. The author employs the formulas as stated in ANSI/ASME codes B31.1, B31.2, B31.3, B31.4, B31.5, and B31.8 plus B31.9. This includes expansion stresses, cold springing, sustained longitudinal stress, allowable stress, plus internal pressure stress. Tables are provided for weld and longitudinal joint factors, allowable stresses in liquid petroleum and transportation piping systems.

Chapter 2 contains extensive tables for modulus of elasticity, coefficient of thermal expansion for various ferritic and nonferritic metals. This is accompanied by an example illustrating the determination of the temperature correction factor (F) for steam in skirt design.

Chapters 3 and 4 forge ahead with exhaustive tables, showing allowable stress ranges for petroleum piping abstracted from ASME power piping code B31.1 and B31.3 for various ASTM designated materials. Chapter 5 covers stress intensity factors and flexibility factors. Beginning with various definitions, this follows with different types of piping heads (welding, elbow, meter, tees, etc.) and stress intensification factors for welding tee, branch welded on piping, reinforced fabricated and unfabricated tees, flanged elbows plus two and three-weld meter elbows. Chapter 6 forges ahead with rotational nozzle flexibilities for cylindrical vessels. Equations based on ONRL report 115-3 are employed and accompanied by computer-tabulated tables stating the inplane (longitudinal bending) and out-of-plane (circumferential bending) formed by intersection of the branch piping and vessel. Care must be given to the assumptions made in the analysis.

Chapter 7, the lengthiest, describes pressure and stress ratios. This may be utilized in determining (a)allowable working pressure, (b)working stress, (c)required wall thickness. Tables are provided for the various y values in the general formula. This represents the effect of creep at high temperature. The y values are subject to the corrosion allowance for various pipe sizes and schedule numbers. Examples are given for 1)determination of allowable working pressure, 2)determination of required yield strength, 3)determining the required wall thickness. The chapter concludes with reinforcement of welded branch connections per section 304.33 of ANSI code B31.3.

Chapter 8 speaks about design criteria for allowable loads, moments and stresses. This encompasses pumps with steel nozzles (API code 610), pumps with cast iron or aluminum nozzles and casings (ANSI code 31.3), turbines with steel and aluminum nozzles (ANSI code 31.1) and air-cooled heat exchangers (API 661). Each of the foregoing have certain limits and specific equations applied to the respective nozzles and structures. Chapter 9 delves into simplified solutions for pipe stress. An L-shaped piping layout introduces the chapter and is considered to be a guided cantilever. Tables are furnished for various pipe sizes of force (lb/in.) of expansion for L-shaped pipe with no elbow. An example and stress nomogram are presented for rectangular and circular loops pipe layouts.

Chapter 10 details, in extensive charts, the complete properties of pipes. This covers outside diameter, thickness, schedule, inside and outside diameters, weight of pipe plus contained water, radius of gyration, moment of inertia and section modulus. Chapter 11 continues with weight and dimension of pipes and respective attached components plus the various piping and insulation materials. In addition, standard dimensions of flanges, fittings, valves and pipe bends with their respective formulas are given. Chapter 12 shows how allowable pipe spans may be computed based on the

average of the fixed and simply supported spans. Tables for various piping materials are present for use of the designer. Equations for piping wind loads and accompanying wind tables complete the chapter.

The next chapter reports on pipe support selection and design. The various types of pipe supports are (*a*)rigid, (*b*)coil type (most common), (*c*)Belleville (seldom used), (*d*)variable spring (spring hangers), (*e*)constant springs (used in large deflections, where small variables are a problem), and (*f*)cryogenic supports (avoidance of metal-to-metal contact). The final sections in this chapter detail the various vibration control and sway braces plus different types of anchors. All are accompanied by extensive tables.

The final chapter discusses the fundamentals of expansion joints. Explanations of the workings of the following expansion joints (*a*)simple, (*b*)double, (*c*)universal, (*d*)pressure balance, (*e*)hinged, (*f*)gimbal are detailed. The calculation of forces acting on main and intermediate pipe anchors plus spacing of pipe guides are the next important topics on the agenda. The book concludes with the different types of welded end connections, i.e., Van Stoned flanges and fixed flanges.

This is an interesting book. The reviewer would have preferred seeing additional information on (*a*)piping layout and its calculation, (*b*)glossary of symbols used in the text, (*c*)seismic loading and dynamic stress analysis of piping, (*d*)computer program applied to pipe stress analysis, (*e*)flange design analysis, (*f*)short section on metal fatigue applied to piping, (*g*)mention of other piping codes in Europe and differences between them and U.S. codes. The addition of the foregoing topics would greatly enhance the book for those interested in pipe stress analysis.

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