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DIRECTOR NOTES

The rate of development of new science and technology continues to increase both in the United States and abroad. It has been estimated by some that 60% of all new developments originate outside the United States. Whether or not this estimate is correct is not really relevant. What is of concern is whether new technology flows as readily into the United States as domestically financed research results are made available to our friends abroad. This does not appear to be the case.

About 75% of all scientific and technical papers produced in the United States are offered for sale by the National Technical Information Service (NTIS). Approximately 10% of NTIS sales are to foreign countries, indicating an aggressive pursuit of U.S. technology by key countries around the world. Most other countries have nothing resembling NTIS. They cannot be criticized for this, nor can the U.S. government be criticized for establishing NTIS. Rather, these facts provide a signal that the United States, in its own best interest, should change its present indolent pursuit of foreign technology into a very active program.

There is ample evidence to support this need. Dr. Ruth M. Davis in the keynote address at the DoD Materials Technology Conference, February 1978, said, "In a global sense, it must be concluded that the U.S. is no longer the world leader in Materials Technology." Dr. Alan M. Lovelace said at a recent meeting of the AIAA, "Yet, we see a growing overseas competition in areas where the United States has traditionally been a leader; high power transmitters, low-cost space systems, efficient small receivers, effective use of very high frequencies -- these are becoming the problems of other national industries, such as the Japanese, the Germans, and the Canadians."

Is the U.S. at the forefront in all phases of shock and vibration technology? I think not. Are there developments in other countries that would assist us in advancing our own shock and vibration programs? I think so. We should try in every way possible to promote efficient international technology exchange.

H.C.P.

EDITORS RATTLE SPACE

A NEW PUBLICATION POLICY

A recent issue of the Fluids Engineering Division News (ASME) introduced a new policy dealing with the publication of research and engineering results in the Journal of Fluids Engineering (JFE). Discussions of the Executive Committee of the Fluids Engineering Division indicate some serious reflection by the committee with respect to publication costs. Interestingly, however, the proliferation of publications seems to undergo examination only when money has become an issue.

Recently (May 1978) I noted that much of the published technical material is already available in government reports (available from NTIS), conference proceedings, theses, and special publications of collected works. Policies that have allowed multiple (often two and three times) publication of technical material have helped to cause the information explosion -- and the increased printing costs and retrieval problems associated with it. The editors of the JFE have now charged that specialists within a specific technology usually read the proceedings, reports, or theses long before any paper appears in a technical journal. Because the specialists do not need the paper, there is no justification for publishing it.

Some individuals do need to know about the special technology published in detailed technical reports -- design/development engineers, research specialists in other disciplines, and novice workers. The editors of the JFE have correctly noted that these readers are most interested in knowing about technological progress made, its practical relevance, the methodology involved, and supporting data. An extended summary or review of the technical report would therefore be more useful to such individuals than a complete article. If the novice or designer requires more information he can go back to the original report.

The editors of the JFE are suggesting a revised policy: when a report or proceedings is available, the paper published in the Journal will be about 2,000 words in length and in the format of a summary. In addition, when the article is submitted for review, copies of the original report will accompany it.

In my opinion this is a creative solution to an ongoing problem. Not only does it deal with ever-increasing publication costs and retrieval problems but also makes available to practicing engineers a valuable summary of new technical work. The executive committee of the Fluids Engineering Division are to be congratulated for their work. It is hoped that other ASME Technical Divisions and other societies will also develop cost effective publication policies that serve practicing engineers.

R.L.E.

SOUND ATTENUATION OVER GROUND COVER

K. Attenborough*

Abstract - This review covers recent developments in the solution of the problem of a point source above an absorbing plane with particular reference to the approximations which have been made in order to simplify numerical calculation. The physical significance of these approximations is outlined. Various assumed models for the ground surface are classified and explored.

INTRODUCTION

The last three years have seen a considerable upsurge in interest in sound propagation over absorbing terrain. In our previous review [1], we mentioned the prediction scheme for the calculation of road traffic noise in the UK. Currently in the USA, predicted noise levels to be used in assessing highway noise impacts shall be obtained from either of two methods [2, 3]. A factor for ground attenuation is included in one of these methods (1.5 dB per doubling of distance) irrespective of receiver height, in excess of the loss to be expected from free-field cylindrical spreading (3 dB per doubling of distance). It has been suggested [4] that the use of a constant ground attenuation factor for highway noise should be reconsidered since the free-field propagation loss is significantly affected by the nature of the ground cover and that, furthermore, slight errors in the assumed propagation loss factor will translate into major errors in the noise levels predicted at distant locations. In addition, further research is necessary on the propagation of traffic noise over terrain with different types of ground cover. Finally, it has been indicated that the line source assumption is not correct under low flow conditions. In these circumstances, the fundamental theoretical problem concerns reflection of a spherical wave over an absorbing boundary. Recently improvements in the methods for predicting aircraft noise have been suggested based upon developments in the solution of this fundamental theoretical problem [5]. These improved methods are recommended both for flyover noise predictions and in correcting static test-stand data to free-field conditions. The recommended procedure for measuring the noise from highway vehicles and embodied into much legislation ensures that the measurements come through a spikey acoustic filter over the ground, the characteristics of which could be important [6]. In the next section, recent developments in solutions of the fundamental theoretical problem are reviewed.

SPHERICAL WAVE REFLECTION FROM A FINITE IMPEDANCE BOUNDARY

A straightforward interpretation of spherical wave reflection from a boundary between two semi-infinite fluids is that all the reflected waves are travelling from an image source located within the reflecting medium at a depth equal to the height of the source above the boundary. The sound field at the receiver will then depend upon the phase difference between the direct and reflected waves. The phase difference is the sum of that introduced as a result of the path difference between the direct ray and the ray from the image source and the phase change on reflection This simplified model can be used to explain many observed results [6] particularly those obtained over an acoustically hard boundary [7] or over paths high above the ground.

An equation for the far field pressure distribution which derives from this model and for the geometry shown in Figure 1 is

$$P_t = \frac{P_i e^{ik_1 r_1}}{r_1} + R_p \frac{P_i e^{ik_1 r_2}}{r_2} \qquad (1)$$

where P_i is the incident wave amplitude, k_1 is the propagation constant in air, r_1 is the length of the direct path from source to receiver, r_2 is the length of any reflected path, R_p is the plane wave reflection coefficient, Z_1 and Z_2 are the characteristic impedances of the air and ground (treated as a semi-infinite fluid), and θ_1 and θ_2 are, respectively, the angles of incidence and reflection.

$$R_p = \frac{Z_2\cos\theta_1 - Z_1\cos\theta_2}{Z_2\cos\theta_1 + Z_1\cos\theta_2} \qquad (2)$$

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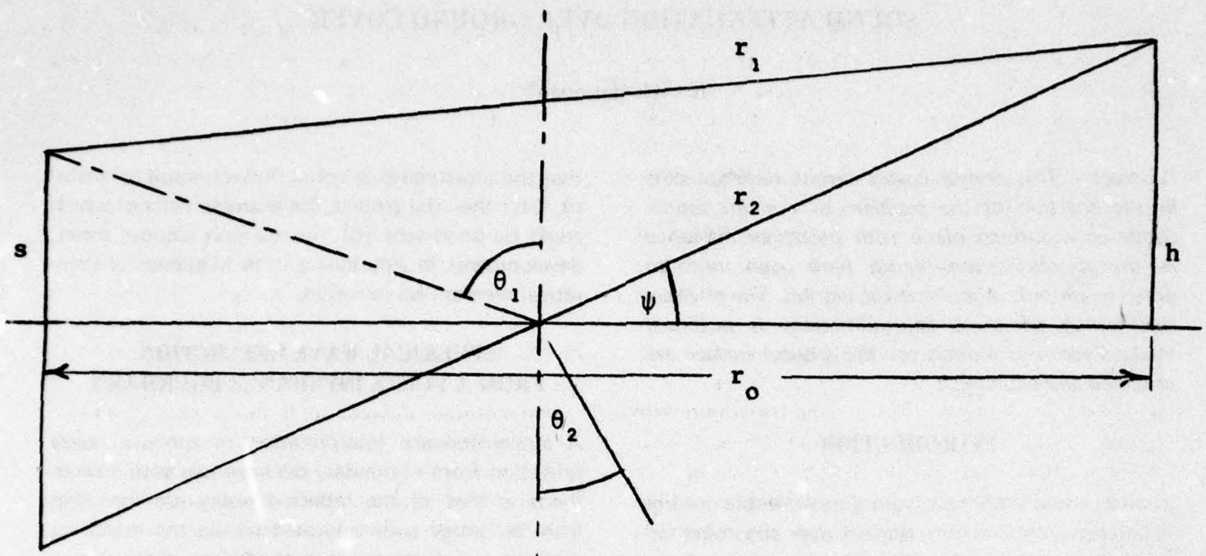

Figure 1. Source Receiver Geometric Configuration

Time dependence $e^{-i\omega t}$ has been suppressed.

For large angles of incidence (grazing incidence) equation (1) breaks down because of the assumption of plane waves. Angles between 85° and 90° incidence are often of importance in the propagation of traffic noise. At grazing incidence, $\theta_1 \approx 90°$ and $R_p \to -1$. This value signifies a phase change of 180° on reflection and a cancellation of incident and reflected waves at grazing incidence even though their path lengths are equal. Thus, the simple model suggests the disappearance of the geometric acoustic pressure and the formation of a shadow zone near to the ground plane. Consequently, the classical solutions to the theoretical problem [1] include an extra term which does not allow complete cancellation of direct and reflected waves at grazing incidence and suggests penetration of the shadow zone. Hence, the field above an absorbing plane is written

$$\frac{P_t}{P_i} = \frac{e^{ik_1 r_1}}{r_1} + \frac{e^{ik_1 r_2}}{r_2} \left(R_p + (1-R_p)F\right) \qquad (3)$$

where F is termed the "boundary loss factor". This form of solution is appropriate usually for large separations of source and receiver and/or high frequencies (e.g., it requires separations of the order of 100 m at 50 Hz and 1 m at 500 Hz). As we shall show later, the form of the third term of equation (3) is appropriate only for a relatively hard boundary [5].

It is usual to solve the problem of spherical wave propagation above a boundary of finite impedance by expanding the incident and reflected spherical waves into cylindrical harmonics and by contour integration of the resulting integral of complex variables for the total field. The complex variable of integration chosen is either the wave number or the angle of incidence and the possible contours for integration are many [8-11] reflecting the different methods of solution of the analogous electromagnetic problem.

Many of the classical solutions to the problem which are suitable for numerical computations [1] have been shown to be in error at low frequencies and for conditions where the boundary admittance (or impedance) is purely imaginary [5]. The required correction modifies the value of F and stems from the path of integration chosen in this type of solution. It has been interpreted physically as a surface wave; i.e., an air-borne wave which is confined to a region near the ground surface with a resultant decrease in amplitude with distance determined essentially by cylindrical spreading. An additional attenuation of the surface wave vertically away from and parallel to the ground surface results from dissipation of energy at the boundary due to coupling with the ground surface and depends on the value of the normal impedance of the surface. The surface-wave term appears only for certain values of the real (R_n) and imaginary (X_n) parts of ground impedance and the angle of incidence. Although the correction term has the physical attributes of a surface wave (for $R_n = 0$), it is hard to justify physically since surface waves usually propagate within the refracting medium [12], i.e. the medium of higher sound speed. As such, its existence is controversial, although model experiments have lent support to the concept [13]. The simplest type of surface-wave which emerges from a theoretical analysis is the Rayleigh wave (basically a type of shear wave) which occurs at and within the free boundary of a solid, i.e. a solid/vacuum boundary. This was first introduced as a degenerate case of reflection of plane waves.

When an impulsive source and a receiver are located in a lower velocity medium separated by a distance large compared with the distance of other from a plane of contact with a higher velocity medium, it is observed that the first disturbance arrives at a time which can only be due to traversal of part of the path at the higher velocity. This is known is seismology as the refraction arrival [13]. It can be understood by a simple physical argument based upon ray acoustics. Rays incident from the lower velocity medium will be refracted away from the normal in the higher velocity medium. There will be a certain limiting angle of incidence, known as the critical angle beyond which there is no refraction, only "internal" reflection. At the critical angle, the refracted/reflected ray travels along the surface to re-emerge into the medium of lower velocity at the critical angle. This ground or lateral wave has been investigated theoretically with regard to seismic refraction experiments to determine the acoustic properties of the ocean bottom [14].

However, the assumption shared by the solutions examined so far [1, 5, 7-11] is that the ground is locally reacting, i.e. the refracted waves travel normal to the boundary irrespective of the angle of incidence. An essential pre-requisite for this assumption is that the ground is the lower velocity medium. As such, it should not be possible to generate lateral waves of the seismological kind. Indeed, it seems hardly likely in a physical sense for a wave to be able to travel along a boundary in air but closely coupled to the boundary, if the boundary permits motion only normal to the surface. The assumption of local reaction is explored further in the next section. It has been pointed out that the identification of a surface wave term in the solutions based upon contour integration is not a consequence of physical realities but of choice of particular integration contours for numerical purposes [10]. Choice of a different but valid path of integration would let the individual surface wave term disappear but still present the complete and correct total field.

When the source and receiver are on the boundary (i.e. $\theta_1 = 90^\circ$) and the impedance of the ground surface is purely resistive but not infinite (i.e., the phase change on reflection is zero) Fe^{ikr_0}/r_0 can be interpreted, by direct analogy to the propagation of electro-magnetic waves above the earth, as a ground wave [15, 16]. As such, it suffers no excess attenuation compared with propagation over an infinitely hard surface but for longer distances exhibits a loss of 6 dB/dd in addition to that provided by the inverse square law.

Another method of solution has been advocated recently which does not explicitly require a surface wave interpretation [17] and the possibility of obtaining exact expressions without the assumption of local reaction has been outlined [18]. However, so far, numerical calculations from this solution have only been carried out for the limiting case of source and receiver in the absorbing plane. Furthermore, experimental verification has been limited to the frequency range 4-6 kHz.

The important practical test of any solution is its ability to predict excess attenuation. Good agreement has been shown between theories which allow for a surface wave and measurements of excess attenuation for source-receiver separations of up to 300 m and for various heights over flat grass land [10, 11, 15, 16]. The correspondence between theory and experiment is valid only for relatively limited data sets (NRC, Canada; BRE; England and the Lund Institute, Sweden) obtained over "institutional" grass and an airfield. It may not hold true, necessarily over other types of surface.

At the stage prior to integration, the integral representations of the total field [11] may be considered exact, although it has been suggested that many of these representations are fundamentally in error since they rely on far-field expressions for a spherical wave and hence do not adequately predict the field near the source, i.e. where r_1 and $r_2 \to 0$. The accuracy of numerical comparison with experiment then depends partly on the assumption of a locally-reacting semi-infinite or layered model of the ground and partly upon the method of evaluating the integrals. The evaluations usually require asymptotic series expansions of the boundary loss factor F. The various approximations have been explored thoroughly [19]. They relate to source/receiver separation; boundary impedance; and the grazing angle. Some of these approximations were stated in our earlier review [1] however they are restated here for completeness. Noting again that equation (3) is valid strictly only for horizontal separations (r_o) of source and reciever that satisfy $k_1 r_o >> 1$ (i.e., $k_1 r_2 >> 1$) and for a high impedance or acoustically hard boundary (i.e., $Z_2 >> Z_1$), then we have

$$F = 1 + i\sqrt{(\pi w)} \cdot e^{-w} \cdot \operatorname{erfc}(-i\sqrt{w}) \qquad (4)$$

where $\operatorname{erfc}(-i\sqrt{w}) = \frac{2}{\sqrt{\pi}} \int_{-i\sqrt{w}}^{\infty} e^{-t^2} dt$

and $w = \frac{2ik_1 r_2}{(1-R_p)^2} \frac{Z_1{}^2}{Z_2{}^2} (1 - \frac{k_1{}^2}{k_2{}^2} \cos^2\psi)$

and is known as the numerical distance. k_2 is the propagation constant in the ground and ψ is the grazing angle $= \frac{\pi}{2} - \theta_1$. For a locally reacting boundary (i.e. $\theta_2 = 0$ in equation (2))

$$w = ik_1 r_2 [\sin\psi + (Z_1/Z_2)]^2/2 \qquad (5)$$

Reference 15 uses r_1 in place of r_2 in the above expression for w. The solution due to Ingard [1] uses a different expression for w, however it has been shown to lead to the same result under the approximations for which it is valid [19]. Hence w and F are complex functions of source/receiver separation; grazing angle (or angle of incidence) and boundary impedance.

Asymptotic series expansions of $\operatorname{erfc}(-i\sqrt{w})$ are available both for large and small w. For $|w| << 1$, we must have small grazing angles. This follows from equation (5) since the approximations $k_1 r_2 > 1$ and $(Z_1/Z_2)^2 << 1$ are implicit already. Then the power series expansion quoted incorrectly in reference 1 and reference 5 is appropriate, hence

$$F = 1 + ie^{-w}\sqrt{(\pi w)} - 2e^{-w}(w - \frac{w^2}{1!3} + \frac{w^2}{2!5} - \frac{w^4}{3!7} \ldots) \qquad (6)$$

With the extension of this assumption to place both source and receiver on the boundary, i.e. $S = h = \psi = o$ and for $|w| << 1$ the bracket in the third term of equation (6) can be neglected, the resulting F inserted into equation (3) with $\psi = 0$ in equation (5) and $r_1 \sim r_2 \sim r_o$ to give $w = ik_1 r_o (Z_1/Z_2)^2/2$ and

$$\frac{P_t}{P_i} = \frac{2e^{ik_1 r_o}}{r_o} + i(\frac{2\pi k_1}{r_o})^{1/2} \frac{Z_1}{Z_2} e^{-i[k_1 r_o((Z_1/Z_2)^2 - 1) + \pi/4]} \qquad (7)$$

When both source and receiver are on the ground, the solution in equation (7) has been called the ground wave [15, 16]. The first term attenuates according to the inverse square law and the second term may be interpreted as the contribution of a surface wave the attenuation of which is given by both the $r^{-1/2}$ factor and the real part of the exponent viz. $k_1 \operatorname{Im}(Z_1/Z_2)^2$. A slightly different expression is given in reference 19, however it becomes the same as equation (7) if the approximations $k_1 h |Z_1/Z_2| << 1$ and $(Z_1/Z_2)^2 << 1$ are made which are consistent with approximations already stated. For $|w| >> 1$, i.e., very large source/receiver separations so that $|Z_1/Z_2|^2 k_1 r_2 >> 1$, which is a less reliable approximation in view of those implicit already, the appropriate expansion for F is [5, 19]

$$F = 2i\sqrt{(\pi w)} S(\operatorname{Im}\sqrt{w}) e^{-w} - \frac{1}{2w} - \frac{3}{(2w)^2} \cdots \qquad (8)$$

where $S(\operatorname{Im}\sqrt{w})$ is the unit step function such that

$$S(\operatorname{Im}\sqrt{w}) = \begin{cases} 1 & \text{if } \operatorname{Im}\sqrt{w} > 0 \\ 1/2 & \text{if } \operatorname{Im}\sqrt{w} = 0 \\ 0 & \text{if } \operatorname{Im}\sqrt{w} < 0 \end{cases}$$

This differs from equation (14), [1] by the first term which may be interpreted as the contribution due to the surface wave. With the additional condition that source and receiver are on the boundary and curtailing equation (8) after the first two terms we have

$$\frac{P_t}{P_i} = \frac{2e^{ik_1 r_o}}{ikr_o^2 (Z_1/Z_2)^2} + 2iS(\text{Im}\sqrt{w})\left(\frac{2\pi k_1}{r_o}\right)^{1/2} \left(\frac{Z_1}{Z_2}\right) e^{-i[k_1 r_o (Z_1/Z_2)^2 - 1) - \pi/4]} \, . \tag{9}$$

Again, this may be interpreted as a ground wave -- this time containing a term decaying as r^{-2} and includes a surface wave which exists only for $\text{Im}\sqrt{w} \geqslant 0$. For grazing incidence $\psi = 0$, this condition implies that

$$\text{Im}[(\frac{ik_1 r_o}{2})^{1/2} Z_1/Z_2] \geqslant 0 \, . \tag{10}$$

If we write $Z_1/Z_2 = (R_n + iX_n)^{-1}$ consistent with the local reaction assumption where R_n and X_n are the real and imaginary components of the specific normal impedance*, then this condition reduces to

$$-\pi/2 \leqslant \tan^{-1}(-|X_n|/R_n) \leqslant -\pi/4$$

(quoted incorrectly in reference 5)

or

$$\infty \geqslant |X_n| \geqslant R_n \tag{11}$$

(see also reference 8)

This condition is satisfied up to 1100 Hz according to some ground impedance measurements [1] and up to 800 Hz for other measurements [15, 16] (see Figures 2 and 3).

