buildings and nuclear power plant equipment and structures. The chapter developed by C. W. Lin is general and contains papers that complement specific topics covered in other chapters.

As long as earthquakes occur, there is a challenge to improve the reliability of engineered systems to withstand the forces of nature. New knowledge will continue to be developed. The 67 papers in this volume collectively represent our understanding of this technology today.

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**Fluid Structure Vibration and Liquid Sloshing,** ASME Special Publication PVP-Vol. 128, ASME, New York, 1987.

An International Symposium on Vibration and Seismic Response of Fluid-Structure Systems is being sponsored by the Operations, Applications, and Components (OAC) Committee of the Pressure Vessel and Piping Division. The aim of this symposium was to provide a forum for the discussion of the recent development in the vibrational characteristics and seismic response of the fluid-structure systems which can be either: 1) fluid contained within structures such as liquid-storage tanks; or 2) structures surrounded by fluid such as submerged reactor components.

A total of twelve papers are presented in the symposium and are published in the special publication "Fluid-structure Vibration and Liquid Sloshing." They can be divided into two groups: 1) vibration characteristics and seismic response of LMR (Liquid Metal Reactor) submerged components and structures and other fluid-structure systems; and 2) computational methods of fluid-structure interaction. In the eight papers presented in the first group, Brochard et al. present a mathematical model which considers the reactor core system as an equivalent homogeneous medium which replaces the physical heterogeneous medium (tubes and fluid). The method can be used to understand the global behavior of the core vibrational mode and may be applied to other problems such as perforated plates, flow in porous media, etc. Martelli et al. present the results of a very comprehensive dynamic test of the Italian PEC reactor core system for better understanding of fluid-structure interaction problems. Computer analysis based on CORALIE and CLASH codes on the PEC core system are also illustrated to confirm the conservatism in the design calculation. In the LMR vessel seismic response, Brabant et al. present a substructing method implemented in the TRISTANA code for solving the modal response and seismic response of the pool-type LMRs which can be treated as a system consisting of many substructures defined in their natural modes calculated with free boundary conditions at all connection modes. Ma et al. report the results of a seismic analysis performed on a 400-MWe pool-type LMR reactor. Sloshing phenomena and fluid coupling behavior between the submerged components are illustrated. Ito and Fujita present the experimental test to investigate the fluid inertia effects and sloshing behavior in a pool-type reactor vessel. The test results are also used for validating the accuracy of the computer code. Eberle et al. present theoretical predictions of frequency response calculated for both the perfect and the imperfect tanks and compare them with the corresponding experimental counterparts.

Yu and Nash present a nonlinear analysis of sloshing in circular cylindrical tanks by the perturbation method, whereas Su presents a numerical algorithm based on the volume of the fluid technique to study the nonlinear behavior of liquid sloshing in partially filled prismatic baffled tanks subjected to longitudinal acceleration.

In the four papers of the second group, Huerta and Liu present an Arbitrary Lagrangian Eulerian (ALE) viscous fluid formulation to evaluate fluid force acting on a vibrating rigid body and to simplify coupled rigid body-viscous fluid formulation to a standard structural problem using the concept of added mass and added damping. Formulas for added mass and added damping are given for a cylinder immersed in an infinite viscous fluid. Lazzeri presents a Modified Boundary Element (MBE) technique to solve the fluid-structure interaction problems. The method consists of choosing the solution of the Laplace equation in terms of a series expansion where each term satisfies such equations and in minimizing the work lost in the boundary to compute the expansion coefficients. Ibrahim and Latorre present the experimental results of dynamic parameters (i.e., added mass and damping) of an immersed rod in a viscous fluid. The results show that the liquid inertia and damping are dependent upon the tank roll frequency and fairly agree with the analytical results. In the last paper, Lakis presents a theory for prediction of the effects of internal flow on the vibration characteristics of thin vessels. Knowing the effects of inertia, centrifugal and coriolis forces of the moving fluid, this theory can predict the response of vessels due to a pressure field arising from the turbulent boundary layer of an internal flow.

It is hoped that this symposium will be beneficial for future research and will upgrade the current analysis and design methodology of fluid-structure systems under dynamic loadings.

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**Theory and Design of Pressure Vessels,** J. F. Harvey, Van Nostrand Reinhold Co., New York, N.Y., 1985, 613 pp., $48.95.

Pressure vessels have come a long way. Previously, design was based on the "seat of the pants" approach. Combined analytical and experimental endeavors have put pressure vessel design on a firm footing. Finite Element (FE) adds greater impetus to its use in modern-day power plant and chemical plant design. The author presents design methods and explicit derivations of equations which are illustrated by numerical problems. This tends to focus attention upon the applicable theory. The book is, essentially, a complete revision of a previous book with the addition of new material. This makes for a more comprehensive text. Since weight is a present priority due to the requirement to cut costs in the design of offshore platforms, mineral mining potential and aircraft pressure vessels, and aforesaid aim requires concentrated effort. The book consists of 8 chapters, an excellent section on notation plus an elaborate set of references.

Chapter 1 introduces the subject and explains stress-strain curves, ductility, use of strain gages and photoelasticity for stress measurements. This follows with stress significance and design approach mentioning FE. Chapter 2 explains stresses in circular rings, cylinders and spheres subjected to applied internal pressure. General theory of membrane stresses for cylin-

drical, conical vessels and ellipsoids under internal pressure are derived. Any resulting failures would be local buckling or developement of high shear stress. This continues with torus under internal pressure and stresses in thick-walled vessels. Shrink-fit stresses, built-up cylinders and autofrettage are important aspects of residual stresses. Thermal stresses in long hollow cylinders, steady-state thermal stresses and transient thermal stresses could play havoc with the safety of pressure vessels. They must be accounted for in a proper way. Going from low to ultra-high pressure results in new thinking. To prevent buckling a cylindrical vessel may be built up from (*a*) wedges, (*b*) segment principle (uniform tensite strength through the thickness), (*c*) cascade principle (introduction of prestressed sections with total vessel wall), and (*d*) yoke principle.

