WEDNESDAY, 5 NOVEMBER 1975 MACONDRAY ROOM, UNITARIAN CENTER, 8:30 A.M.

Session W. Shock and Vibration III: Vibration and Radiation; Structural Design

Miguel Junger, Chairman

Cambridge Acoustical Associates Incorporated, Cambridge, Massachusetts 02138

Contibuted Papers

8:30

W1. Physics of vibrators. E.J. Skudrzyk (Department of Physics and the Applied Research Laboratory, The Pennsylvania State University, University Park, PA 16802)

A vibrator can be represented by an infinite number of series resonance circuits in parallel. Circuit theory is an aid to the understanding of the behavior of complex vibrators and to the simplification of existing theories. If the mode density is constant, then the geometric mean between the resonance peaks and the antiresonance minima is determined (with an accuracy of 8%) by contributions of only the two modes whose frequencies are closest to the frequency of the force. This fact also makes it possible to generalize the theory for situations where the mode density varies discontinuously. The basic variable is a characteristic velocity that propagates through the vibrator and is reflected at its boundaries. This velocity—a simple function of the mode density and the mode masses—represents the geometric mean line through the frequency curve of the vibration velocity. The complex fluctuations in the frequency response of vibrators for points not coincident with the driven point, and the effect of ribs, attachment, and structural discontinuities can be easily understood on the basis of the characteristic velocity. [Work supported by ONR.]

8:42

W2. Natural frequencies of elastically supported orthotropic rectangular plates. Edward B. Magrab (Institute for Basic Standards, National Bureau of Standards, Washington, DC 20234)

An expression is obtained from which the natural frequencies of a rectangular orthotropic plate, under any combination of boundary conditions of simply supported, elastically supported, or clamped. The Mindlin—Timoshenko theory, which includes the effects of transverse shear and rotary inertia, is used to describe the plate motion. The solution is obtained with an extension of the Galerkin procedure previously developed, in part, by the author. Comparison of results with the limited results of previous investigations is excellent. Numerous data are presented for the lowest natural frequencies of rectangular and square plates for boundary conditions on all four edges that vary continuously from simply supported to clamped, and for various combinations of length-to-thickness ratios.

8:54

W3. Vibrations of a circular plate elastically restrained along the edge and carrying a concentrated mass. P.A.A. Laura, L.E. Luisoni, and A. Arias (Institute of Applied Mechanics, Base Naval Puerto Belgrano, Argentina)

This investigation deals with the determination of fundamental frequencies of vibration of a circular plate carrying a concentrated mass at the center. The plate is elastically restrained along the edge and subjected to a hydrostatic state of in-plane stress. The calculated fundamental frequencies are in excellent agreement with those available in the open literature (rigid clamp along the edge and no in-plane forces). The method of solution consists of expanding the displacement function in a simple polynomial which identically satisfies the boundary conditions. A variational method is then used to generate the frequency equation. The approximate solution is also valid when the mass is placed off-center.

9:06

W4. Modification of panel response by a rib. A.J. Tucker, W.H. Vogel, and G. Maidanik (David W. Taylor Naval Ship Research and Development Center, Bethesda, MD 20084)

The response of a fluid loaded, single ribbed panel simulated by a membrane is developed. The response is determined for two extreme types of excitation; namely, a localized excitation generated by a line force and an extended excitation generated by a single wave. For each of these cases the response of the ribbed panel is proportional to that of the unribbed panel, where the factor of proportionality consists of two terms. The first term is unity, and therefore the second term completely describes the modification of the response caused by the rib. The second term, in turn, consists of two factors. The first of which describes the modification of the response caused by the finite impedance of the rib; this factor becomes unity when the rib is assumed to be hard (i.e., fixed). The remaining factor describes the modification of the response when the rib is hard. The deviation of the first factor from unity when the rib is not hard (i.e., the extent to which the assumption is valid) is discussed.

9:18

W5. Iterative solution for random vibration problems involving structure—fluid interaction. Y.K. Lin (Department of Aeronautical and Astronautical Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801)

In the spectral analysis of a random vibration problem, a considerable effort is devoted to the evaluation of frequency response functions. This task becomes very difficult when the interaction between the vibrating structure and the surrounding fluid must be taken into account. An iterative scheme is developed in the present paper which is applicable to extremely complicated configurations. For illustration, the scheme is used to compute noise transmission through a flexible panel into a cavity and the result is compared with some known solutions.

9:30

W6. Numerical-perturbation technique for the transverse vibrations of highly prestressed plates. Ali H. Nayfeh and M.P. Kamat (Department of Engineering Science and Mechanics Virginia Polytechnic Institute and State University Blacksburg, VA 24061)

Under the usual assumptions of small strains with moderately large rotations, the problem of the transverse vibrations of highly prestressed nonuniform annular plates is reduced to the solution of the differential equation governing the transverse vibration of the corresponding prestressed membrane subject to modified boundary conditions that account for the effects of bending. The method of composite expansions is used to determine these modified boundary conditions. The agreement of the present solution or results with known exact solutions for simple geometries demonstrates the efficiency of this method when compared with other well-known numerical techniques.