For an acoustically soft boundary, i.e. where $Z_1/Z_2 \gtrsim 1$ and non-grazing incidence (but $k_1 r_2 >> 1$) the basic expression for the sound field is best written in the form [5]

$$\frac{P_t}{P_i} = \frac{e^{ik_1 r_2}}{r_1} + A \text{ when } \upsilon_2 > -f(\upsilon_1, \theta_1) \tag{12a}$$

*Most typical results of measurement show that X_n is negative [15, 16] however, it may also be positive.

$$\frac{P_t}{P_i} = A + B \text{ when } \upsilon_2 < -f(\upsilon_1, \theta_1) \tag{12b}$$

where $Z_1/Z_2 = \upsilon = \upsilon_1 + i\upsilon_2$ (the specific boundary admittance).

$$f(\upsilon_1, \theta_1) = \text{cosec}\theta_1 \, (\cos\theta_1 + \upsilon_1)(1 + \upsilon_1 \cos\theta_1)$$

$$(1 + 2\upsilon_1 \cos\theta + \upsilon_1^2)^{1/2}$$

$$A = [R_p + \frac{2i\upsilon}{k_1 r_2} \frac{1+\upsilon\cos\theta_1}{(\cos\theta_1 + \upsilon)^3}] \frac{e^{ik_2 r_2}}{r_2}$$

$$B = \tfrac{1}{2} k_1 \upsilon e^{-\upsilon k_1 (h+s)} H_o^{(1)} [(1 - \upsilon^2)^{1/2} k_1 r_2]$$

$H_o^{(1)}$ ( ) denotes the Hankel function of zero'th order and the first kind. Here the second term of A may be taken to represent the wave attenuating as r_2^{-2} and B may be taken as a surface wave contribution.

More exact expressions for A and B have been derived which allow for any value of the ratio (Z_1/Z_2) and for $k_1 r_2 \lesssim 1$ [10] and may be written

$$A' = 1 + 2k_1 \upsilon e^{ik_1 r_2} \int_0^\infty C^{-1/2} e^{-k_1 r_2 t} dt$$

$$B' = A' + B$$

where $C = (\cos\theta_1 + \upsilon)^2 + 2i(1 + \upsilon\cos\theta_1) t - t^2$

These expressions retain integrals which may be computed numerically rather than requiring power series expansions. At grazing incidence, the more exact condition for the existence of a surface wave may be deduced from equation (46) [10] viz.

$$\text{Re}(1 - \upsilon^2)^{1/2} > \text{Im}(\upsilon)$$

which reduces to $$\frac{|X_n|}{R_n} > \frac{R_n}{[2R_n^2 + X_n^2]^{1/2}} \tag{13}$$

which is slightly less stringent than the condition imposed by inequality (11) since the right-hand side of inequality (13) is always less than 1.

From equation (9) and (10), noting that the decay is dominated by the exponential terms, the decay of the surface wave depends upon the magnitude

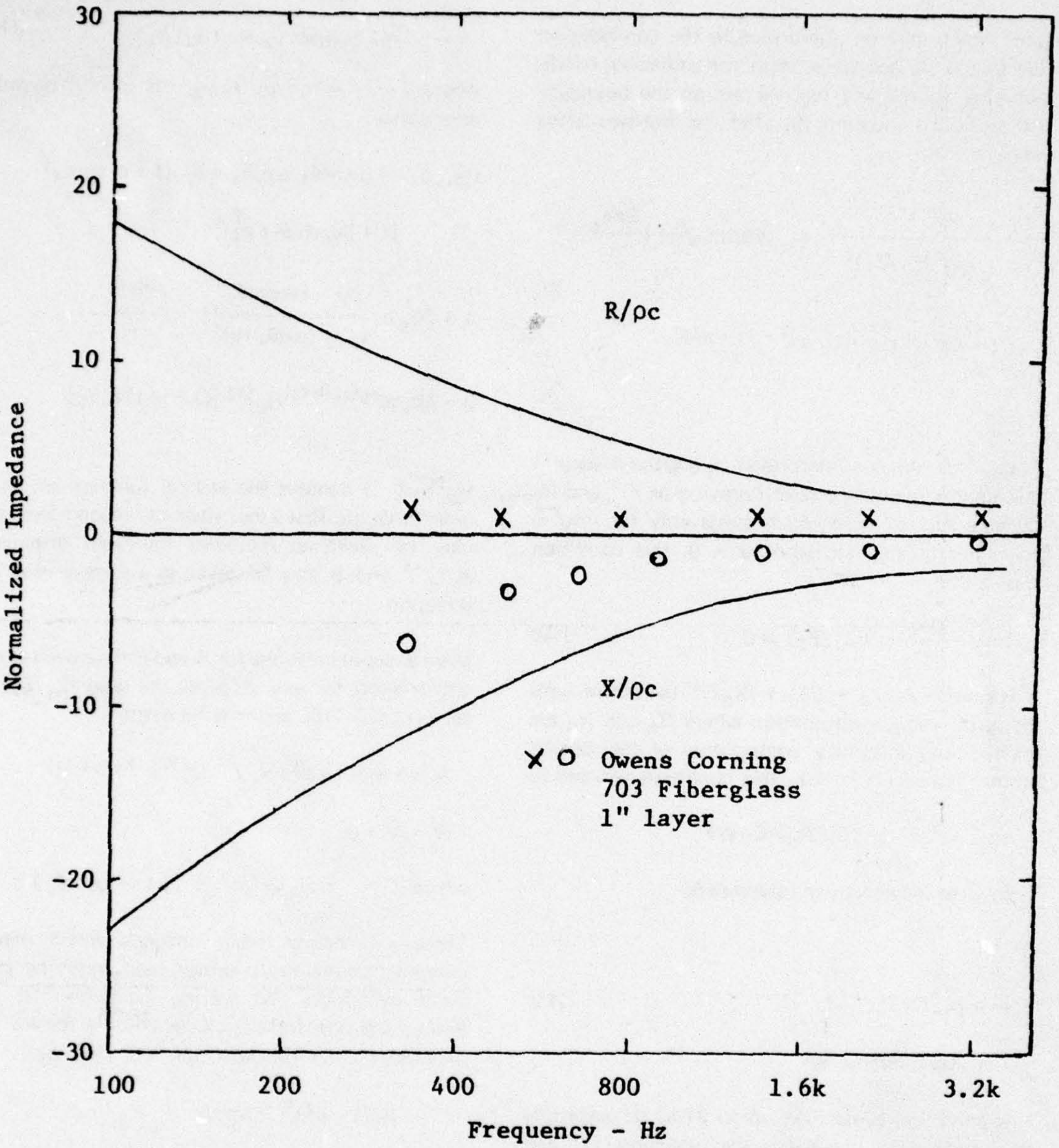

Figure 2. NRC Data for Normalized Impedance

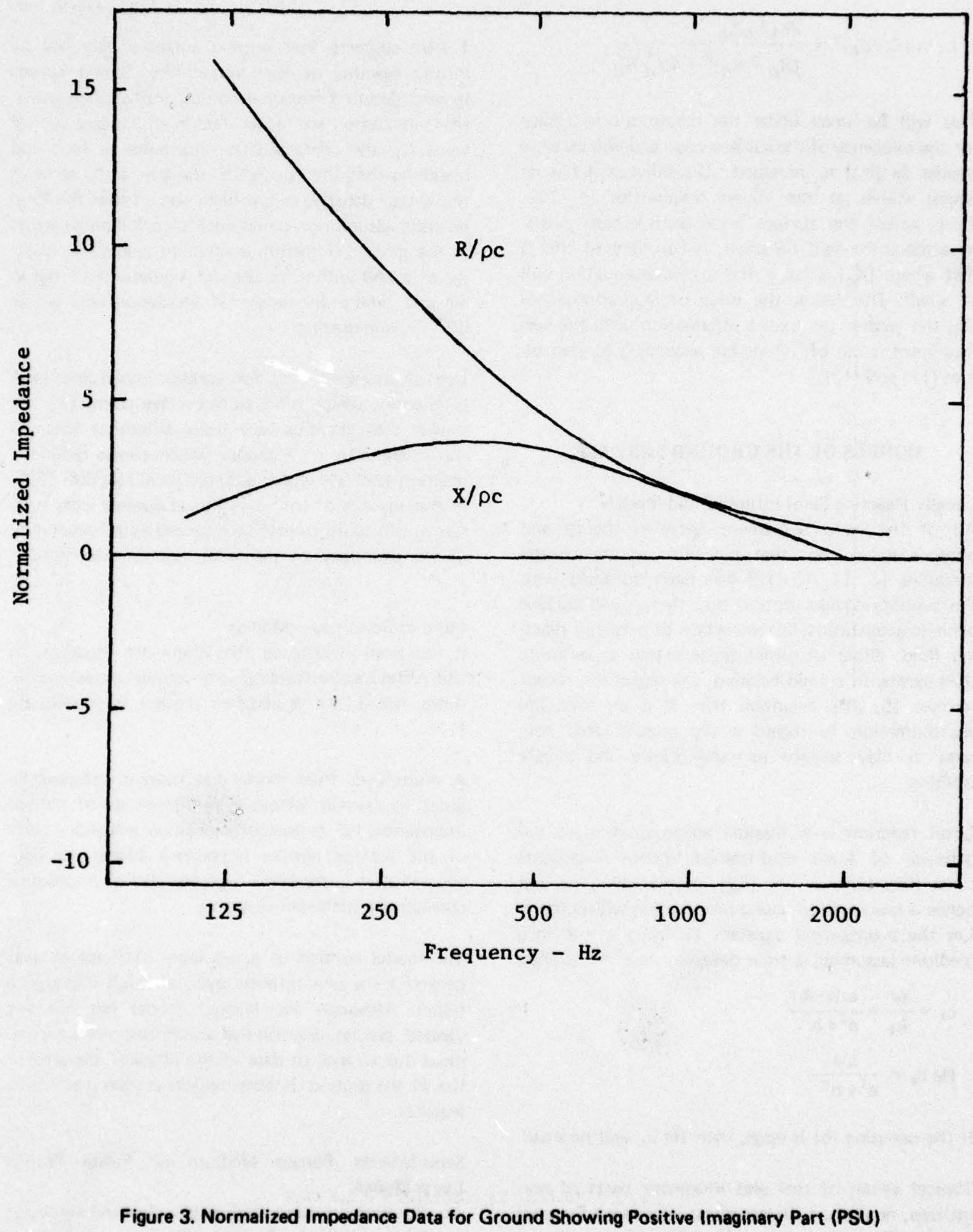

Figure 3. Normalized Impedance Data for Ground Showing Positive Imaginary Part (PSU)

of $k_1 \, Im(Z_1/Z_2)^2 = \frac{2k_1 R_n X_n}{(R_n + X_n)^2 + 4X_n^2 R_n^2}$

This will be small under the conditions necessary for the existence of the surface wave and will become smaller as $|X_n|$ is increased. Typically $|X_n|$ has its largest values at the lowest frequencies [1, 15]. Thus, where the surface wave contribution exists, its attenuation will be small. A corollary of this is that where $|X_n|$ is large, the excess attenuation will be small. The nearer the value of $|X_n|$ approaches R_n, the greater the excess attenuation until the surface wave is cut off altogether according to inequalities (11) and (13).

MODELS OF THE GROUND SURFACE

Locally Reacting Semi-Infinite Fluid Models

All of the good agreement between theory and outdoor experiment that has been quoted in the literature [1, 11, 15, 16] has been obtained with the simplifying assumption that the ground surface behaves acoustically as the surface of a locally reacting fluid; either of semi-infinite extent or of finite thickness with a rigid backing. Consequently, recent reviews [5, 16] maintain that it is an adequate approximation to regard a flat grass-covered soil, sand or clay surface as semi-infinite and locally reacting.

Local reaction is a feasible approximation to the behavior of some rigid-framed fibrous absorbents since they have a very high internal damping and hence a low speed of sound propagation within them. Let the propagation constant be $k_1 = a + ib$ in a medium (assuming a time dependence $e^{-i\omega t}$). Then

$$c_1 = \frac{\omega}{k_1} = \frac{\omega(a-ib)}{a^2+b^2}$$

$$\text{Re } c_1 = \frac{\omega a}{a^2+b^2}$$

If the damping (b) is large, then Re c_1 will be small.

Typical values of real and imaginary parts of normalized, normal or characteristic impedance for grass covered flat open ground [1, 15] are an order of magnitude greater than the characteristic impedance of a typical fibrous medium below 1 kHz (Figure 2). The appreciable difference in impedance below 1 kHz suggests that ground surfaces may not be locally reacting at low frequencies. Sound speeds in sand deduced from mechanical (rather than acoustical) excitation are higher than in air. Using a typical value for the characteristic impedance of sand and assuming that the "acoustic" density is the same as the actual density, it has been shown that the local reaction assumption could lead to considerable errors in the ground reflection coefficient where the velocity of sound within the ground is greater than that in air and where the angle of incidence falls below 90°, i.e. non-grazing.

Use of averaged data for surface impedance [15] in theories which omit surface wave terms [1] has shown that there is very little difference between the predictions of a theory which allows extended reaction and one which assumes local reaction [20]. In the absence of consideration of surface wave type terms, this work cannot be regarded as definite proof of the adequacy of the local reaction assumption.

Fluid or Solid Layer Models

It has been recognized that there are situations in which the locally reacting semi-infinite model (sometimes called the impedance model) is inadequate [1].

A multi-layer fluid model has been investigated in order to explain certain measured values of normal impedance, i.e. consistently positive imaginary parts of the surface normal impedance (using the convention that a negative imaginary part of impedance represents a stiffness reactance).

The model consists of a top layer (0.05 m) of sand backed by a semi-infinite layer of finite impedance (clay). Although the layered model has not yet yielded precise quantitative agreement with experiment due to lack of data of the physical characteristics of the ground, it does explain certain qualitative features.

Semi-Infinite Porous Medium or Finite Porous Layer Models

An alternative explanation of the observed values of imaginary part of impedance would follow from a porous semi-infinite model of the ground surface since this implies an acoustic density $\rho_1 = d + ie$ which is complex. Hence

$$\rho_1 c_1 = \frac{\omega(d + ie)(a - ib)}{a^2 + b^2}$$

$$= \frac{\omega[ad + eb + i(ae - bd)]}{a^2 + b^2}$$

The imaginary part Im $\rho_1 c_1$ would change sign where bd > ae. Typically for a porous fibrous absorbent a and b have similar magnitudes at low frequencies while e is small.

The physical meaning of a complex density has not been made clear in the literature. The concept of a complex density was first justified physically with reference to the conceptual model of a capillary pore medium. For such a model it is attributed to the change in inertia of, and the frictional drag suffered by, the air as it moves through the pores. The complex density is intended also to include inertial effects due to movement of the fibres and the orientation of the pores.

A porous medium with a rigid frame and pores that do not interconnect in directions parallel to its surface will be locally reacting by definition. A semi-infinite rigid-framed porous model does not adequately explain the form of the normal impedance vs. frequency plot of some measured values of normal impedance [21]. It has been suggested that a semi-infinite flexible porous model might be adequate. A calculation based upon a model with an exponentially decaying porosity with depth (but a rigid frame) seems to give the best fit to experimental results for grass-covered ground (below 1 kHz) [21]. Although it seems likely that the compression and compaction of the ground will increase with depth there is no data available as yet to justify this assumption.

The conclusions in reference 21 with regard to the various possible models for the ground surface are based exclusively on the NRC ground impedance data (Figure 2) and hence, are relevant essentially to "institutional" grass. This is true also of reference 20 where good agreement between the NRC data and the predictions of a power law relationship between impedance and flow resistance (based upon data for fibrous absorbents) is found. These results have been supported recently by measurements over a university band field. However, other measurements made over grass and clay and the forest floor [1] give rather different forms for the frequency dependence of ground impedance (Figure 3). Indeed, the pronounced flattening of the resistive component at low frequencies [1] is precisely the effect predicted [21] for the rigidly-backed porous layer model. In reference 21 the idea of modeling the ground surface as a rigid-framed porous layer with a rigid backing is dismissed. However, reference 11 uses exactly this approach. It is found possible to model the rigid-framed porous layer with four real constant parameters which are related to the real and imaginary parts of the effective compressibility, the porosity, the dynamic density of air in the pores and the thickness of the layer. It is accepted that some of these "constants" may be frequency dependent and no method of measuring or calculating these "constants" directly from knowledge of the physical and structural nature of the ground surface is offered. Instead, reliance is placed on an indirect phenomenological (trial-and-error) method. The source and receiver are located close to the ground surface and a relatively small distance apart and the excess attenuation spectrum is measured. Reasonable values of the parameters are then tried in a theory of propagation above a locally reacting boundary [10] by computer iteration until satisfactory agreement between calculated and measured plots is obtained. The corresponding best fit values of the parameters can then be used to predict excess attenuation over longer distances. It is concluded that the locally reacting propagation constants of both the airborne wave and the structure-borne wave in flexible porous absorbents are critical in determining whether or not the absorbent is locally reacting. Local reaction will be a successful approximation only if the energy content of the structure-borne wave is small. This has been shown to be the case in certain fibrous absorbents [27]. However, there is little evidence in the literature of measurements of propagation constants in typical ground media as a result of airborne excitation.

CONCLUSIONS

The refinements to the theory of spherical sound propagation above an absorbing boundary made during the last few years have made it possible to predict dB(A) attenuations of traffic noise over certain ground cover almost exactly. With improvements in traffic noise legislation, however, more detailed (spectrally) emission limits are likely to be set using more sophisticated noise units as are already used for other types of noise source (aircraft, industry) and will require more exact predictions of the acoustic filtering due to ground cover. In this event, the current situation is unsatisfactory. Most of the solutions currently available require extensive approximations in order to permit numerical evaluation. Furthermore, the physical basis for them is not yet completely or satisfactorily expounded. Finally, it should be noted that the role of any structure-borne (frame) wave or sideways pore connections in the ground have not yet been explored and their influence on the prevalent and questionable local reaction assumption has not been checked.