Chapter 3 covers stresses in flat plates. Beginning with bending of plates in one direction, this progresses to two perpendicular directions, i.e., bending of uniformally loaded plates (simply supported (SS)) and clamped edges (CE)). Now comes the important circular plates. This comprises bending of the following: (*a*) uniformly loaded plates for both SS and CE, (*b*) centrally loaded (SS and CE), (*c*) concentrically loaded along a circle (SS and CE), and (*d*) symmetrically with circular central hole (bending by couples along edge plus edge restrained from rotation). This follows with reinforced circular plates containing grillages on concentric rings, tube to tube sheet joints, local flexibility at the supports of clamped edge beams and plates. The concluding section considers the stresses in stacked and built-up plates.

Chapter 4 continues with discontinuity stresses in pressure vessels. Beginning with beams on an elastic foundation and infinitely long beams, this follows through with cylindrical vessels under axially asymmetrical loading and load deformation in pressure vessels (attenuation factor, equivalent elastic foundation), discontinuity stresses in cylindrical vessels with either hemispherical, ellipsoidal or flat heads. This brings up the important subject of stresses in bimetallic joint (piping and turbines) plus deformation in flanges and their respective stresses.

Chapter 5 covers the important topics of fracture and fatigue control. The initial topic is an explicit deformation of slope and properties of stress-strain curves with mention of Lueders' lines. This continues with failure analysis and determination of stress patterns from plastic flow observations plus a short discourse on dynamic loading. Material analysis comes to the fore with an elaborate discussion on strain hardening, toughness, neutron irradiation of steel plus embrittlement. Metal fatigue is emphasized by introducing the topics of (*a*) fatigue life prediction, (*b*) low-cycle fatigue, (*c*) cumulative fatigue damage (Miner's rule), (*d*) steady-state stress condition, (*e*) maximum shear (Tresca condition), (*f*) Hencky-Mises (distortion energy theory), (*g*) fatigue stress theory due to internal pressure. Journeying ahead the important influence of surface effects on fatigue are discussed. They are (*a*) surface finish, (*b*) surface coating, (*c*) residual stress. The effect of environment which considers thermal stress fatigue, temperature, corrosion, autofrettage, creep and creep rupture, stress relaxation and hydrogen embrittlement can induce fatigue. The important topic of fracture mechanics concludes this chapter. This encompasses fatigue crack growth, brittle fracture, nil ductility transition temperature (NDT) and the equation for linear fracture mechanics. This includes crack opening displacement (COD), *J*-integral evaluation, fracture toughness plus the various criteria used in design (leak before break, defect size evaluation and an integrity assessment diagram for fracture of vessels).

Chapter 6, another lengthy chapter, speaks about design constructure features with emphasis on the significance of local stresses. The opening section describes stress concentrations in cylinders, wedges, circular hole in a plate subjected to tension, elliptical opening in a plate and sphere. Additional stress concentrations, occur due to shock and impact. The author mentions the detrimental effects of welding and their contribution to fatigue failure of pressure vessels. Additional stress concentrations occur due to thermal stresses, reinforced openings (nozzle and multiple nozzle). The fatigue notch factor are applied to examples of semi-circular grooves, notch radius and circular hole. Bolted joints and gaskets take no "back seat" since failures and leakages have been known to occur in service. Another good aspect of sound design is the proper design of vessel supports and skirts with great considerations fostered with respect to thermal gradients. The chapter concludes with three requirements for presentation of brittle fracture and proper means of correcting this type of fracture. As reported by the author, "Virtually all failures are a result of fatigue-fatigue in areas of high localized stresses. An excellent chapter that should be read carefully!"

Chapter 7 focusses upon fabrication and due consideration of economics. The choice of material and its proper intertwining with design considerations following code requirements are basic ingredients. Other important materials to be given attention are (*a*) composites, (*b*) multi-layer construction, (*c*) bonded and wire wrapped construction, (*d*) filament wound, (*e*) prestressed concrete, and (*f*) lobed pressure vessels.

The last chapter delves into the subject of buckling of vessels under external pressure. After describing the impending failure of a vessel subjected to internal pressure (buckling) with little warning, the author further describes elastic buckling of circular rings and long cylinders under internal pressure. Inelastic collapse pressure of a vessel (cylinder) can be predicted from the elastic collapse pressure using a plastic reduction factor. This continues with cylinders and tubes during initial nonlinearity and the resultant collapse of thick walled cylinders subjected to internal pressure. Supports and stiffener rings play important roles in prevention of buckling. Next on the podium is the buckling of spheres, torispherical and ellipsoidal formed heads. High stress concentrations in openings (reinforced and unreinforced) can cause local buckling. The book finishes with buckling under combined external pressure and axial loads. The interaction equations of combined buckling and axial loads can be designed according to a number of basic codes promulgated by different countries. They are (*a*) DAS (German), (*b*) ASME (USA), (*c*) ECCS (European), and (*d*) DnV (Norwegian).

This is an excellent book and chock full of information. The reviewer would have preferred seeing a more detailed section on structural dynamics and seismic loading on pressure vessels. A more detailed section on stress concentration of circular hole inclined to the surface in a uniform plate. Another important topic barely mentioned is Finite Element method with direct application to pressure vessels. The reviewer does recommend this book to those interested in pressure vessel design.

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