9:42

W7. Vibration response of a fluid-loaded infinite plate with symmetric or asymmetric stiffeners. W. H. Vogel and D. Feit (David W. Taylor Naval Ship Research and Development Center, Bethesda, MD 20084)

The velocity distribution along a rib-stiffened thin plate immersed in a fluid and driven by a temporal harmonically varying line force is considered. To solve the coupled fluid-elastic equations of motion, the Fourier transform approach is used. The resulting integrals are numerically integrated directly without the aid of contour integration. Previous studies have primarily dealt with the radiated acoustic field from plates reinforced with symmetric stiffeners. The presence of an asymmetric stiffener provides a mechanism whereby flexural wave energy can be converted into longitudinal wave energy or vice versa. The significance of this energy conversion due to inertia coupling between the flexural and longitudinal motions of the plate is investigated. Results are presented for symmetric and asymmetric stiffeners with and without fluid loading. In addition, the effect of structural damping and fluid loading on the velocity field of a uniform infinite plate is discussed.

9:54

W8. Vibration response of liquid-loaded structures to low-speed flow noise. R. L. Chandiramani (Bolt Beranek and Newman Inc., 50 Moulton Street, Cambridge, MA 02138)

Consider a spatially homogeneous and temporally stationary random pressure field exciting a spatially homogeneous structure (plate, cylinder). It is well known that when the power exchange between the pressure field and the structure results from a "surface interaction" rather than from a scattering-induced "edge interaction," it is immaterial whether a finite or infinitely extended model of the structure is used to calculate this power exchange. This equivalence is used to estimate vibration response of a liquid-loaded flat plate when excited by a low-speed turbulent boundary layer flow. Connections, established previously for structures *in vacuo*, between group velocity, modal density and point and line conductances, are also generalized to apply to liquid-loaded structures. Finally, an approximate but simple method is suggested for estimating some useful vibration characteristics of spatially nonhomogeneous structures excited by surface interactions.

10:06

W9. Vibration and sound radiation of a plate. Robert J. Hannon (Department of Physics and Applied Research Laboratory, The Pennsylvania State University, University Park, PA 16802)

Because of their many vibratory resonances, plates are mechanically soft and their suspending structures have considerable effect on their vibration and sound radiation. Experimental evaluation of acoustic properties of plates is therefore difficult. Plates of different shapes and dimensions were supported in such a way as to eliminate the effects of the supports on the vibrations and the velocity amplitudes due to point forces were recorded by phonograph cartridges and microphones in the near sound field. The results show that the many vibratory modes generate "hotspots" on the plates. The attachment of ribs and supports disturbs the vibration field and leads to localized areas of increased sound radiation. Long wavelength acoustic holography was used to locate on the vibrating plates the sources of farfield sound. These regions were also investigated by recording the vibratory and nodal line patterns of the plates by a nearfield microphone method. This combination of techniques has a unique capability to locate acoustic sources on vibrating structure. [Work supported by NASA and ONR.]

10:18

W10. Power radiation from point-excited plates. D. D. Toth and C. I. Holmer (Institute for Basic Standards, National Bureau of Standards, Washington, DC 20234)

The application of statistical energy analysis (SEA) techniques to predict the sound power radiated from point excited plates is well known. These techniques are typically restricted to plates for which thin plate approximations apply, and to the frequency region in which high modal overlap ($M>1$, where M = model bandwidth/mode spacing) occurs. Experimental data are presented for three plates (0.95-cm transite, 1.3-cm aluminum, and 4.3-cm concrete) which violate either or both of the limitations, and for which the ratio of power radiated to mean square force input is significantly (as much as 10 dB) less than the SEA theory predicts. Using Mindlin's thick plate theory, modifications to the SEA theory to account for the frequency averaged driving point impedance and mode spacing have been developed. The use of these modifications gave good agreement with the experimental results for the frequency range where the plates are thick and $M>1$. Several sources for the discrepancies between analytic and experimental data for low modal overlap are under investigation and will be discussed.

10:30

W11. Pressure amplitudes for surface-wave modes radiating from an elastic cylinder in a fluid. Joseph W. Dickey and Raymond C. Simanowith (Naval Ship Research and Development Center, Annapolis, MD 21402) and H. Uberall (Physics Department, Catholic University, Washington, DC 20017)

A numerical approach is used to calculate the pressure amplitudes for various surface wave modes which radiate from an elastic cylinder into a fluid. The Sommerfeld Watson transformation is used to separate the various surface-wave modes according to physically distinct types; e.g., Rayleigh, Stoneley, Franz, and Whispering Gallery. Each mode is identified with a singularity of the scattering amplitude in the complex wave-number plane and the contribution of each mode to the total radiated (or scattered) field is evaluated. Specific examples are used of plane waves in water and air incident on an aluminum cylinder. The resulting surface waves and their individual contributions to the scattered field are presented. The allowable modes with dispersion and attenuation curves are given for each surface wave, and the grouping of the infinity of surface waves into four physically distinct families is shown naturally by the mathematics. The individual surface wave contributions to the scattered field are summed and the resulting differential-scattering cross section is given for elastic, rigid, and soft cylinders. The wavenumber—radius product ka ranges from 10 to 300. The reduction of the problem to the case of an elastic half space is treated briefly.

10:42

W12. An investigation of the uses of holography for the study of sound radiation from vibrating surfaces. C. H. Hansen and D. A. Bies (Department of Mechanical Engineering, University of Adelaide, Adelaide, South Australia 5000)

The radiation of the first six low-order modes of vibration of a damped circular plate mounted in an infinite baffle has been investigated both experimentally and theoretically. Time lapse holography has been used to identify modes and to determine the mean square normal velocity over the surface of the plate for the various modes. The radiated sound power has been measured in a reverberant room and the radiation efficiency computed. The use of a series of similar plates but of various thicknesses-scaling procedures has allowed a determination of the radiation efficiency over a wide range of dimensionless frequency. Theoretical predictions of the radiation efficiency have been computed using spheroidal wave functions and an evaluation of the Rayleigh integral. The experimental