ACKNOWLEDGMENT

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

Recent research on the dynamic response of fluid-filled shells is reviewed by Professor DiMaggio of Columbia University. Papers considering gravity effects or fluid flow are not reviewed.

The series of review articles on seismic waves by Dr. De continues with a description of mathematical methods.

RECENT RESEARCH ON THE DYNAMIC RESPONSE OF FLUID-FILLED SHELLS

F.L. DiMaggio*

***Abstract** - This article reviews papers, published between 1975 and 1978, involving the dynamic response of fluid-filled shells. Papers considering gravity effects or fluid flow are not reviewed.*

In an earlier paper [1], the problems of steady state and transient responses of fluid-filled shells were formulated and discussed, and publications involving analytical investigations were reviewed. The present article reviews investigations published from 1975 1977. Studies involving gravity effects on free fluid surfaces (e.g., sloshing problems) and those involving motion of either the fluid or container are excluded. No claim is made of definitive coverage, but the references cited and the bibliographies included within them include most of the important contributions.

CYLINDRICAL SHELLS

Investigations of the propagation of waves in cylindrical tubes have been motivated by possible applications to arterial blood flow, acoustic delay lines, and water hammer in pipes.

Two major studies have been concerned with small amplitude steady-state axisymmetric waves in infinite circular cylindrical shells. Scarton and Rouleau [2] used the method of eigenvalleys to calculate the first 32 fluid modes and plotted dispersion curves for the case of a rigid tube containing a viscous, compressible fluid. This excellent paper also reports the discovery of backward propagating waves; boundaries between low, high, and intermediate frequencies; and a new type of boundary layer.

An equally impressive study for thin viscoelastic tubes of constant thickness containing a compressible viscous fluid is that of Rubinow and Keller [3]. It is an extension of an earlier paper concerned primarily with an inviscid fluid [4]. The dispersion equation relating the propagation constant k to the angular frequency ω was solved using analytical and numerical methods [3]. Asymptotic formulas for $k(\omega)$ were obtained for both low and high frequencies. Numerical values for intermediate frequencies were plotted as dispersion curves for material parameters that characterize arterial blood flow. Extensive asymptotic results are presented for the special case of a rigid tube. The authors point out the the root

$$k = (i\alpha\omega)^{1/2} \qquad (1)$$

introduced by Scarton and Rouleau [2] is false.

$$\alpha = \frac{E}{\mu}\frac{\rho_0}{\rho_1}(1-\sigma^2) \qquad (2)$$

E is Young's modulus, μ the shear viscosity coefficient, ρ_0 the fluid density, ρ_1 the shell density, and σ Poisson's ratio. In addition, they found a previously unknown root, denoted by k −, for an elastic shell. The root is proportional to ω at low frequencies. They also showed that a nonuniformity exists in the dependence of the phase velocities of the propagating modes on μ and ω at $\mu = 0$, $\omega = 0$.

Barclay, Moodie, and Haddow [5] studied the response of fluid in a semi-infinite tube, the circular cross-sectional area of which varied with length according to either an exponential or power law. The tube was filled with an inviscid incompressible liquid, and a disturbance was present at one end. The use of a one-dimensional approximation for the fluid equations means that the shell response is not coupled to that of the fluid. Thus, insofar as the fluid motion is concerned, the tube does nothing more than provide the geometry, as would a rigid tube. When the disturbance is an oscillatory function, a high-frequency expansion is assumed. For a Heaviside disturbance, expansion in the form of a progressive wave is chosen. The numerically exact solutions and asymptotic expansions were compared.

The design of such internal reactor system components as shrouds and thermal liners must provide for vibrations induced by fluid flow. This need has

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led to a series of studies involving infinitely long pairs of coaxial circular cylindrical shells separated by a fluid. Stokes [6] determined the fluid virtual mass -- also referred to as added mass or entrained mass -- for a rigid cylinder translating within a rigid cylinder with incompressible liquid between them.

Chen, Wambsganss, and Jendrzejezyk [7] solved the problem of the damped harmonic oscillations of a rigid rod in a rigid shell separated by an incompressible linear viscous fluid. They obtained closed form solutions for the virtual mass and damping factors that represent the effect of the fluid on the vibrating rod.

The frequency-dependent virtual mass effect for prescribed non-axisymmetric harmonic motion of an infinite cylindrical surface inside a rigid cylindrical surface separated by a compressible, inviscid fluid, obtained earlier in closed form [8], has been rederived [9]. Yeh and Chen [10] considered two elastic shells (governed by Flügge's equations) separated by a viscous fluid, thus generalizing an earlier paper [11], in which an inviscid fluid was assumed. They presented [10] numerical results for the added mass and damping effect for an incompressible fluid.

Self- and mutual-added mass coefficients for a group of (parallel) rigid circular cylinders in a rigid circular cylindrical channel containing an inviscid, incompressible fluid have been obtained [12, 13]. The introduction of a finite element procedure allowed the consideration of noncircular geometries [13].

The axisymmetric response to a ring load traveling axially at a constant speed has been studied for an elastic, infinite, circular cylindrical shell filled with an inviscid linearly compressible fluid [14]. The effects of shear and rotatory inertia were included in the shell equations. Extensive numerical results confirmed that, as the speed of the load increased, the effect of the internal fluid became more significant.

An interesting application has to do with coaxial cylindrical shells of finite length that represent the lower part of a nuclear reactor containment vessel (see Fig. 1). Water, assumed to be linearly compressible, occupies the space between a comparatively rigid pedestal and a linearly elastic thin steel shell stiffened with elastic steel T-beams. DiMaggio, Bleich, and McCormick [15] studied the dynamic response of this model to the axisymmetric cylindrical pressure pulse exerted on the outer shell wall when all discharge pipe valves were released. Bending moments and shears along the outer shell wall caused by these pulses had the spatial and temporal variations shown in Figures 1 and 2 respectively.

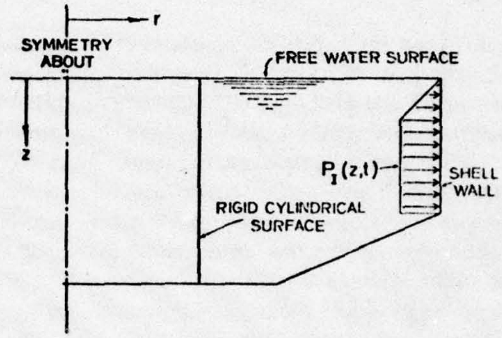

Figure 1. Model of Containment Vessel and Variation of Incident Pressure with Depth

Most studies of head injury have been based on spherical and spheroidal shells. Liu and Chandran [16], however, used a rigid, finite cylindrical container to model the skull. They simulated the brain as a compressible, inviscid, fluid, and attached a spring and dashpot externally to the container to account for hair, skin, and a helmet. Numerical results were based on an infinite series solution for the impact of this model on a rigid wall.

SPHERICAL SHELLS

The papers on fluid-filled spherical shells that have come to this reviewer's attention during the past three years appear to be part of a continuing research effort to establish mechanical models for skull and brain injuries to the human head [1].

A closed for solution for the potential functions governing the response of an incompressible elastic medium in a rigid spherical shell subjected to an acceleration in the form of a Dirac delta function

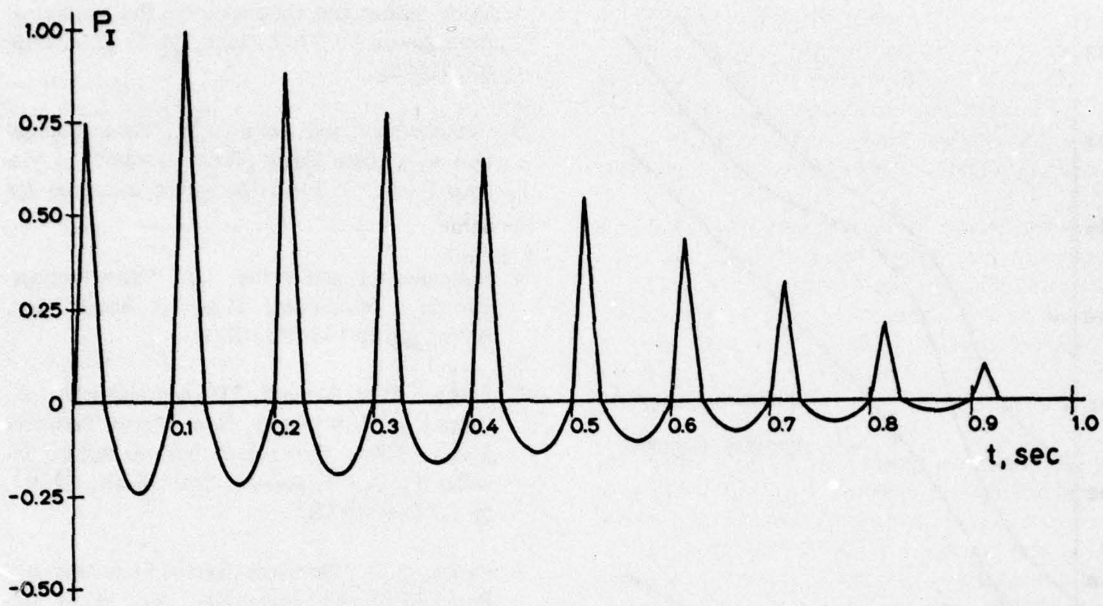

Figure 2. Time History of Incident Pressure P_I (z, t)

has been obtained [17]. Numerical solutions, using finite difference techniques, have also been published for the case of a Maxwell fluid subjected to translational and rotational acceleration of its rigid spherical container [18] and of only angular acceleration with a Kelvin material modeling the brain [19].

Akkas [20] considered a thin, elastic, three-layered shell filled with an inviscid compressible fluid. A finite difference scheme was used to determine the shell stresses and fluid pressures for an axisymmetric impact. Numerical results have been presented for loading with spatial and temporal variation previously used [21].

An approximate solution for a hemispherical rigid shell having a flat bottom filled with a viscoelastic fluid (satisfying the Navier-Stokes equations) and subjected to a sudden rotation has been published by Ljung [22]. He first obtained the solution for an infinite cylindrical shell and a semi infinite cylindrical shell with a flat end and determined the effect of the flat bottom. He then applied a similar correction to his results for a spherical shell.

SPHEROIDAL SHELLS

Rand and DiMaggio [23] obtained frequency spectra for elastic prolate spheroidal shells filled with an inviscid, linearly compressible liquid; flexural effects in the shell were neglected. Lee and DiMaggio [24] have generalized these results by including the effects of bending. Figure 3 is a comparison of the new spectra with those obtained previously. As has been discussed [1], the inclusion of bending affects only the lowest branch, involving essentially radial motion, by eliminating the unrealistic cut-off frequency predicted by membrane shell theory. The symbols in Figure 3 have been defined [24]; their values are characteristic of a human skull and brain.

The transient response of an extensional elastic prolate spheroidal shell filled with an inviscid compressible fluid to a uniformly distributed Heaviside pressure pulse has been studied [25]. The results have been generalized by considering the response of thick shells of viscoelastic material to excitations having various time histories [26].

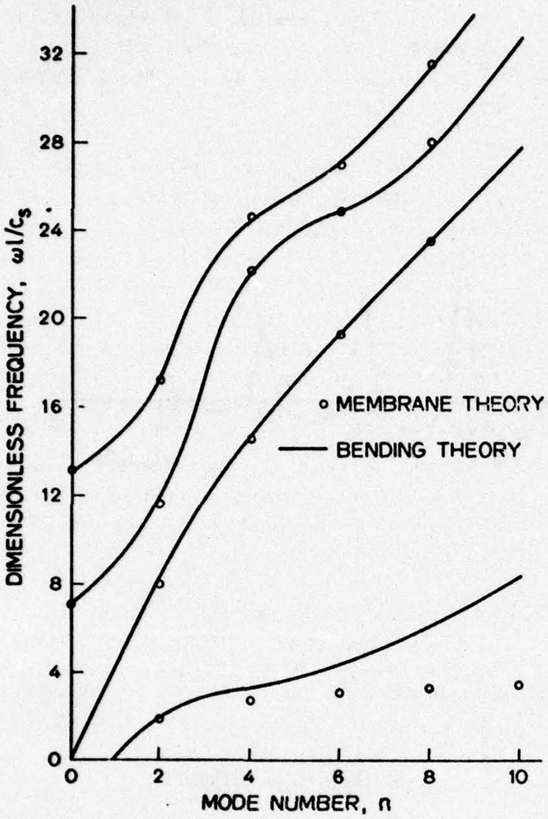

Figure 3. Frequency Spectra for Fluid-Filled Spheroidal Shells with $\upsilon = 0.3$, $c_s/c = 1.0698$, and $h/\ell = 0.025$

MISCELLANEOUS

A formulation of the theory for the large deformation of fluid-filled membranes of revolution has been presented by Engin [27].

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ON SEISMIC WAVES
PART III: MATHEMATICAL METHODS

S. De*

Abstract - The frequency equations for the Rayleigh and Love waves in various models of the earth -- from a single half-space to multilayered semi-infinite media -- are well known. Some of the layers are considered to be heterogeneous or anisotropic. Because suitable solutions for the equations of motion for most cases of lateral nonhomogeneity are not possible, the principle of constructive interference associated with the ray theory is used to derive the frequency equation. The Thomson-Haskell matrix method has been applied to multilayered media. This article and the last article in the series describe various mathematical methods used to study seismic waves.

In 1934, Jeffreys [1] attempted to determine Love and Rayleigh wave dispersion curves for media with vertical heterogeneity; he used Rayleigh's principle to obtain approximate results. In 1961, he showed that Rayleigh's principle can be used to derive small corrections in the theory of surface waves [1].

Rayleigh used the variational method to estimate eigenvalues -- particularly the periods of normal modes or oscillation of a bounded vibrating system. During the past 20 years, theorems relating to vectors in Hilbert space have been used in variational problems for estimating such quantities as the transmission coefficients for diffracted or scattered waves.

Methods that Utilize Rayleigh Waves

The propagation of Rayleigh waves over the free surface of nonhomogeneous semi-infinite medium in which density and elastic parameters are functions of depth has been considered [2, 3]. The loci that govern the limits to which a Rayleigh wave can penetrate a half-space have also been examined [4]. Both interior and surface sources were considered.

The frequency equation for Love waves in a homogeneous layer overlying a vertical heterogeneous semi-infinite medium has been described [5]. A method for determining all vertical nonhomogeneities for which the SH-wave equation can be solved in terms of standard transcendental functions has been described [6]. The frequency equation for SH-wave propagation in an anisotropic, nonhomogeneous, layered stratum lying between two isotropic, homogeneous half-spaces has been derived using the Thomson-Haskell matrix method [7].

Love wave propagation in a transversely isotropic nonhomogeneous medium has also been studied by defining elastic parameters in the equivalent isotropic case [8]. The effect of anisotropy on the cut-off frequency of Love-wave clustering has also been considered [9]. The propagation of Love waves has been based on finite strain theory [10]. Primary Love waves were associated with secondary Rayleigh waves and tertiary Love waves.

The principle of constructive interference has been used to derive the frequency equation of Love waves propagating in an elastic layer overlying a semi-infinite elastic medium [5, 11, 12]. The equivalence between the acoustic waves in a fluid layer and the SH waves in a solid layer over a rigid half-space was also studied [12].

Finite deformation theory was used to show [13] that the propagation of primary Rayleigh waves is accompanied by the propagation of secondary Rayleigh waves with half the wavelength and period of the primary one. The amplitude of the secondary wave is small compared to that of the primary one. A simple numerical method has been developed [14] to analyze generalized Rayleigh waves in multilayered elastic media. The method avoids displacement potentials and leads to a simple eigenvalue problem that can be solved with computer codes.

The outerlayer of the earth contained several regions: oceanic, continental, ridge, and arc. The multiple regression method has been applied [15] to great-circle Rayleigh-wave data to obtain the dispersion characteristics of each region. Measurement of phase and group velocities for two paths circling the earth have been given [16]. ρ values for Rayleigh

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waves with periods from 15 to 50 sec have been determined from frequency-averaged spectral densities obtained at pairs of stations along great circle paths [17]. Isolated Rayleigh waves R_3, R_5, or R_7 from the Rat Island earthquake of February 4, 1965, were used to investigate the variation of ellipticity as a result of path differences [18].

A finite difference iterative formulation, applied successfully to acoustic surface wave scattering in homogeneous, layered-isotropic, and nonlinear media was extended to Rayleigh mode propagation in anisotropic materials [19]. Rayleigh waves on elastic crystals have been considered [20]. The equation for unattenuated Rayleigh waves traveling on a free surface of an anisotropic elastic half-space could always be reduced to one purely real equation. It was also shown that surface waves are impossible on a fixed boundary.

The finite element method in two dimensions was modified to study Rayleigh waves in an oceanic model [21]. It is necessary to determine horizontal displacements within finite elements of water from vertical displacements and the condition of irrotational motion. The finite element method leads to a discontinuity in horizontal displacement at the ocean bottom. Phase velocities of Rayleigh waves calculated by the method of Haskall and Dorman were within 0.2 percent of those measured by a seismometer on the bottom of the Pacific Ocean. The finite element method can also be used to calculate the variation with depth of the horizontal and vertical amplitudes of Rayleigh modes.

Rykunov [22] studied the propagation of Rayleigh waves, given a layer the thickness of which changes abruptly. He also studied the characteristics of the Rayleigh-wave field in a half-space containing a disturbance in the form of a vertical slit and the effect on the Rayleigh-wave field of topographic characteristics of the free boundary.

Basic equations for the theory of Rayleigh waves traveling through the shallow layers of a homogeneous and isotropic half-space have been presented [23]. The variational theory of perturbations of eigenvalues, or phase velocity, was briefly considered [24]. A procedure for simplifying computation was given for perturbations of group velocity, or spectral amplitude. The theory and experiments pertaining to the propagation of Rayleigh waves along perturbed boundaries have been considered [25]. The effect of a layer on surface wave propagation on a half-space has also been studied [26].

Waves at the interface of two isotropic solid half-spaces subject to stress and displacement have been studied [27, 28]. Calculations for waves at the interface of two anisotropic media -- namely, two crystalline half-spaces in cubic symmetry but with different orientations -- have been given [29]. The results indicated that many geometrical dispositions allow propagation of a generalized Stoneley wave. The interface chosen is a (0, 0, 1) plane for each crystal; waves either have a real phase velocity of travel slowly along an arbitrary direction in the interface of angles of ϕ_1 and ϕ_2 to the (1, 0, 0) axes of the crystals. The angles between the two (1, 0, 0) axes are ϕ_1 and ϕ_2.

The magnetoelastic surface waves particularly Rayleigh, Love, and Stoneley waves, in an initially stressed conducting medium have been considered [30]. The Thomson and Haskel matrix method has been used to obtain the dispersion relation for generalized surface waves in multilayered media; the layers can be either isotropic or anisotropic [31]. Experimentally determined Rayleigh-wave dispersion curves for group velocity have been given for five points [32].

The existence of Rayleigh waves in an anisotropic elastic semi-space has been investigated [33]. Johnson [34] considered wave propagation along a plane of symmetry in an anisotropic medium. (The maximum number of independent elastic constants was therefore reduced from 21 to 13.) Stoneley waves at solid-solid interfaces are possible only for certain elastic constants and density parameters. Regions in which waves might occur were calculated for waves traveling in various directions and for media with cubic, orthorhombic, and monoclinic symmetries; these regions in anisotropic media were similar to those calculated by Scholte [35] for isotropic media. For certain elastic constants, the region from one direction of wave propagation to another varied greatly. The phase velocities of various waves -- solid-solid Stoneley waves, liquid-solid Stoneley waves, and Rayleigh waves -- were calculated for the three symmetries as a function of the direction of wave propagation for specific substances

[36, 37].

The propagation of Rayleigh waves along a traction-free surface of a semi-infinite anisotropic elastic body, has been applied to interfacial waves in an infinite body composed of two anisotropic elastic half-spaces welded together. An appropriate equation was constructed directly from complex vectors provided by the analysis of free Rayleigh waves in the constituent half-spaces. This equation was reduced to a single real relation, confirming that Stoneley waves, when they exist are not confined to discrete directions of propagation.

Long-period Love waves in a medium consisting of layers of various thickness have been discussed [38]. The excitation of Love waves with a period of 100 sec has been studied as a function of magnitude in the earth's mantle [39]. The spectral densities of 153 measurements of Love waves during earthquakes since 1930 ranged from 6.0 to 8.9; they were used to determine an excitation curve. Fundamental-mode Love and Rayleigh-wave dispersion computations for multilayered, perfectly-elastic media have been studied [40].

The continuum theory has been used [41] to study surface wave propagations in layered media. Exact dispersion curves were also worked out for a relatively simple laminated medium. The continuum theory was also used to study Rayleigh-wave dispersion on a laminated half-space for which exact dispersion equations cannot be obtained.

Conditions for experimental studies of seismic waves have included a medium in which wave velocity increased slightly with depth and heterogeneities caused small velocity changes [42]. The phase velocity dispersion curve was complicated. The correlation between this curve and various harmonies of the inverse square of layer velocity was analyzed.

A finite element technique has been developed [43] to study the propagation of Rayleigh and Love waves across two-dimensional nonhorizontally-layered media. A layered model with lateral nonhomogeneity was constructed [44] for the Himalayan region where, according to plate theory, a mobile continent collides with a relatively stationary crustal block. Love-wave dispersion characteristics of such a model were evaluated using the ray-theory. A variational principle for Love waves -- especially those with a long period -- propagating in a layer of variable thickness overlying a half-space has been formulated [45]. An averaging procedure was used to determine the wave modulation due to the gradual variation in thickness. The wave number and amplitude modulation for both a monochromatic wave and a transient wave train due to an impulsive source were also determined.

The possibility that Love waves can propagate in an electrostrictive dielectric medium has been investigated [46]. Such waves can propagate, but the electric surface potential has some effects. Love and Rayleigh surface waves were studied using large-base quartz extensometers [47]. Group velocities of both Rayleigh and Love waves with periods from 30 to 150 sec have been accurately determined by band-pass filtering and group-delay time methods. Rayleigh waves in an elastic medium with two horizontal layers overlying a semi-infinite elastic medium above which lies a liquid layer have been discussed [48].

Extremely rapid changes in Love-wave velocity have been observed in some tectonic areas. Two non-uniform channels with exponential velocity and variable rigidity in vertical and lateral directions were used to consider Love-wave disperison characteristics in such areas [49].

Analysis of a sum of 13 auto-correlograms of horizontal component seismograms have predominantly transverse motion revealed that fundamental-mode Love-wave data can be contaminated by higher torsional modes [50]. Phase velocities of Rayleigh waves have been measured worldwide for waves with periods in excess of 160 sec for a number of profiles and many geologic structures [51]. The propagation of such waves in the earth has been investigated for waves with periods ranging from 60 to 590 sec [52].

The influence on Love-wave propagation of a discontinuity at a vertical boundary in a medium has been considered [53]. Two surface waveguides were investigated, and interactions between Love waves were shown. It was also shown that earthquakes could excite the first higher mode of Love surface waves with periods ranging from 30 to 90 sec; the mode could travel at a group velocity comparable to that of the fundamental mode [54]. These results are applicable to the effect of multipath interference of two waves of similar mode traveling at an angle with respect to each other. Propagation of Love waves in a multilayered anisotropic medium with hexagonal symmetry has been studied [55]. The dispersion of Love waves that propagate in a laterally heterogeneous layer lying over a homogeneous semi-infinite medium has been studied using constructive interference [5, 56]. The dispersion characteristics of Love waves in a transversely isotropic and laterally nonhomogeneous surface layer lying over a homogeneous half-space was also considered using constructive interferences [57]. The propagation of Love and Rayleigh waves along an approximately north-south section of the San Fernando Valley has been studied [58].

Dispersion curves for leaking modes of Love waves have been computed for a single-layer crust-mantle model [59]. Group velocities well below the Airy phase of normal modes were determined. No phase velocities occurred between the velocity of the half-space and that corresponding to the Brewster angle. The Thomson-Haskell matrix method was used to derive the following: response spectra of a multilayered elastic half-space to plane body waves, dispersion equations for both Rayleigh and Love waves, relative excitations of surface waves at any depth, and particle motion conditions for Rayleigh waves at a free surface and at any depth [60].

The influence of primary stress upon the propagation of Love waves in a welded layer and half-space was examined by the theory of nonlinear elasticity [61]. Multipath propagation of Love waves was analyzed [62] from data obtained from three instruments at the Large Aperture Seismic Array (LASA). In most cases, the propagation paths for both Love and Rayleigh waves could be associated with refractions and reflections at the continental margins.

A method has been proposed to detect one Rayleigh wave in the presence of the coda of a larger Rayleigh wave [63]. The quasi-linear stress-strain relations were used to study the propagation of finite Love waves in a heterogeneous elastic half-space lying over a homogeneous elastic half-space [64]. SH-wave propagation in an anisotropic nonhomogeneous crustal layer lying on a yielding and rigid isotropic half-space has been considered [65], as has the propagation of SH waves using the velocity distribution function compatible with the actual distribution of shear-wave velocity inside the earth [66]. The constants involved in the velocity distribution function were calculated from the Gutenberg-Birch model.

A unique root corresponding to Rayleigh exponential wave was obtained for a general form of the Rayleigh equation [67]. The group velocity of Rayleigh waves for ten seisms from different regions has been studied experimentally [68]. The beginning of the recordings show two predominant groups separated by a minimal amplitude. A sharp maximum of the energy spectra corresponds to a wavelength near the depth accepted for the low velocity layer.

Crampin [69] reported that a phase relationship between vertical and transverse horizontal motions exists for second-mode seismic wave trains along many paths in Eurasia; such relationships are not possible with elastic waves in isotropic layered media. These coupled, or generalized, surface wave trains are caused by an anisotropic layer immediately beneath the crust. Crampin suggested that the anisotropy results from an orientation of crystalline mantle material by convection currents. Surface-wave propagation in unlayered and multilayered anisotropic media was examined numerically using an extension of the Thomson-Haskell matrix method [70]. Surface wave propagation in an isotropic earth model containing an anisotropic layer in the upper mantle differed little from propagation in a purely isotropic model. The propagation of the third generalized mode, corresponding to the second Rayleigh mode in isotropic structures, was an exception; particle motion in this mode differed considerably from motion in isotropic media. Interesting problems regarding surface waves have been studied [71-100, 102].

It has been reported [103] that oceanic surface waves can be altered by low rigidity sediments along the propagation path. Love and Rayleigh waves from mid-Atlantic ridge earthquakes are so affected. Thin sediments disperse short-period Love waves. Sediments thicker than two km remove energy from surface waves having periods up to 40 sec. These sediments also alter the particle motion of Rayleigh waves and complicate the dispersion relationship.

Such thick sediments substantially reduce the phase velocity of surface waves with periods exceeding 100 sec. Some problems of interest regarding wave phenomena in nonhomogeneous media have appeared [104, 105].

For a given direction of propagation on the free surface of a half-infinite anisotropic crystal, the phase velocity of the surface wave will always be less than the limiting velocity except when the bulk wave that defines the limiting velocity satisfies the condition of a free surface [106].

An elastic half-space containing a surface obstacle with elastic constants different from those of the half-space and only slight deviation in boundary shape has been studied [107]. A perturbation method and a finite difference solution were combined to calculate the motion of the half-space due to an impulsive source. Results showed that Rayleigh and reflected waves are influenced by the obstacle. This property could be used to screen elastic waves. It is known that small variations in the elastic parameters of a solid cause scattering of elastic waves and thus a reduction in their amplitudes. The attenuation coefficients associated with reduction in amplitude have been calculated for surface waves [108]. Expressions have been derived for waves, the lengths of which are long compared with the mean wavelength of those whose elastic parameters have been varied in space. The attenuation coefficients were those that would be expected if the attenuating mechanism involved viscoelasticity.

The radiation of Rayleigh and Love waves from two different horizontal circular sources of stress has been studied [109]. The displacement on the free surface -- deduced from the equation of motion and the boundary conditions -- was integrated over a finite radius to simulate a disturbance that propagates with a constant finite velocity. An explicit expression for the layer matrix, which serves as the basis for calculating spheroidal oscillation eigenvalues using the Thomson-Haskell matrix method was obtained by an analytical inversion of the characteristic matrix fro a spherical homogeneous layer [110]. The formulation was applied to an interpretation of the observed dispersion of Rayleigh waves.

In stratified piezoelectric media a pure Rayleigh wave with displacements in the Sagittal plane and pure Love waves exist for certain symmetry conditions [111]. If the sagittal plane is a symmetry plane, the Rayleigh wave is piezoelectrically coupled and the Love wave is not. If the sagittal plane is normal to a binary axis, the Love wave is piezoelectrically coupled and the Rayleigh wave is not.

The propagation of waves in an initially stresseo magnetoelastic conducting layer has been considered [112], as has the propagation of the thermoelastic waves in an infinite transversely isotropic circular cylinder [113]. In the latter study the theory of thermoelasticity was used to account for the interaction between the field of displacement and temperature. The propagation of small amplitude waves in an incompressible elastic medium subjected to a large homogeneous equibiaxial stress has also been investigated [114].

A method for solving the dynamical axisymmetric problem in a nonhomogeneous elastic body has been given [115]. Rayleigh surface waves were considered in a body bounded by a plane; a parallel plane surface bound a thin surface layer with different properties.

Propagation of Lamb and Love waves in an infinite homogeneous micropolar elastic plate bounded by two parallel free planes has been considered [116]. The displacement field u_1, u_2, 0 and a microrotation field 0, 0, ϕ_3 led to Lamb waves. A displacement field 0, 0, u_3 and a microrotation field ϕ_1, ϕ_2, 0 led to Love waves.

The conditions for propagation of interface or Stoneley waves between two thermoelastic half-spaces have been studied [117]. The possible existence of a Stoneley mode at an unbounded interface between two elastic half-spaces has been investigated theoretically [118]. The Stoneley wave equation for solid-liquid interfaces was also investigated [119]. The ray theory was used to obtain an approximate solution to the elasto-plastic wave problem [120]. The propagation of shock and acceleration waves in an isotropic viscoelastic homogeneous medium has also been studied [121], as have magnetoelastic waves and disturbances in initially stressed conducting media [122]. Rayleigh, Love, and Stoneley waves were included in the latter study. The propagation of small-amplitude plane waves through a homogeneous, isotropic elastic medium, having a particular strain-energy function and subjected to a large primary deformation produced by a homogeneous biaxial stress has been considered [123].

S_n velocities of a short period shear wave in the lithosphere have been analyzed [124]. Waves with a long period car travel well below the M-discontinuity as they seek a least time path. Propagation of ground waves over a nonuniform overburden having an arbitrarily variable complex dielectric coefficient and depth has been analyzed [125].

The propagation of Rayleigh waves in a half-space and the propagation of Love waves in a welded layer and half-space have been examined when initial tensile or compressive stresses are present [126]. A modified Rayleigh equation and a modified Love equation were obtained from perturbed and linearized equations of elasticity that included the effects of initial stress. The phase velocities of the waves changed under initial tension or compression. A similar problem in crystalline media has been analyzed [127]. Some interesting problems have been reported [7, 128-152].

The effect of microstructure on the propagation of plane waves in a micropolar elastic half-space and their reflections from a stress-free flat surface have been studied [153]. Waves on the free surface and on the division surface that originate as a result of action of arbitrary disturbances of the basin bottom have also been investigated [154]. Long and short waves were treated separately. A cylindrical shear wave has been analyzed [155]. Three approximate methods were proposed to solve the system of partial differential hyperbolic equations of the first order with two independent variables; Courant's iteration method, involving finite differences along characteristics; direct integration of the relations along characteristics; and the method of trapezoids.

Head waves in a large number of two-dimensional and inclinded layer seismic models have been described [156]. Expressions for the P- and S-wave displacement field resulting from finite dynamic Volterra dislocations have been derived [157]. A second order approximation has been given for calculating the excitation of finite amplitude standing waves (without dissipation) in a solid layer [158]. The method allows for detection of amplitude/modulated longitudinal and transverse waves caused by the nonlinear properties of the medium. The dependence of damping on frequency was also analyzed.

A method for determining the displacement and rotation field that forms in an infinite micropolar elastic medium as a result of the action of body forces and body couples has been presented [159]. Axisymmetric deformation of the body is also discussed. Two-dimensional propagation of time-harmonic plane waves through a plane horizontally-layered viscoelastic medium has been described [160]. The problem was formulated directly in terms of stresses and displacements and was solved with matrix methods.

The propagation of shear (or compression) waves in a plane-parallel layer of finite thickness was studied by Sabodash [161]. The waves were excited by an instantaneous displacement of points on the lower plane, allowing for multiple reflections of the fronts from both boundaries of the layer. The material in the layer obeyed the laws of linear viscoelasticity; that is, the Kelvin-Voigt and Maxwell models. Sabodash investigated stationary vibrations of the layer, allowing changes in the physicomechanical properties that affect the thickness of the nonhomogeneous medium, and determined resonance frequencies.

A discrete continuum theory for periodically layered composite materials has been formulated [162]. It is based on a two-term truncated power series expansion of the displacement field about the middle plane of each layer. Two-dimensional equations of motion were obtained for each layer. Appropriate continuity conditions were introduced at the interfaces between neighboring layers before the governing field equations for periodically layered media were derived as a system of differential-difference equations. The propagation of plane harmonic waves in an unbounded layered medium was also examined.

The Boltzmann constitutive representation is a consistent way to incorporate dispersion effects into mathematical models of wave behavior in layered elastic media. Christensen [79] considered long wavelengths with waves propagating normal to the planes of layering. He derived special forms of a general Boltzmann law for periodic layering and one-dimensionally random layering. He also reported that no attenuation of harmonic waves occurred in periodic media and presented an analysis of attenuation in random media.

The surface wave in a semi-infinite micropolar elastic solid embedded in a constant primary magnetic field has been studied [163]. It was assumed that the reduced frequency wave is so small that its first and higher order terms can be neglected.

Exact solutions have been obtained for the displacement field in an elastic half-space composed of two quarter spaces welded together [164]. The configuration is excited by a plane SH wave impinging upon the discontinuity at an arbitrary angle. The Kontorovich-Lebedev transform was used to obtain two simultaneous integral equations that were solved exactly. The discontinuity could enhance spectral displacements up to a factor of two.

An intrinsic theory of wave propagation in linear elastic surfaces has been developed [165], and used to calculate various wave properties -- velocities shapes, and decay strengths for a three-dimensional linear elastic solid. Equations describing an elastic isotropic Cosserat continuum have been presented [166, 167]. Solutions for various modes of plane harmonic waves in an infinite medium are discussed, and the surface-wave solution for straight crested waves on a Cosserat half-space is developed and interpreted. A wave analogous to the classical Rayleigh wave exists except that it is dispersive. The phase velocity of the surface wave could increase or decrease with frequency, depending on the relative magnitude of the micromaterial moduli.

A method for calculating the surface elevation associated with long waves on a rotating earth when fluid is created or passes over geometrical boundaries has been published [168]. Tables for spectral displacements of seismic surface waves from shear dislocations in flat multilayered earth models have been prepared [169], and dynamic photoelastic measurements of Rayleigh-wave propagation in a series of 17 seismic models of wedges have been described [170].

Heat is exchanged when fluids flow through fractures in impermeable rock. The fundamental equations governing the transport of heat in such systems have been derived [171]. The occurrence of weak oscillations in the flowing fluid were studied with a perturbation method. The response of a layered elastic half-space to a progressive exponentially decaying normal surface pressure has been evaluated [172]. The constant velocity V of the moving pressure was greater than that of the P and S waves, respectively, in the upper layer (super seismic) and smaller in the underlying half-space (subseismic).

Simplified one- and two-dimensional models of time-dependent propagations of disturbances on glaciers have been analyzed by Lick [173]. He gave limiting solutions for short- and long-wavelength disturbances and showed that short-wavelength disturbances diffuse but do not travel relative to the glacier surface. He calculated surface height and speed for specific conditions at the ice-rock interface.

The transmission of stresses associated with Rayleigh waves has been considered [174]. The possibility of using the ellipticity of Rayleigh-wave particle motion for determining earth structures has been studied [175], as have surface displacements in the near field due to an arbitrarily oriented fault model in a multilayered medium [176].

A dispersion equation has been derived [177] for surface waves of small amplitude for a semi-infinite incompressible elastic medium subjected to a large primary extension (or compression) in a direction Ox_1 parallel to the free surface Ox_1x_2. When the direction of propagation approached Ox_2, the surface wave displacement was almost parallel to Ox_1; i.e., nearly transverse to the direction of wave propagation.

The parametrization of the seismic rays in an elastic, heterogeneous isotropic medium was derived from the eikonal equation and used to formulate equations for travel time and energy per unit area of wave front [178]. The cases of sub-shear, super-shear, subsonic, and supersonic propagation of a crack were considered [179]. Applications of the solution to earthquake problems were discussed.

In a study of dispersion effects on uniaxial propagation in spatially heterogeneous periodic elastic media [180], the frequency dependence of the wave phase velocity was a power series valid for small frequencies. A simple algorithm for rapidly and exacting computing the attenuation factors of torsional free modes has been developed [181]. Calculations for torsional modes having radial order numbers (j) from 1 to 10 and angular order numbers (υ) up to 300 show that, for periods less than 120 sec, the attenuation factor (but not ρ) is approximately independent of the radial order number when the angular order number is less than 20. For low angular order numbers and a radial order number greater than one, both period and attenuation factor are roughly independent of angular order number for a given value of j.

The propagation of compression waves in a weakly conducting magnetoelastic medium in a magnetic field, to which a distributed load in the form of a Heaviside function is applied, has been studied [182]. Laplace transforms were used and an asymptotic solution was obtained for small time intervals by expanding inverse transform parameter indices in the image space and reverting to the original solution.

The two-dimensional propagation of Stoneley waves along a perturbed interface between two semi-infinite isotropic media has been considered [183]. The interface was perturbed by potential functions; perturbation technique was used to obtain the role of the perturbation in the propagation. Expressions for the components of the total strain due to perturbed and unperturbed contributions were obtained, and, the period equation for the perturbed interface was considered.

Plane harmonic waves in a rotating elastic medium have been studied [184]. When centripetal and Coriolis accelerations were included in the equations of motion, the medium behaved as if it were dispersive and anisotropic. The general techniques for treating anisotropic media were modified, to obtain results for slowness, surfaces, energy flux, and mode shapes. The concepts were applied in a discussion of the behavior of harmonic waves at a free surface.

The propagation of nonlinear waves in a semi-space when a stepwise and moving material with supersonic velocity loading acts at the boundary was studied [185]. It was assumed that the material (soil) obeys the deformation theory of plasticity. The non-linearity of the material of the semi-space and the elastic problem create a jump variation of the normal stress on the transverse wave.

A model for the mantle allowed the shear velocity to attain a minimum and then increase in accordance with Lehmann's observations [186]. If the small variation were periodic, it would generate G waves. But in the model, the waves were filtered. P- and S-waves travel-times from shallow- and deep-focus earthquakes at a distance of 5° to 25° have been interpreted, and surface waves have been observed [187]. T, or seismic water, waves generated by deep-focus earthquakes have been observed by sensitive ocean-bottom seismographs in the basin of the western Pacific.

Seismic interference waves corresponding to a layer in which wave velocity increases and which had a thickness from one to several wavelengths have been studied [188]. The focus and origin of an earthquake and the (apparent) velocity of an elastic wave were calculated from measurements of arrival times. The dynamic characteristics of surface Rayleigh waves were used in a study of heterogeneity of crustal structure and the existence of fractured zones within the mountainous region of the Crimea [189]. The propagation of elastic waves in a porous, saturated elastic (or anelastic) medium has been investigated [190]. The stress equations of motion were solved by the power series method [191] for a nonhomogeneous, isotropic, elastic semi-space. The period equation for Rayleigh waves was also derived.

Elastic properties of the media were assumed to change slowly along the horizontal directions and boundaries of the layers were slightly bent in one study [192]. The vertical distribution of the wave intensity was described by an eigenfunction of the Sturm-Liouville boundary value problem. The propagation of the wave along the surface was studied by the ray theory. Transfer equations describing a change of intensity along the rays were solved.

A linear long-wave equation was solved for arbitrary ground motion on a uniformly sloping beach [193]. Near-shore large-amplitude waves were also investigated using nonlinear theory. A waveguide problem of a surface wave was solved using the antisymmetry principle of infinite space [194]. The closed form solution was obtained in an asymptotic form. The appearance of the surface wave was also determined. The change of velocity of two shear waves propagating in an isotropic elastic body with initial uniaxial stresses was investigated using second order elasticity theory [195]. Wave velocity was measured in steel specimens in axial tension and compression. The properties of simple elastic media in motion differ from those not in motion because of the compressional and shear wave velocities produced by the motion.

A WKB solution was derived for elastic waves propagating into a nonhomogeneous elastic medium [196]. Both plane harmonic waves in unbounded media and Rayleigh surface waves propagating along a half-space consisting of linearly elastic materials that conduct heat have been considered [197]. Harmonic P- and SV-plane nonhomogeneous waves that propagate in linear viscoelastic media have been investigated [198]. Miscellaneous problems of interest have been studied [87, 181, 199-234].

A 1970 seismic survey at the reclaimed Port Island of Kobe Harbour included measuring the velocity of shear waves propagated in near-surface layers consisting of reclaimed granite soil alternating with silt, sand, and gravels [235]. A model showing the distribution of P-wave velocities in the upper mantle beneath the Australian Shield was constructed to fit the travel times of the first waves to arrive from major regional earthquakes.

Irregular Boundaries and Wave Propagation

The effect of irregular boundaries on the propagation of waves in an elastic medium is important in seismology. Because of the complex mathematics involved, however, investigations have been concentrated on slightly curved boundaries. The displacement vector therefore consists of two parts: one is the same as that for plane boundaries and the other accounts for additional effects due to nonzero curvature of the boundary.

Sato [236] studied the propagation of Love waves in a layer with an abrupt change in thickness; De-Noyar [237] considered propagation in a layer over a half-space with a sinusoidal interface. Kuo and Nafe [238] investigated the propagation of Rayleigh waves in a similar model. Obukov [239] considered the effect of a wavy boundary.

The effect of a curved boundary in the presence of a buried line source has been studied [240, 241]. Similar problems have been approached with different techniques and simpler models [242-244]. In one case [245] a finite difference approximation of the elastic equations of motion was used to solve various wave propagation problems that had been solved analytically. The method was extended to the problem of Love waves propagating across an ocean continent.

The perturbation technique was used [245] to study the propagation of Love waves in a layer of nonuniform thickness lying over a half-space. A simple but rigorous derivation was given for wave scattering incident at the nonhomogeneity. The theory is applicable to a nonhomogeneity of any shape. A finite element technique was developed [243] to study the propagation of Love waves across nonhorizontally-layered structures.

Takahashi [245] solved the eigenvalue problem for Love waves at a hyperbolic interface between the upper layer and the mantle. Knopoff and Mal [246] discussed Love-wave propagation in a single layer of variable thickness overlying a half-space; they assumed that both the layer and the half-space are composed of homogeneous materials and that either the interface or the free-surface is plane.

Reflection by irregular surfaces has been considered [247-251]. De [252] examined the influence of boundary perturbation on the propagation of Love waves in a medium containing various irregularities. The propagation of Love waves over the circular cylindrical surface of a layered earth model containing cylindrically aeolotropic material has been studied [253], as was change in the dispersion equation due to harmonic variation in the thickness of the cylindrical crustal layer when the earth is composed of anisotropic material. The effect of periodic irregularities of a boundary on scalar waves has been discussed [254]. Fourier transforms were used to obtain a double integral that was approximated by the saddle point method to produce a geometrical picture.

Handelman [255] studied surface waves over a slightly curved elastic half-space with the perturbation technique. The first order correction terms are a sum of three waves: one is the ordinary surface wave, the second is a cylindrical shear wave with a diminishing amplitude, and the third is a cylindrical dilatation wave with a diminishing amplitude. Similar problems of interest have been published [178, 247, 255-267].

The exact solutions for some elastodynamic problems involving circular cylinders have been published [266]; the Rayleigh wave contribution was isolated. Propagation velocity diminished as the ratio between wavelength and radius of curvature diminished and reached an asymptotic value at zero wavelength. By comparison, the small-wavelength asymptotic approach of Keller and Karal [268] does not account for dispersion, and a critical or cutoff wavelength exists above which no proper Rayleigh wave can exist. Thus, a Rayleigh wave that propagates toward a point of minimal radius on an interface with variable curvature can be scattered and partially transformed into body waves.

Certain theoretical studies of the propagation of Rayleigh waves on a cylindrical surface have shown that the curvature is more important for waves with very short periods [264]. Experimental verification on two-dimensional models confirmed these results. On a concave cylindrical surface, Rayleigh waves with complex wave numbers are damped and undergo inverse dispersion in the direction of propagation [263].

The diffraction of normally incident longitudinal and antiplane shear waves by two parallel and coplanar Griffith cracks embedded in an infinite, isotropic, and homogeneous elastic medium has been investigated [260]. Dynamic propagation of screw-like crack in relation to a crack-resistance force has also been examined [269]. Experiments have been conducted on the influence of differential pressure on the passage of longitudinal and transverse waves across fractures [270].

It has been suggested [265] that the dispersion of surface wave propagating along a rough plane surface of an elastic solid is attributable to perturbations caused by the roughness in the deeper region of the solid. The arguments in favor of this suggestion are based on the Rayleigh principle.

The crust and mantle are nonhomogeneous in both vertical and horizontal directions and contain curved seismic interfaces and block structures. Several approximate and numerical methods have been applied to practical seismological problems when analytical solutions fail [271]. The ray method is used to calculate rays, travel times, amplitudes, and seismograms. The numerical finite difference method has been combined with the perturbation method to study diffraction of elastic waves on elastic wedges and hollow cylinders. These methods have advantages and limitations [271]. The Wiener-Hopf technique has been used [257] to examine diffraction by a nonplanar boundary.

A formal asymptotic theory valid at high frequencies has been developed by Gregary [258] to account for the propagation of time-harmonic Rayleigh surface waves over the general smooth free surface Σ of a homogeneous elastic solid. He showed that these Rayleigh waves can be described on Σ by a system of surface rays that are geodesics of Σ. The waves are dispersive. Gregary derived an explicit first-order dispersion formula.

The method of matched asymptotic expansions has been used [267] to study scattering of plane SH waves by topographic irregularities of a restricted range in an otherwise plane half-space when the characteristic length of the irregularity is much smaller than the wavelength of the incident wave. Results are given for irregularities in the shape of triangles, trapezoids, and semicircles. The scattering of surface waves by mass defects has been estimated as a function of frequency and defect depth [272]. Attenuation of surface waves of microwave frequencies on polished surfaces is also discussed. Most of the energy was scattered into other surface waves -- rather than body waves -- so that the energy of the surface waves passes into the interior relatively slowly. (This could explain the duration of seismic signals on the moon after the lunar excursion module crashed during the Apollo 12 mission.)

An integral equation for the transmission of SH waves across a step-like irregularity in the surface of the elastic half-space has been derived [273]. A perturbation method was used [274] to study the scattering of plane waves by small surface imperfections on an elastic half-space. The solution of the first order approximation is given as convolution integrals of the surface imperfection with kernel functions defined by Fourier inversion integrals. The scattered far-field displacements are obtained explicitly for arbitrary imperfections. (The scattered field consists of a Rayleigh surface wave and four body phases that travel with the speed of dilatational or distortional waves at the free surface.)

It has been shown [275] that random nonhomogeneities in an elastic half-space generate scattered P and S waves when excited by a spherical P wave initiated at the surface. The scattered energy is characterized by statistical correlations of the displacement components at two receivers on the free surface. Simple expressions were obtained for the correlations on the basis of assuming far-field Rayleigh scattering using a simple perturbation theory, and neglecting boundary effects.

The motion caused by a point source and a source of finite extent in an elastic half-space with a corrugated boundary was obtained [276] and compared with the motion in a flat half-space. The method was a combination of a perturbed theory and a finite difference method. The effect of corrugation on body and surface waves was also investigated.

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BOOK REVIEWS

LIMIT ANALYSIS USING FINITE ELEMENTS

Proceedings of a symposium presented at the ASME Winter Annual Meeting, December, 1976
Edited by R.H. Mallett

Finite element methods for elastic/perfectly-plastic (EPP) models are available, but they are expensive, time-consuming, and in some cases provide for more information than is desired. If the simpler rigid/perfectly-plastic (RPP) model is used, ordinary solution methods break down because stresses in a rigid region are not generally unique.

In pre-computer days, the theorems of limit analysis were used to obtain upper and lower bounds on the yield-point load of an RPP model which, in many applications, is a good approximation of the true carrying capacity of a real structure. The six papers in this volume are concerned with the use of the computer as a means for efficiently finding good bounds on the yield-point loads of complex structures. The papers differ in their emphasis on upper and/or lower bounds, in the type of problem considered, in the finite elements used, and in the extent to which the bounding principle is conserved. Several of the papers point out that when a nonlinear yield condition is used, a lower bound approach may not provide a true lower bound on the model, and for any yield condition it may not provide a true lower bound for the original continuum.

The paper by Anderheggen defines the element arrangement and then considers both stress and velocity fields. A piecewise-linear yield condition is assumed. The two bounding theorems lead to a primal-dual formulation of a linear programming problem. The primal and dual each lead to the exact yield point load for the model, and intermediate steps provide upper or lower bounds, but there is no guaranteed relation between the model and continuum yield-point loads. Applications are given to various triangular and quadrilateral elements for two-dimensional problems.

Biron's paper is concerned with a lower bound approach to shells. For rotationally symmetric shells he uses a nonlinear yield condition, and his method provides a true lower bound for the shell. An essential feature of the approach is that the equilibrium equations can be solved exactly for the circumferential stress and moment. He points out that this feature does not extend to more general shell problems; therefore, a lower bound approach no longer provides a true bound for the shell, although it may furnish a good approximation.

In the third paper, Hutala points out that, rather than regard the yield condition as constraint, any equilibrium solution can be used and the maximum yield function found; then parameters are chosen to minimize this maximum. Assuming the Mises yield condition and using a de Veubke quadrilateral element with a cubic stress function, he reduces this max-min problem to a sequence of steps involving solution of linear equations and minimization with respect to a single parameter. He also formulates an upper bound approach that is mathematicallly similar and can use the same computer program. Both approaches give true bounds on the continuum solution.

A paper by Zavelani-Rossi, Peano, and Binda generalized the de Veubke element to the general rotationally symmetric problem by adding a secondary linear stress function. A piecewise-linear yield condition is assumed. The lower bound approach is reduced to a linear programming problem that provides a true lower bound for the continuum.

In the fifth paper Peano uses a lower bound approach with piecewise-linear yield conditions. He is concerned with the computational comparison of several different element models, all of which are essentially triangular with linear stress fields, and all of which yield true lower bounds via the dual formulation of a linear-programming problem. As a simple measure of computational efficiency, he defines a number β as the number of degrees of freedom F per vertex (for an infinite domain) divided by the number of independent parameters; i.e., by F minus the number of equilibrium constraints E per vertex, $\beta = F/(F-E)$. The smaller value of β, the more efficient the model. He examines seven models, beginning with the simplest one, in which vertex stress components are the independent variables that lead to a β value of 7. The basic goal is to reduce the number of free parameters and constraints by automatically satisfying certain equilibrium requirements; various ways of doing this lead to β values of 6, 4, 3, and 1.6. This last value is again the de Veubke model in which triangular elements are formed from quadrilateral ones by construction of the diagonals. Two further models use stress functions rather than stress components as the starting point. The de Veubke quadrilateral with stress function gives $\beta = 1$, which is optimal. However, certain problems can occur for multiply connected domains.

The final paper, by Robinson, differs from the others in that it is concerned more with results than with methods. He considers the problem of two intersecting cylindrical shells under internal pressure. He computes approximate lower bounds for a wide variety of the parameters a/R, t/T, and B/T (a and R are radii of the two shells; t and T are their thicknesses) and compares them with available experimental and theoretical upper bound results.

Taken as a whole, this volume is a valuable addition to the literature. All of the articles concentrate on the essential ideas presented and refer to other sources for details. The bibliographies appear pertinent. Anyone interested in the challenge of using finite element models for direct information on the yield-point load of structures should certainly start with this volume. The use of listed references for details related to a particular problem of interest should provide a good background for either the solution of practical problems or further research in this area.

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MECHANICS OF VISCO-ELASTIC MEDIA AND BODIES

IUTAM Symposium, Gothenburg, Sweden, 1974
Springer-Verlag, 1975, Editor, Jan Hult

This reviewer, having attended the Symposium, is now also reviewing its proceedings. The Symposium was intended as a forum for specialists from various countries with common interests in the subject of viscoelasticity and was not restricted to the area of shock and vibration. Indeed, of the 34 articles published, perhaps six have to do with shock and vibration.

Johnson considered the small amplitude vibrations of prestrained viscoelastic solids. This basically involves an analysis of small disturbances about equilibrium states that are given a general definition. The constitutive relation considered seems sufficiently general to include the responses of most real materials. Datta considered the behavior of progressive waves in an elastic medium with fluid-filled cavities. The fluid is viscous, and, in a two-dimensional context, the cavities are cylindrical. The problem seems somewhat idealized, however, and the possibility for real applications are limited. Habip considered the behavior of progressive waves in particulate composites consisting of elastic and viscoelastic solids. In particular, he gave attenuation and phase velocity as functions of frequency and the properties of the constituents.

Nonlinear considerations are given in two articles -- one by Ting, Chen, and Schuler and the second by Engelbrecht and Nigul. The latter paper was not presented at the Symposium, as is the common practice of Russians.

Ting considered the evolutionary behavior of propagating singular surfaces of all orders in nonlinear viscoelastic bodies. The constitutive relation is general, and the results reflect its influences on the behavior of the singular surfaces. Chen and Schuler gave an experimental procedure whereby some of the properties of the stress-relaxation function can be determined using the properties of composites without explicit constitutive relations. Engelbrecht and Nigul summarized the evolutionary behavior of shock discontinuities in various media including viscoelastic ones. Their results are by no means original and have been published elsewhere.

The proceedings also contain articles concerning nonlinear viscoelastic constitutive relations, aging, creep, and a finite element method for two-dimensional problems. These articles contain both theoretical and practical material.

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RESONANCE OSCILLATIONS IN MECHANICAL SYSTEMS

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Elsevier Scientific Pub., The Netherlands, 1976

This book presents, in eight chapters, a comprehensive treatment of resonance oscillations. The chapter headings are:

Chapter 1. Background. Basic Concepts
Chapter 2. Method of analysis
Chapter 3. Dynamic resonances, $\nu = (p/q)\omega$
Chapter 4. Parametric main resonance
Chapter 5. Combination resonances
Chapter 6. Combination differential resonances
Chapter 7. Internal resonances
Chapter 8. Parametric main and combination resonances oscillations in structures

The methodology applied throughout the book, which is based in large part on the research of Professor Evan-Iwanowski and his students, is that of asymptotic analysis. However, the mathematics is based on both physical intuition and experimental results.

The book production is somewhat disappointing. This reviewer, at least, is not wildly enthusiastic about expensive ($29.75), hard-cover books that are not type set but photographed from (apparently) author-prepared typescript. Nevertheless, for those interested in nonlinear resonant responses of discrete systems, this book will be useful.

Clive L. Dym
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts 01003

INDUSTRIAL NOISE CONTROL HANDBOOK

P.N. Cheremisinoff and P. Cheremisinoff
Ann Arbor Science, Ann Arbor, MI, 1977
$29.50

The authors state that this book was designed for use by consultants, planners, students, and engineers faced with industrial noise problems. Unfortunately, it really does not meet the needs of any of these groups. Although the book is designated as a "handbook," it is really better described as a survey. The 19 chapters -- including subjects such as noise legislation, personal safety devices, noise reduction with lead, fundamentals of vibration, and noise level interpolation and mapping -- treat many specific topics in an extremely superficial way.

This reviewer chose several problems that might be encountered in industry so that the book's usefulness as a handbook could be demonstrated. For example, I tried to find solutions to, or guidance for, the following "typical" situations: quieting a noisy induced-draft fan; reducing noise transmission between offices; determining the source of noise in a compressor/gearbox pair and eliminating the problem; surveying and controlling community noise; initiating a noise control and/or a hearing conservation program with regard to equipment, personnel, etc; obtaining information on various noise control materials; finding further references. These problems are not uncommon and one would expect a handbook to provide answers to most of these problems. Unfortunately, there is nothing in the index on "gears," "diagnostics," "materials," "references," "community noise," or "fans." On the other hand "compressors," "construction site noise," and "nylon gears" are listed. Thus, for some topics the reader might find some information by the use of the index, while other topics would require either a more refined descriptor or a thorough browsing.

As one looks at the text it is quite obvious that some of the treatments of those items found in the index are very sketchy. For example, the "compressor" topic has about one and a half pages total coverage; one and quarter pages on a compressor noise abatement installation (which seems to be taken from a consultant's brochure) and one quarter page on the advisability of using a "floating floor" for a compressor when it is mounted on the top of a building. This is definitely not sufficient information to develop any noise control technique for compressors. Most of the other topics mentioned above are similarly treated, although there are a few topics that are covered thoroughly.

Many of the chapters have been written by "contributors" and are very specific in their discussion. For example, the chapter on enclosures includes only the use of lead and there is a chapter discussing only noise reduction by glass. The former was taken mostly from brochures of lead industries and the latter was authored by a glass company employee. The chapter on additional sound control materials includes foam, polymer fills, acoustical panels, and nylon (used only in reference to gears). There is no mention of the use of plywood, sheet steel, gypsum board, aluminum, glass fiber, and several other commonly used materials for noise control. Furthermore, some of the more recent works on noise control materials are not cited.

The chapters dealing with fundamentals seem too basic and are actually too short to give the reader a thorough understanding of the physics involved. If one is familiar enough with the field to use a handbook and not require an elementary text, one would expect a rather sophisticated approach to the "fundamentals" to refresh the reader's first knowledge or to provide information as to where the reader can obtain elementary knowledge. Some of the figures are too simplistic. For example, in one figure, there is a box that surrounds the word "noise" attached to an arrow that leads to a box that surrounds the words "protective device" which then is attached to an arrow that leads to a box surrounding the word "ear," illustrating the "acoustic problem in general." The book is also filled with so-called case histories, not in enough detail to reproduce the solutions, but rather to show, superficially, what others have done. Most of the case histories are complete with brand names and the companies that make them. Normally this would be very handy but it appears more to be an exercise in company exposure than a means of technology transfer. Many of the references found at the end of most chapters are merely engineering brochures or sales brochures of materials- (and/or applications-) oriented firms.

There are some useful chapters, the figures in general are clear, and many of the explanations are reasonably simple. However, the book does not do two major things: it does not tell you how to pick noise control components correctly, and it leaves out several important concepts that would be of use to noise control engineers or acousticians who need information on component or system noise control. It appears that the majority of references are not to basic journals, magazines, or texts in the field but rather are references to sales brochures. This reviewer was surprised to see no mention of the major journals, magazines, or associations that are valuable to those who need information on noise control.

Cyril Harris is planning to issue a new edition of his ***Handbook of Noise Control***. It is recommended to the reader contemplating the purchase of a handbook in noise control that he or she wait for Harris's new book. This ***Industrial Noise Control Handbook*** can be of some use as a reference source if one does not have access to a collection of articles or textbooks that have appeared in recent years. This reviewer, however, would prefer to scan the indexes of the magazines/journals that relate to the field.

Richard J. Peppin
1711 Westwind Way
McLean, Virginia 22101

Reprinted from JASA, 63 (2), p 645 (Feb 1978)

SHORT COURSES

JULY

NOISE CONTROL ENGINEERING

Dates: July 31-August 4, 1978

Place: Univ. of Michigan, Ann Arbor, MI

Objective: This course provides engineers and managers with comprehensive knowledge of noise-control engineering and criteria for application to practical problems.

Contact: Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

AUGUST

PYROTECHNICS AND EXPLOSIVES

Dates: August 14-18, 1978

Place: Philadelphia, PA

Objective: This seminar combines the subjects of pyrotechnics and solid state chemistry along with explosives and explosive devices. It will be practical so as to serve the men working in the field. Presentation of theory is restricted to that necessary for an understanding of basic principles and successful application. Coverage emphasizes recent effort, student problems, new techniques, and applications. The prerequisite for this seminar is a bachelor of science degree in engineering or equivalent.

Contact: Registrar, The Franklin Institute Research Labs., Philadelphia, PA 19103 - (215) 448-1236.

FUNDAMENTALS OF NOISE AND VIBRATION CONTROL

Dates: August 21-25, 1978

Place: Massachusetts Institute of Technology

Objective: This program is designed to provide a background in those aspects of sound and vibration that are important to noise control engineering. The major subjects of discussion are sound generation and propagation, vibration of structures, and interaction of structures and sound. The vibration of simple structural elements and the relation of these vibrations to interaction with the sound field will be covered. The general approach is based on engineering concepts rather than theoretical analysis.

Contact: Office of the Summer Session, Room E19-356, Massachusetts Institute of Tech., Cambridge, MA 02139 - (617) 253-2101.

SEPTEMBER

7TH ADVANCED NOISE AND VIBRATION COURSE

Dates: September 11-15, 1978

Place: Institute of Sound and Vibration Research, University of Southampton, UK

Objective: This course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground and then offers a choice of specialist topics. The course comprises over thirty lectures including the basic subjects of acoustics, random processes, vibration theory, subjective response and aerodynamic noise which form the central core of the course. In addition, several specialist applied topics are offered, including aircraft noise, road traffic noise, industrial machinery noise, diesel engine noise, process plant noise and environmental noise and planning.

Contact: Dr. J.G. Walker or Mrs. O.G. Hyde, Institute of Sound and Vibration Research, The University, Southampton, S09 5NH, England.

MACHINERY VIBRATION

Dates: September 20-22, 1978

Place: Cherry Hill, New Jersey

Objective: Lectures and demonstrations on rotor-bearing dynamics, turbomachinery blading, and balancing have been scheduled for this Vibration Institute-sponsored seminar. The keynote address on the development of balancing techniques will be given on the first day along with sessions on modal analysis, oil whirl, and computer programs. Simultaneous sessions on rotor-bearing dynamics and turbomachinery blading will be held on the second and third days. The following topics are included in the rotor-bearing dynamics sessions: critical speeds, stability, fluid film bearing design and analysis, balancing sensitivity, generator rotor balancing, gas turbine balancing, and industrial balancing. The sessions on turbomachinery blading feature excitation and forced vibration of turbine stages, structural dynamic aspects of bladed disk assemblies, finite element analysis of turbomachinery blading, steam turbine availability, metallurgical aspects of blading, torsional-blading interaction, and field tests of turbogenerator sets. Each participant will receive a proceedings covering all seminar sessions and can attend any combination of sessions.

Contact: Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

OCTOBER

MACHINERY VIBRATION SEMINAR

Dates: October 24-26, 1978
Place: MTI, Latham, New York
Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. P.E. Babson, Mktg. Mgr., Machinery Diagnostics, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2371.

NOVEMBER

DIGITAL SIGNAL PROCESSING

Dates: November 6-10, 1978
Place: The George Washington University
Washington, D.C.
Objective: The course is designed for engineers, scientists, technical managers, and others who desire a better understanding of the theory and applications of digital signal processing. The objective of this course is to provide the participants with the essentials of the design of IIR and FIR digital filters, signal detection and estimation techniques, and the development of Fast Fourier Transform Algorithms. The applications of digital signal processing to speech processing will also be discussed. The mathematical concepts needed for understanding this course will be developed during the presentation.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

VIBRATION AND SHOCK TESTING

Dates: November 6-10, 1978
Place: Washington, D.C.
Objective: Lectures are combined with physical demonstrations: how structures behave when mechanically excited, how input and response forces and motions are sensed by pickups, how these electrical signals are read out and evaluated, also how measurement systems are calibrated. The relative merits of various types of shakers and shock machines are considered. Controls for sinusoidal and random vibration tests are discussed.

Contact: Wayne Tustin, Tustin Institute of Tech., Inc., 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 963-1124.

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

SAE MEETING TO FEATURE DYNAMIC SESSIONS

The SAE Technical Committee G-5, Aerospace Shock and Vibration, is organizing two sessions to be presented at the 1978 SAE Aerospace Engineering & Manufacturing Meeting November 27-30, 1978, Town and Country Hotel, San Diego, California. The titles of the two sessions are: Modal Vibration Testing/Analysis and Seismic Testing/Analysis. Information on the finalized program may be obtained from R.W. Mustain, Rockwell International Space Div., M.S. AB97, 12214 S. Lakewood Blvd., Downey, CA 90241.

CALL FOR PAPERS SEVENTH VIBRATION CONFERENCE DESIGN ENGINEERING DIVISION

American Society of Mechanical Engineers

The seventh biennial ASME Conference on Mechanical Vibration is scheduled to be held as part of the 1979 Design Technical Conference in St. Louis, MO on September 9-12, 1979. The St. Louis Section of ASME will be host.

The theme of this conference, like the past conferences, will be the applied aspects of vibration engineering. Emphasis will be on technology and experience associated with real apparatus, systems and problems.

Technical papers are solicited in the areas indicated below. Abstracts should be submitted to the appropriate Subcommittee Chairman on ASME Form M & P 1903 by October 1, 1978. Form M & P 1903 is available from ASME, 345 E. 47th Street, New York, NY 10017 - (212) 644-7722 or from the Subcommittee Chairmen.

Overseas contributors may obtain this form from the appropriate overseas representatives listed below. Abstracts of papers of very broad interest or which do not fall into the topic areas listed below should be submitted to the Conference Chairman.

Complete manuscripts, in quadruplicate, are due by 1 December 1978 to the Subcommittee Chairman. Accepted papers will be preprinted for the conference and will also be considered for publication in the Journal of Mechanical Design.

Conference Chairman
Professor F.C. Nelson
Department of Mechanical Engineering
Tufts University
Medford, MA 02155
(617) 628-5000 Ext. 240

Overseas Representatives
United Kingdom
Dr. D.J. Mead
Dept. of Aeronautics and Astronautics
University of Southampton
Southampton S09 5NH, England
Europe
Professor M. Lalanne
Laboratoire de Mecanique des Structures
Institut National des Sciences Appliquees de Lyon
69621 Villeurbanne, France

Representatives will also be appointed for South America, India, and Japan.

Rotating Machinery
Balancing; stability; foundation interaction; crack propagation and fatigue; synchronous and non-synchronous response; vibration control with damped rotor-bearing systems; torsional vibration

Dr. E.A. Bulanowski
Research and Advanced Product Development
DeLaval Turbine, Inc.
853 Nottingham Way
Trenton, NJ 08638
(609) 587-5000 Ext. 3526

Vibration Reduction and Control

Passive and active vibration isolators; vibration absorbers; design of dampers and damping treatments

Professor C.B. Basye
UMR Graduate Center, St. Louis
8001 Natural Bridge Rd.
St. Louis, MO 63121
(314) 453-5431

Structural Dynamics

Advances in the solution of vibratory systems; sub-structure methods; synthesis of vibrating systems; the use of calculators and mini-computers

Professor V.H. Neubert
Dept. of Engineering Science and Mechanics
Pennsylvania State University
University Park, PA 16802
(814) 865-6161

Finite Element Vibration Analysis

Finite element application to industrial problems; state-of-the-art reviews for particular industries or technical areas; novel applications of the method

Dr. J.A. Wolf, Jr.
Dr. M.M. Kamal
Engineering Mechanics Department
General Motors Research Laboratory
Warren, MI 48090
(313) 575-3357 (Wolf)
(313) 575-2929 (Kamal)

Mechanical Signature Analysis

Diagnostic techniques; defect identification; analytical and computational methods; applications to rotating machinery, structural testing, process monitoring and noise abatement

Dr. S. Braun
Research Staff
Ford Motor Company
24500 Glendale Ave.
Redford, MI 48239
(313) 533-1035 Ext. 352

Machinery Noise

Prediction methods; control of noise sources; determination of noise paths; coherence and correlation methods; spectral methods; acoustic radiation; techniques for noise reduction of machines and machine components

Dr. L.L. Faulkner
Battelle-Columbus Laboratories
505 King Avenue
Columbus, OH 43201
(614) 424-5280

Blade Vibration

Excitation mechanisms; blade and blade group vibration; blade-disc interaction; experimental measurements in stationary and rotating conditions

Professor N.F. Rieger
Department of Mechanical Engineering
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, NY 14623
(716) 475-2874

Fluid-Structure Interaction

Vortex-induced vibration; flutter; vibration caused by oscillating flows; turbulent buffeting of structures; instabilities in tube arrays; leakage-flow-induced vibration; design applications

Dr. S.D. Savkar
General Electric Co.
Research and Development Center
Building K-1, Room 5B28
Schenectady, NY 12301
(518) 385-8053

Recent Developments in the Acquisition and Analysis of Vibration Data

Acoustic emission; ultrasonic testing; holographic measurements; signal analysis; data reduction via spectral methods; shock response analysis; industrial applications

Mr. H. Saunders
General Electric Co.
Building 41, Room 319
Schenectady, NY 12345
(518) 385-0251

Special Problems in Vibration

Nonlinear vibration; random vibration; impedance methods; statistical energy analysis; seismic induced vibration; machine tool chatter

Professor J.F. Hamilton
Purdue University
Ray W. Herrick Laboratories
West Lafayette, IN 47907
(314) 749-6317

THE XIITH CONFERENCE ON MACHINE DYNAMICS

The conference will be held between April 23-27, 1979, in the High Tatra Mountains, with international participation, by the Institute of Machine Mechanics of the Slovak Academy of Sciences, in cooperation with the Institute of Thermomechanics of the Czechoslovak Academy of Sciences, the Polish Academy of Sciences and under the sponsorship of IFToMM. For further information contact the Organizing Committee, XIIth Conference on Machine Dynamics, Institute of Machine Mechanics, Slovak Academy of Sciences, 809 31 Bratislava, Czechoslovakia, Dúbravská cesta.

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

78-907

On Least Squares Approximations to Indefinite Problems of the Mixed Type

G.J. Fix and M.D. Gunzburger

Dept. of Mathematics, Carnegie-Mellon Univ., Pittsburgh, PA, Intl. J. Numer. Methods Engr., 12 (3), pp 453-469 (1978) 12 figs, 7 refs

Key Words: Least squares method, Flutter

A least squares method is presented for computing approximate solutions of indefinite partial differential equations of the mixed type such as those that arise in connection with transonic flutter analysis. In this work the method is formulated and numerical results for model problems are presented. Some theoretical aspects of least squares approximations are also discussed.

INTEGRAL TRANSFORMS

(See No. 954)

OPTIMIZATION TECHNIQUES

78-908

Optimal Design of Dynamically Loaded Continuous Structures

E.J. Haug, Jr. and T.-T. Feng

College of Engrg., The Univ. of Iowa, Iowa City, IA, Intl. J. Numer. Methods Engr., 12 (2), pp 299-317 (1978) 7 figs, 2 tables, 18 refs

Key Words: Beams, Plates, Transient response, Minimum weight design

A computational algorithm is developed and applied for optimization of beam and plate structures, subject to constraints on transient dynamic response. A continuous design formulation is retained, with dynamic response governed by partial differential operator equations. Adjoint equations are employed for sensitivity analysis and a function space gradient projection optimization approach is presented. Finite element analysis methods are applied for solution of the system dynamic and adjoint differential equations. Displacement constrained beam and plate minimum weight examples are solved, with a variety of boundary conditions.

78-909

An Advanced Structural Analysis/Synthesis Capability - ACCESS 2

L.A. Schmit and H. Miura

Univ. of California, Los Angeles, CA., Intl. J. Numer. Methods Engr., 12 (2), pp 353-377 (1978) 8 figs, 5 tables, 18 refs

Key Words: Minimum weight design, Finite element technique, Mathematical programming, Computer-aided techniques, Design techniques

An advanced automated design procedure for minimum weight design of structures (ACCESS 2) is reported. Design variable linking, constraint deletion, and explicit constraint approximation are used to effectively combine finite element and non-linear mathematical programming techniques. The approximation concepts approach to structural synthesis is extended to problems involving fibre composite structure, thermal effects and natural frequency constraints in addition to the usual static stress and displacement limitations. Sample results illustrating these new features are given.

PERTURBATION METHODS

(See No. 984)

STABILITY ANALYSIS

78-910

Nonlinear Behavior of Flutter Unstable Dynamical Systems with Gyroscopic and Circulatory Forces

P.R. Sethna and S.M. Schapiro

Dept. of Aerospace Engrg. and Mechanics, Univ. of Minnesota, Minneapolis, MN., J. Appl. Mech., Trans. ASME, 44 (4), pp 755-762 (Dec 1977) 4 figs, 18 refs

Key Words: Flutter, Dynamic stability

Postflutter behavior of nonlinear discrete dynamical systems having a combination of gyroscopic and circulatory forces are studied. The study leads to Hopf bifurcations. The method of analysis is based on the method of Hopf and the method of integral manifolds. The results of the analysis are applied to an example and the accuracy of the analysis is checked against numerical solutions of the equations of motion.

78-911
Dynamic Instability of Certain Conservative and Non-Conservative Systems
G.T.S. Done and A. Simpson
Univ. of Edinburgh, UK, J. Mech. Engr. Sci., 19 (6), pp 251-263 (Dec 1977) 5 figs, 13 refs

Key Words: Dynamic stability, Mechanical systems

This paper is concerned primarily with the analysis and resolution of the problems and contradictions that arise in the classification as conservative or non-conservative of a certain type of dynamical system. The systems concerned have equations of motion of gyroscopic type when the deflections are expressed with reference to particular co-ordinate axes, and they exhibit dynamic instability. Three examples are considered which possess their own special characteristics and subtleties; these are the rotating flexible asymmetric shaft, the helicopter ground resonance system and the clamped clamped flexible tube conveying fluid. For each of these cases, the energy input mechanism is examined and the problems of classification resolved.

78-912
On the Application of the Energy Method to the Stability Problem of Nonconservative Autonomous and Nonautonomous Systems
H.H.E. Leipholz
Dept. of Civil Engrg., Univ. of Waterloo, Waterloo, Ontario, Canada N2L 3GL, Acta Mech., 28 (1-4), pp 113-138 (1977) 10 figs, 8 refs

Key Words: Energy methods, Stability methods, Mechanical systems

The energy approach is extended to cover the stability problem of nonconservative mechanical systems. The eigenvalue curve is obtained by the condition that a certain matrix be singular, and flutter loads follow from the requirement that the derivative of the determinant of this matrix with respect to the frequency of the motion be zero.

MODELING

78-913
Vibration of Fixed-Ended Linear Chains of Discrete Point - Masses and Tri-Diagonal Secular Determinants
O.R. Ainsworth, C.K. Liu, and R.A. Mann
Univ. of Alabama, University, AL, J. Franklin Inst., 304 (2/3), pp 101-119 (Aug/Sept 1977) 4 figs, 2 refs

Key Words: Mathematical models, Coupled systems, Resonant frequencies

The properties of the secular determinants which arise in the study of harmonically coupled systems are further explored by extending the analysis to externally coupled systems. This treatment completes the modeling of such vibrating systems as long chains of point-masses with free or fixed ends. The results of the present and earlier analyses provide compact expressions for the normal frequencies of systems that in fact may be quite complex. The modeling of such vibrating systems in terms of known resonant frequencies and of the constants occurring in these expressions provides a new technique for the description of such systems.

DIGITAL SIMULATION

(Also see No. 1046)

78-914
Digital Processing of System Responses
D. Rees
Dissertation, Ph.D., Polytechnic of Wales, UK, 250 pp (1976)
UM 1/2957c

Key Words: Measurement techniques, Dynamic properties, Digital techniques, Spectrum analysis, Fourier transformation

This thesis describes an investigation into the development of techniques for the measurement of system dynamic characteristics based on digital processing methods. The techniques are developed to meet the requirements of rapid measurement time, noise and harmonic rejection capability and ease of interpretation of results. A computational procedure using spectral methods and based on the fast Fourier transform is described, which considers a pseudorandom binary sequence as a series of sine waves of 'discrete' frequencies of well defined amplitudes and phase relationships. Three computational algorithms have been considered, the discrete Fourier transform, the radix-2 fast Fourier transform, and the mixed radix fast Fourier transform.

78-915
Development of a Unified Approach to the Simulation of Static and Dynamic Behavior of Large Mobile Hydraulic Systems
S.K.R. Iyengar
Ph.D. Thesis, Oklahoma State Univ., 125 pp (1977)
UM 7801269

Key Words: Hydraulic equipment, Digital simulation

This study considers the digital simulation of large mobile hydraulic systems. The objective is to develop a unified approach to the portrayal of static and dynamic behavior of such systems. A digital simulation program based on the new canonical forms is developed and an example system analysed to illustrate its efficacy. A method for qualitative appraisal of large systems is developed and used to examine the behavior of the example system.

DESIGN TECHNIQUES

(See Nos. 909, 930)

CRITERIA, STANDARDS, AND SPECIFICATIONS

(Also see No. 1042)

78-916

Seismic Qualification of Systems, Structures, Equipment and Components

E.G. Fischer

Mechanics Dept., Westinghouse R & D Center, Pittsburgh, PA 15235, Nucl. Engr. Des., 46 (1), pp 151-168 (Mar 1978) 22 figs, 10 refs

Key Words: Nuclear power plants, Standards and codes, Seismic design

The purpose of this paper is to give an overview of the various qualification procedures available to the vendors of nuclear power plants and equipment for hopefully achieving NRC (Nuclear Regulatory Commission) plant licensing and overall guaranteed safe operation. These procedures usually involve computer-aided analyses for large systems and structures, but trend toward shaking table tests for small equipment and components.

78-917

Procedures Manual. Dynamic Stability Analysis for U.S. Navy Small Craft

J.G. Koelbel

Asset Inc., Fairfax, VA, Rept. No. 23095-1, 80 pp (Jan 1977)

AD-A047 493/2GA

Key Words: Manuals and handbooks, Ships, Dynamic structural analysis

This manual presents the procedures and background information necessary to perform a transverse dynamic stability analysis of U.S. Navy small craft.

SURVEYS AND BIBLIOGRAPHIES

78-918

Ride and Handling Dynamics of Road Vehicles (A Review of Recent Literature)

F.D. Hales

Univ. of Tech., Loughborough Leicestershire LE11 3TU, UK, Shock Vib. Dig., 10 (3), pp 3-8 (Mar 1978) 59 refs

Key Words: Reviews, Ground vehicles, Ride dynamics, Human response

This is a brief review of road vehicle ride and handling dynamics since 1975. The literature is grouped as follows: ride quality, including vehicle design, measurements of quality, human response to motions, and evaluation techniques; and handling, including tires, bicycles, automobiles, and trucks. The article concludes with a discussion of trends in vehicle ride and handling dynamics.

78-919

Linear Elastic Wave Propagation. An Annotated Bibliography: Part II

R.A. Scott

Dept. of Applied Mechanics and Engrg. Science, Univ. of Michigan, Ann Arbor, MI 48109, Shock Vib. Dig., 10 (3), pp 11-39 (Mar 1978) 429 refs

Key Words: Reviews, Elastic waves, Wave propagation

This survey of the literature on linear elastic wave propagation consists of two parts. Part I covers homogeneous isotropic media. Part II covers discretely nonhomogeneous media, continuous nonhomogeneous media, anisotropic media, and diffraction.

78-920

Parametric Vibration. Part III. Current Problems (1)

R.A. Ibrahim

Arab Organisation for Industrialisation, Sakr Factory for Developed Industries, P.O. Box 33, Heliopolis, Cairo, Egypt, Shock Vib. Dig., 10 (3), pp 41-57 (Mar 1978) 204 refs

Key Words: Reviews, Parametric vibration, Structural members, Rods, Beams, Pipes (tubes), Plates, Shells

This survey of the theory of parametric vibration and its related current problems consists of five review articles. The titles are: I. Mechanics of Linear Problems, II. Mechanics of Nonlinear Problems, III. Current Problems (1), IV. Current Problems (2), V. Stochastic Problems. Current problems having to do with the free surface of liquids in closed containers; rods, beams, and pipes, plates; and shells are reviewed in this article.

78-921
Automobile Safety: Seat Belts (A Bibliography with Abstracts)
M.E. Young
National Tech. Information Service, Springfield, VA, 191 pp (Dec 1977)
NTIS/PS-77/1146/8GA

Key Words: Bibliographies, Automobiles, Seat belts, Collision research (automotive)

The development and use of passive safety restraint systems in motor vehicles are abstracted in the bibliography.

78-922
Automobile Safety: Bumpers (Citations from the NTIS Data Base)
M.E. Young
National Tech. Information Service, Springfield, VA, 56 pp (Dec 1977)
NTIS/PS-77/1147/6GA

Key Words: Bibliographies, Automobiles, Bumpers, Energy absorption, Crashworthiness, Collision research (automotive)

The energy absorption qualities of automobile bumpers play an important part in vehicle safety programs. Federally-funded reports on bumper tests, design, materials, and crashworthiness are cited in the bibliography.

TUTORIAL

78-923
Research Activities of the Institute of Sound and Vibration Research. Annual Report for the Year Ending March 1977
Inst. of Sound and Vibration Research, Southampton Univ, UK, 43 pp (1977)
N78-14446

Key Words: Test facilities

Activities are reported in the following fields: fluid dynamics and acoustics, automotive noise, operational acoustics and audiology, structural dynamics, and industrial noise and condition monitoring.

MODAL ANALYSIS AND SYNTHESIS

78-924
A Modal Analysis for the Damped Linear Gyroscopic Systems
H.B. Hablani and S.K. Shrivastava
Indian Inst. of Science, Bangalore 560012, India, J. Appl. Mech., Trans. ASME, 44 (4), pp 750-754 (Dec 1977) 2 figs, 10 refs

Key Words: Damped structures, Modal analysis

A modal analysis of a flexible linear damped gyroscopic system is developed here. The simple structure of the corresponding real constant generally nonsymmetric dynamic matrix allows the use of the biorthogonality relation and dual-expansion theorem for a linear operator in a vector space. A closed-form response to both periodic forces and general initial conditions is thus obtained. The method is illustrated by deriving the response of an inertially coupled gravity-stabilized pervasively damped satellite.

78-925
Dynamic Response of Linear Damped Continuous Structural Members
J.S. Strenkowski
Ph.D. Thesis, Univ. of Virginia, 244 pp (1977)
UM 7800446

Key Words: Modal analysis, Structural members, Damped structures, Beams, Plates, Shells, Shafts

This dissertation presents a comprehensive theory for the dynamic response of continuous damped structural members using a modal analysis. The theory involves a general formulation which depends only on the equations of motion and is independent of any particular structural member. This general framework includes all present linear models of damping, non-homogeneous boundary and in-span conditions, and arbitrary forcing functions, all of which are appropriate for both self-adjoint or non-self-adjoint systems of equations. Several structural members are presented to illustrate application of this general theory in determining the dynamic response. These members include beams, plates, shells, and rotating shafts.

COMPUTER PROGRAMS

GENERAL

78-926

Hybrid Structures of Revolution

D. Bushnell

Palo Alto Research Lab., Lockheed Missiles and Space Co., Inc., Palo Alto, CA, Rept. No. LMSC-D564369, 75 pp (Sept 1977)

AD-A047 982/4GA

Key Words: Eigenvalue problems, Computer programs, BOSOR (computer program)

This report consists of a brief description of the implementation of a new equation solving and eigenvalue extraction package into BOSOR6 (a program for the analysis of hybrid structures of revolution) and a new user's manual for BOSOR4.

78-927

The Effects of External Stores on the Flutter of a Non-Uniform Cantilever Wing

V.C. Sherrer

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/GAE/AA/77D-13, 104 pp (Dec 1977)

AD-A048 360/2GA

Key Words: Wing stores, Aircraft wings, Flutter, NASTRAN (computer program), Computer programs, Finite element techniques

A computer study of the effects of external stores simulated by lumped masses was conducted with a finite element, cantilever, nonuniform wing model. The NASTRAN (Level 16.0) computer program flutter format was used to obtain flutter speeds and frequencies.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 949, 989, 1009, 1010, 1013)

78-928

Optimum Design of Structures of Composite Materials in Response to Aerodynamic Noise and Noise Transmission

J.C.S. Yang and C.Y. Tsui

Maryland Univ., College Park, MD, Rept. No. NASA-CR-155332, 48 pp (Dec 9, 1977)

N78-13132

Key Words: Sound waves, Wave propagation, Wave attenuation, Composites

Elastic wave propagation and attenuation in a model fiber matrix was investigated. Damping characteristics in graphite epoxy composite materials were measured. A sound transmission test facility suitable to incorporate into NASA Ames wind tunnel for measurement of transmission loss due to sound generation in boundary layers was constructed. Measurement of transmission loss of graphite epoxy composite panels was also included.

78-929

Aircraft Noise and Structural Vibration

J. Wesler

S/V, Sound Vib., 12 (2), pp 24-28 (Feb 1978) 8 figs, 1 table, 7 refs

Key Words: Aircraft noise, Acoustic excitation, Vibration response, Buildings

Noise-induced structural vibration is one potential impact from Concorde SST operations into U.S. airports. Noise measurements made during the first 12 months of Concorde SST operations at Dulles International Airport are examined to compare the potential for such impacts by the Concorde SST and conventional subsonic long-range aircraft, for a "worst-case" location directly under the approach path.

78-930

Coupled Vibration of a Cylindrical Shell for Radiating High Intensity Ultrasound

E. Mori and K. Yamakoshi

Research Lab. of Precision Machinery and Electronics, Tokyo Inst. of Tech., Nagatsuta, Midoriku, Yokohama 227, Japan, Ultrasonics, 16 (2), pp 81-83 (Mar 1978) 5 figs, 3 refs

Key Words: Cylindrical shells, Acoustic radiation, Coupled response

The coupled vibrations of a cylindrical shell were analyzed by a new method that we called 'the apparent-elasticity method'. Several types of radiators using cylindrical shells were designed on the basis of analytical results and several acoustical characteristics were measured. The analytical results were compared to experimental data.

78-931

Radiated Power and Radiation Loading of Cylindrical Surfaces with Nonuniform Velocity Distributions

P.R. Stepanishen

Dept. of Ocean Engrg., Univ. of Rhode Island, Kingston, RI 02881, J. Acoust. Soc. Amer., 63 (2), pp 328-338 (Feb 1978) 11 figs, 12 refs

Key Words: Interaction: solid-fluid, Cylinders, Vibrating structures, Fluid-induced excitation, Sound waves

A general approach is presented to evaluate the radiation loading and radiated power from a nonuniform harmonically vibrating surface on an infinite cylinder. The approach utilizes a combined Green's function and Fourier integral technique to develop integral expressions for the generalized radiation impedance and power radiated from the surface.

78-932

Sound Radiation from an Accelerated or Decelerated Sphere

A. Akay and T.H. Hodgson

Center for Acoustical Studies, North Carolina State Univ., Raleigh, NC 27607, J. Acoust. Soc. Amer., 63 (2), pp 313-318 (Feb 1978) 6 figs, 20 refs

Key Words: Spheres, Sound waves, Wave propagation

A careful review of the current literature has led to a more complete theoretical analysis of the sound radiation from an accelerated or decelerated sphere. The acoustic field has been calculated for an accelerated sphere in an arbitrary fluid medium, which shows the effect of the fluid density on the radiated sound pressure. The radiated sound pressure from an impulsively accelerated sphere has been compared with a finite acceleration case in order to emphasize the effect of the rate of change of velocity on the pressure waveform. Energy calculations have been made in both the time and frequency domains in order to identify the sources of radiated acoustic energy and the stored nearfield energy and also to demonstrate conclusively that the energy lost in the acceleration or deceleration is dissipated as sound.

PERIODIC

(See No. 1056)

SEISMIC

(Also see Nos. 916, 959, 985, 986, 1022, 1023, 1024, 1025, 1026, 1038, 1043, 1044)

78-933

Simulation of Strong Earthquake Motion with Explosive Line Source Arrays

G.R. Abrahamson, H.E. Lindberg, and J.R. Bruce

Stanford Research Inst., Menlo Park, CA, Rept. No. NSF/RA-770306, 52 pp (Oct 1977)
PB-275 220/2GA

Key Words: Simulation, Earthquakes

This report describes an experimental investigation of the feasibility of simulating strong earthquake motion with contained explosive line source arrays. The technique consists of detonating a plane array of vertical line sources placed in the vicinity of the structure to be tested. Reusable hardware was developed for producing contained explosions in a 1/3-scale source, instrumentation was incorporated for hardware diagnostics and output measurements, reasonable acceleration and frequencies were obtained in soil with the 1/3-scale source, and repeatable results were demonstrated.

SHOCK

(Also see Nos. 956, 999, 1000, 1021, 1049)

78-934

Reflectionless Passage of a Hyperdetonation Shock Wave Through a Jump-Like Nonhomogeneity

S. Kaliski

Inst. of Plazma Physics and Lazer and Microsynthesis, P.O. Box 49, 00-908, Warsaw 49, Poland, Bull. Acad. Polon. Sci., Ser. Sci. Tech., 25 (10), pp 333-336, 953-956 (1977) 6 refs

Key Words: Shock wave propagation

Conditions of reflectionless passage of a plane hyperdetonation shock wave through a jump-like nonhomogeneity are established. Analogous solutions for an ordinary shock wave are discussed as a limiting case. The problem considered are auxiliary problems for thermonuclear microfusion of the explosion type.

78-935

Tactical Implications of Air Blast Variations from Nuclear Tests

J.E. Cockayne and E.V. Lofgren

Science Applications, Inc., McLean, VA, Rept. No. SAI-76-677-WA, DNA-4246F, AD-E300 069, 160 pp (Nov 30, 1976)

AD-A048 802/3GA

Key Words: Nuclear explosion effects, Damage prediction

The objective was to assess the rationale for additional nuclear tests which would produce a better predictive capability for tactical blast environments. The work described herein includes the following: refinement and concise synopsis of the theoretical and empirical basis for the rationale assessment; testing of the assumption of a lognormal distribution for the measurements; and an analysis of variance for some blast data to ascertain if systematic errors (biases) could exist which might require additional measurements.

78-936

Feasibility of Using HE in Model Tests of Structures

S.J. Hung, J.L. Merritt, and K.D. Seifert

Merritt Cases, Inc., Redlands, CA, Rept. No. 76-011-T1, DNA-4219F, SBIE-AD-E300 061, 71 pp (Apr 1, 1977)

AD-A047 976/6GA

Key Words: Underground structures, Model testing, Explosions, Underground explosions

This report presents the results of examining the feasibility of using gun propellants to obtain desirable pressure sources for model tests of deep-based facilities. Numerous calculations and experiments were performed.

78-937

An Overview of Major Aspects of the Aircraft Impact Problem

H. Kamil, N. Krutzik, G. Kost, and R. Sharpe

Tech. Dev., Engrg. Decision Analysis Co., Inc. (EDAC), 480 California Ave., Suite 301, Palo Alto, CA 94306, Nucl. Engr. Des., 46 (1), pp 109-122 (Mar 1978) 13 figs, 60 refs

Key Words: Crash research (aircraft), Nuclear power plants

This paper identifies the major aspects of the aircraft impact problem and spotlights the most relevant topics for future investigations. The emphasis is on three main topics: modeling techniques, influence of non-linear behavior, and importance of damping in the dynamic structural response analyses for aircraft impact loading. Results are presented from brief studies involving response of linear and nonlinear simple systems to short-duration impulsive loadings of the aircraft impact type. An extensive literature survey is carried out on several major topics pertinent to the aircraft impact problem, encompassing various disciplines of engineering. Results and discussions on the basis of this literature survey are presented for major topics.

PHENOMENOLOGY

COMPOSITE

(Also see No. 953)

78-938

Longitudinal Heat Propagation in Three-Phase Laminated Composites at High Exciting Frequencies

G. Horvay, B. Gold, and E.S. Kaczenski

Univ. of Massachusetts, Amherst, MA, ASME Paper No. 77-WA/HT-10

Key Words: Composite materials, High frequency excitation, Harmonic excitation

The rapid variation of temperature near the interfaces in a 2-material MFMFM....-type composite, harmonically excited at the edge is examined with a binder layer B, of volume fraction f_B, between matrix M (volume fraction f_M) and filler F (volume fraction f_F), creating an MBFBMB....-type composite. The role such a binder plays in affecting heat propagation is discussed.

78-939

A Mechanical Model for Fiber-Reinforced and Particulate Composites

D. Turhan

Dept. Engrg. Sciences, Middle East Tech. Univ., Ankara, Turkey, Acta Mech., 28 (1-4), pp 219-238 (1977) 5 figs, 18 refs

Key Words: Composite materials, Fiber composites, Mathematical models, Harmonic waves, Wave propagation

A set of displacement equations of motion suitable for describing the dynamic behavior of composite materials is derived. The composite material may be a fiber-reinforced composite or a particulate composite. The composite is represented by a lattice model in which the continuous mass distribution of the actual body is replaced by a system of springs attached to small rigid masses. Effective values are determined for the masses of the rigid bodies and the stiffnesses of the springs.

ELASTIC

78-940

The Torsional Analysis of Steady State and Transient Wave Propagation in Elastic Cylinders

C. Ni

Ph.D. Thesis, Tennessee Tech. Univ., 103 pp (1975)

UM 7801450

Key Words: Torsional response, Wave propagation, Cylinders, Elastic properties

A number of different investigations concerning torsional wave propagation in elastic materials were developed. The propagation of transient waves in a semi-infinite circular rod was examined in detail, both analytically and numerically. A double-integral transform was presented as a means of formulating an exact solution in which a torsional shear stress was applied to the end surface for a cylindrical rod. The numerical solution was obtained based upon the method of characteristics. The resulting compatibility equations were in a form suitable for solution by a method of finite differences.

FATIGUE

78-941

Random Load Simulation in Laboratory Fatigue Testing

J.M Lee and K.G. McConnell

Seoul National Univ., Seoul, Korea, SAE Paper No. 780101, 16 pp, 13 figs, 21 refs

Key Words: Fatigue tests, Random excitation, Simulation

This paper presents the theory and hardware to simulate non-loglinear spectra (the typical field case), including a unique method of eliminating low amplitude reversals so that any service load history of high cycle fatigue can be simulated in a laboratory fatigue test. The feasibility of the proposed quasi-stationary random process to simulate the three standard SAE load histories on a statistical basis is demonstrated on both the theoretical and experimental basis.

78-942

High-Frequency Torsional Oscillations - I. Penny-Shaped Crack in an Inhomogeneous Medium

O.D. George

Dept. of Mathematics, Univ. of Calabar, Calabar, Nigeria, Intl. J. Engr. Sci., 16 (2), pp 109-122 (1978) 14 refs

Key Words: Torsional vibration, High frequency response, Cracked media, Discontinuity-containing media

The problem of an inhomogeneous medium, whose shear modulus and density vary exponentially with radius, containing a penny-shaped crack undergoing high-frequency torsional oscillations is reduced asymptotically to Wiener-Hopf integral equation and solved by Carleman's method. Uniformly valid asymptotic results are obtained. Explicit expressions are derived for the normal displacement gradient outside the crack region, the stress-intensity factor and the energy of the crack.

78-943

High-Frequency Torsional Oscillations - II. The Reissner-Sagocci Problem at High Frequencies

O.D. George

Dept. of Mathematics, Univ. of Calabar, Calabar, Nigeria, Intl. J. Engr. Sci., 16 (2), pp 123-129 (1978) 10 refs

Key Words: Torsional vibration, High frequency response, Discontinuity-containing media

The Reissner-Sagocci problem at high-frequencies for an elastic medium with exponentially varying shear modulus and density in the radial direction is asymptotically reduced to a Wiener-Hopf integral equation whose solution is obtained by Carleman's method. Uniform asymptotic results are obtained. Explicit results are given for the displacement outside the rigid disc, the moment of the applied forces necessary to oscillate the disc, and the amplitude of oscillation of the disc.

FLUID

(Also see Nos. 907, 975, 976, 1033)

78-944

Added Mass Computation by the Boundary Integral Method

J.A. Deruntz and T.L. Geers

Lockheed Palo Alto Research Lab., Palo Alto, CA, Intl. J. Numer. Methods Engr., 12 (3), pp 531-549

(1978) 9 figs, 3 tables, 16 refs

Key Words: Interaction: structure-fluid, Submerged structures, Finite element technique

Computational techniques for the treatment of fluid-structure interaction effects by discrete boundary integral methods are examined. Attention is focused on the computation of the added mass matrix by finite element methods for a structure submerged in an infinite, inviscid, incompressible fluid. A general computational procedure is presented that is based upon a variational approach involving the assumption of constant source strength over each surface element. This is followed by an analysis of the discretization error for a spherical body that is then used to develop a hierarchy of computational schemes. These schemes are then evaluated numerically in terms of 'fluid boundary modes' for a submerged spherical surface.

78-945

The Effect of Fluid Viscosity on Coupled Tube/Fluid Vibrations

T. Yeh and S. Chen

Components Tech. Div., Argonne National Lab., Argonne, IL, Rept. No. ANL-CT-77-24, 37 pp (Apr 1977) 10 figs, 6 refs

Sponsored by Div. of Reactor Dev. and Demonstration, U.S. Energy Res. and Dev. Administration

Key Words: Interaction: structure-fluid, Fluid-induced excitation, Nuclear reactors

Many reactor systems contain small gaps between various structural and mechanical components to accommodate thermal expansion. These gaps usually contain viscous fluid, which affects dynamic characteristics of the components. The authors investigate the effect of fluid viscosity on coupled vibration.

78-946

Predicting Sonic Vibration in Cross Flow Heat Exchangers - Experience and Model Testing

J.D. Rogers and C.A. Penterson

C-E Power Systems, Combustion Engineering, Inc., Windsor, CT, ASME Paper No. 77-WA/DE-28

Key Words: Heat exchangers, Fluid-induced excitation, Model testing

In this paper, the currently accepted sonic vibration design criteria are reviewed and then compared to boiler field data. The initial results from a laboratory test program that was undertaken to improve design criteria are presented. Alternate design criteria are offered.

78-947

Flow-Induced Tube Vibrations in Shell-and-Tube Heat Exchangers

J.M. Chenoweth

Heat Transfer Res., Inc., Alhambra, CA, Rept. No. SAN-1273-1, 166 pp (Feb 1977)

N78-13487

Key Words: Heat exchangers, Shells, Tubes, Fluid-induced excitation

The results of the presentations and discussions on flow-induced tube vibrations among fourteen panelists and the audience are summarized. Areas for both short term and long term research were identified and recommendations made. Prepared statements by each of the panelists, statements by others, a background technical report, a bibliography, and a list of workshop attendees are included as appendices.

78-948

Possibilities of Reducing Noise from Hydraulic Valves

G. Schmid

British Library Lending Div., Boston Spa, UK, Rept. No. BLL-NEL-TT-2737-(6075.461), 13 pp (1977) (Engl. transl. from Oelhydraulic and Pneumatic, 21 (2), pp 89-91, 1977)

N78-14405

Key Words: Hydraulic valves, Fluid-induced excitation, Noise reduction

Noise emission from hydraulic valves cased by intermittent flow processes which arise at restriction point and/or by pressure pulsations caused by the pump was examined. A simple procedure is described for calculating the acoustic response level of a hydraulic valve through liquid sound.

78-949

Prediction of Noise Aerodynamically Generated by Control Valves

N. Mirizzi, R. Stella, and D. Marino

Universita di Bari, Bari, Italy, ISA Transactions, 16 (4), pp 19-22 (1977) 3 figs, 6 refs

Key Words: Valves, Noise prediction, Fluid-induced excitation

An analysis of control valve noise is developed. The study considers the total sound pressure level aerodynamically generated by the fluid flow through the control valves. In this analysis the noise generated is assumed to be part of the mechanical power lost from the inlet to the outlet section of a valve. The analysis starts with a mathematical formulation of the mechanical power lost, expressing it only in measurable quantities.

SOIL

78-950
Soil-Pile Interaction Under Vibratory Loading
T. Nogami
Ph.D. Thesis, The Univ. of Western Ontario (Canada) (1977)

Key Words: Interaction: soil-structure, Pile foundations, Stiffness coefficients, Damping coefficients

When dynamic loadings are applied to the structure supported by a pile foundation, the pile foundation resists the movement of the structure relative to that of the ground. Thus, the pile foundation provides the stiffness and damping to the structure. The characteristics of stiffness and damping resulting from dynamic soil-pile interaction were not known. This work was concerned with this problem.

EXPERIMENTATION

BALANCING

78-951
Balancing of a Flexible Rotor (The Fifth Report, Vibration and Balancing of a Flexible Rotor on Flexible Bearing with Viscous Damping)
K. Shimada, S. Miwa, and T. Nakai
Aoyama-Gakuin Univ., Tokyo, Japan, Bull. JSME, 21 (151), pp 44-50 (Jan 1978) 7 refs

Key Words: Balancing techniques, Flexible rotors, Rotor-bearing systems, Viscous damping

Unbalanced vibration of a flexible rotor supported on two bearings is analyzed for the case of flexible support with viscous damping. The analytical solution is obtained by using the concept of 'forced mode'. The condition, as well as a possible procedure to balance such a rotor is theoretically demonstrated.

DIAGNOSTICS
(Also see No. 957)

78-952
Using Signature Analysis for Maintenance Planning
Turbomachinery International, 19 (2), pp 42-45 (Mar 1978)

Key Words: Signature analysis, Rotating structures, Diagnostic techniques

Troubleshooting rotating machinery dynamics related problems through observation and analysis of vibration characteristics, or signatures, is a widely accepted and rapidly developing procedure. As the skills and instrumentation used to analyze ever more complex problems emerge, more emphasis is being placed upon systems and techniques which identify incipient failure modes of operation.

78-953
The Characteristics of Acoustic Emission Pulse from Fiber-Reinforced Composite
E. Altus and A. Rotem
Faculty of Mech. Engrg., Technion -- Israel Inst. of Tech., Haifa, Israel, Israel J. Tech., 15 (1-2), pp 79-87 (1977) 12 figs, 1 table, 6 refs

Key Words: Fiber composites, Failure analysis, Acoustic techniques

The failure process of fiber-reinforced materials is analyzed by acoustic emission. The energy emitted from crack development is predicted by analyzing a micro-mechanic model of fracture.

EQUIPMENT

78-954
Dynamic Analysis of a High-Speed Electrohydraulic Transient Rod Drive System
F.E. LeVert
Argonne National Lab., Argonne, IL, ASME Paper

No. 77-WA/F1cs-8

Key Words: Spectral energy distribution, Fast Fourier transform, Electrohydraulic system

A nonlinear model for a fast-response electrohydraulic servosystem is developed which allows for both large and small signal analyses. The model is designed to simulate piston operations at and away from the vertical center of the actuator column. The system model is subjected to a variety of inputs to determine its dynamic characteristics. Spectra densities of acceleration time histories generated for various input step demands are examined using the Fast Fourier Transform Technique.

78-955

A New Test Rig for Truck Tires under Extreme Conditions (Ein neuer Prüfstand für Nutzfahrzeugreifen)

B. Heissing and H. Miksch

Meerssener Str. 8, 5100 Aachen, Germany, Automobiltech. Z., 80 (1), pp 5-8 (Jan 1978) 7 figs, 4 refs

(In German)

Key Words: Test stands, Truck tires

At the Institute for Automobile Engineering of the Technical University of Aachen a 40 kN Research Facility has been installed to measure the characteristics of truck tires under normal and extreme conditions. Its construction has been carried out especially to test tires on concave, flat and convex tracks.

FACILITIES

(Also see No. 1039)

78-956

Water Impact Shock Test System

SECO-DYN, Inc., Pomona, CA, Rept. No. NASA-CR-150473, 85 pp (Nov 10, 1977)

N78-13365

Key Words: Test facilities, Shock tests

The basic objective was to design, manufacture, and install a shock test system which, in part, would have the ability to subject test articles weighing up to 1,000 pounds to both half sine and/or full sine pulses having peak levels of up to 50 G's with half sine pulse durations of 100 milliseconds or full sine period duration of 200 milliseconds. The tolerances associated with the aforementioned pulses were +20% and -10% for the peak levels and plus or minus 10% for the pulse durations. The subject shock test system was to be capable of accepting test article sizes of up to 4 feet by 4 feet mounting surface by 4 feet in length.

INSTRUMENTATION

78-957

A Practical Vibration Primer. Part 7 - Instrumentation for Analysis

C. Jackson

Monsanto Chemical Intermediates Co., Texas City, TX, Hydrocarbon Processing, 57 (3), pp 119-124 (Mar 1978) 19 figs

Key Words: Diagnostic techniques, Test equipment and instrumentation

The amount and type of instrumentation necessary to perform vibration analysis of rotating equipment is discussed.

SIMULATORS

(See No. 933)

TECHNIQUES

(See No. 936)

COMPONENTS

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 908, 977, 979)

78-958

Unstable Vibrations and Buckling of Rotating Flexible Rods

W.D. Lakin and A. Nachman

Univ. of Toronto, Canada. Q. Appl. Math., 35 (4), pp 479-493 (Jan 1978) 4 figs, 16 refs

Key Words: Rods, Rotating structures, Flexural vibration, Rotors

A group of fourth-order boundary-value problems associated with the small vibrations or buckling of a uniform flexible rod which is clamped at one end and rotates in a plane perpendicular to the axis of rotation is considered. The vibrations may be in any plane relative to the plane of rotation and the rod is off-clamped, i.e., the axis of rotation does not pass through the rod's clamped end.

78-959

Theoretical Study on Earthquake Response of a Reinforced Concrete Chimney

T.Y. Yang, L.C. Shiau, and H. Lo

School of Aeronautics and Astronautics, Purdue Univ., Lafayette, IN, Rept. No. NSF/RA-760716, 96 pp (June 3, 1976)

PB-274 820/0GA

Key Words: Chimneys, Reinforced concrete, Earthquake response

A detailed dynamic analysis, presented in a series of reports, was conducted on the seismic response and structural safety of key subsystems (steam generator, high pressure steam piping, coal handling equipment, cooling tower, chimney) of Unit no. 3 of TVA at Paradise, Kentucky. Analytical and experimental methods are used on the chimney and its dynamic responses were analyzed by modal superposition.

78-960

Theoretical Study of the Earthquake Response of the Paradise Cooling Tower

T.Y. Yang, C.S. Gran, and J.L. Bogdanoff

School of Aeronautics and Astronautics, Purdue Univ., Lafayette, IN, Rept. No. NSF/RA-760715, 81 pp (June 1976)

PB-274 816/8GA

Key Words: Electric power plants, Cooling towers, Earthquake resistant structures

A detailed dynamic analysis, presented in a series of reports, was conducted on the seismic response and structural safety of key subsystems (steam generator, high pressure steam piping, coal handling equipment, cooling tower, chimney) of Unit no. 3 of TVA at Paradise, Kentucky. Analytical and experimental methods are used. In this study, the dynamic behavior of the cooling tower is analyzed, using quadrilateral plate and beam elements oriented arbitrarily in space, following analysis and confirmation of their predictive value. Response to 1940 El Centro earthquake parameters is studied, and assumed viscous damping coefficients are considered. Comprehensive results, based on this response, are given.

78-961

Introduction to Wiener-Hopf Methods in Acoustics and Vibration

D.G. Crighton

Dept. of Mech. Engrg., Catholic Univ. of America, Washington, D.C., Rept. No. DTNSRDC-77-0112, 92 pp (Dec 1977)

AD-A048 766/0GA

Key Words: Wiener-Hopf technique, Strings, Beams, Wave propagation, Elastic waves, Vibration response

The report deals with the application of Wiener-Hopf methods to one-dimensional wave motions on strings and beams, and in particular with the reflection and transmission from discontinuities in the mechanical properties of a string. Also included is a section illustrating how a generalized Wiener-Hopf problem can be set up for a three-part problem involving a string of finite length.

78-962

Forced Flexural Vibrations of an Elastic Beam Supported by an Elastic Half-Space

H. Saito and H. Wada

Faculty of Engrg., Tohoku Univ., Sendai, Japan, Bull. JSME, 21 (151), pp 51-55 (Jan 1978) 5 figs, 6 refs

Key Words: Forced vibrations, Flexural vibrations, Beams, Elastic properties, Half-space

This paper analyzes the plane stress problem of flexural vibrations of an elastic beam supported by an elastic half-space and subjected to a sinusoidally varying force at the free end of the beam.

78-963

Transverse Vibrations of Cantilever Beams Having Unequal Breadth and Depth Tapers

B. Downs

Dept. of Mech. Engrg., Loughborough Univ. of Tech., Loughborough, Leicestershire, LE11 3TU, UK, J. Appl. Mech., Trans. ASME, 44 (4), pp 737-742 (Dec 1977) 6 figs, 9 tables, 27 refs

Key Words: Cantilever beams, Variable cross section, Wedges, Flexural vibration

Natural frequencies of doubly symmetric cross section, isotropic cantilever beams, based on both Euler and Timoshenko theories, are presented for 36 combinations of linear depth and breadth taper. Results obtained by a new dynamic discretization technique include the first eight frequencies for all geometries and the stress distribution patterns for the first four (six) modes in the case of the wedge. Comparisons are drawn wherever possible with exact solutions and with other numerical results appearing in the literature.

78-964

Numerical Simulation of the Air Blast Response of Tapered Cantilever Beams

G.V. Price

Defence Res. Establishment, Suffield, Ralston, Alberta, Canada, Rept. No. DRES-TECHNICAL PAPER-447, 46 pp (Nov 1977)

AD-A048 356/0GA

Key Words: Antennas, Cantilever beams, Variable cross section, Blast response

A numerical procedure is developed to predict the elastic response of variable cross-section cantilever beams when subjected to a transient air blast load.

78-965

Blast Response of 35 Ft. Fibreglass Whip Antenna - Event Dice Throw

G.V. Price and C.G. Coffey

Defence Res. Establishment, Suffield, Ralston, Alberta, Canada, Rept. No. DRES-TECHNICAL PAPER-448, 48 pp (Nov 1977)

AD-A048 357/8GA

Key Words: Antennas, Blast response, Cantilever beams

The blast response of 35 ft fibreglass Whip Antennas was investigated in a free-field blast trial and in numerical simulation experiments.

78-966

Cable Strumming Suppression

B.E. Hafen and D.J. Meggitt

Civil Engrg. Lab. (Navy), Port Hueneme, CA., Rept. No. CEL-TN-1499, 103 pp (Sept 1977)

AD-A047 996/4GA

Key Words: Cables, Vortex-induced vibration, Vibration damping

This report presents a consolidation of existing data on various devices used to suppress vortex-induced motions of cables and circular cylinders in the ocean. The types of devices discussed herein include 'fringe,' 'hair,' and ribbon flexible fairings and helical ridges.

78-967

Dynamic Moduli of Continuous Filament Yarns Subjected to Low Frequency Excitation Superimposed on High Initial Longitudinal Strain

Z.P. Smith

Ph.D. Thesis, North Carolina State Univ. at Raleigh, 134 pp (1977)

UM 7729645

Key Words: Strings, Viscoelastic properties, Low frequencies

The results of an experimental and theoretical investigation into the dynamic viscoelastic properties of twisted continuous filament yarn subject to low frequency longitudinal strain superimposed on high initial strain are reported. The object is to relate the effective dynamic mechanical properties of twisted yarn to the dynamic mechanical properties of the constituent filaments and the geometry of the filaments in the structure.

BEARINGS

78-968

The Active Magnetic Bearing – A Revolutionary Principle

H. Habermann and G. Liard

Ball Bearing J., 192, pp 1-7 (1977) 5 figs

Key Words: Bearings, Electromagnetic properties

The active electromagnetic bearing consists of a moving body (the rotor) which is kept in the desired position relative to a stationary body (the stator) by means of a magnetic field, produced by electromagnets mounted on the stator. Integral sensors monitor the position of the rotor continuously. The sensor signals adjust the currents passing through the electromagnets and thus the strength of the magnetic field by means of an electronic control system. The active magnetic bearing is characterized by rotation without mechanical contact, resulting in noiseless operation and no wear. Very high speeds can be permitted and excellent running accuracy achieved. The bearing can operate in a vacuum as well as in a corrosive environment and can also withstand extreme temperatures.

78-969
Experimental Studies on Ball Bearing Noise
V.D. Jayaram and F. Jarchow
Lehrstuhl für Maschinenelemente und Getriebetechnik, Ruhr-Universität, Bochum, Germany, Wear, 46 (2), pp 321-326 (Feb 1978) 7 figs, 9 refs

Key Words: Ball bearings, Noise generation

The effect of the operating speed and the imposed load on the noise characteristics of commercially available ball bearings was studied at different speeds and loads using various lubricants.

78-970
A Finite Element Dynamic Analysis of Pressure Dam and Tilting Pad Bearings
J.C. Nicholas
Ph.D. Thesis, Univ. of Virginia, 256 pp (1977)
UM 7800439

Key Words: Fluid film bearings, Finite element technique

Systems of finite elements are organized using matrix notation for finite length bearings. Most fluid film bearings have surface areas which can be divided into a grid of elements whose nodes are labeled in matrix form. The resulting equations for nodal pressures are block tridiagonal and the solution is easily obtained with direct methods.

78-971
Effect of Recess Geometry on Shock Wave Formation in Circular Gas Bearings
E. Salem and W. Kamal
Faculty of Engrg., Mech. Engrg. Dept., Alexandria Univ., Alexandria, Egypt, Wear, 46 (2), pp 351-366 (Feb 1978) 13 figs, 7 refs

Key Words: Gas bearings, Shock waves, Mathematical models

An analytical method, based on the concept of shock wave formation in the bearing clearance, is used to develop a mathematical model by which the pressure distribution along the fluid film can be predicted. Based on this model, the limiting conditions for shock free operation are determined. The effects of recess geometry and inlet gas conditions are analyzed. Experimental pressure distributions along the fluid film at different values of film thickness, supply pressure and rotating speed are reported.

78-972
The Journal Bearing Considering Cavitation and Dynamic Stability
G. Lundholm
Dissertation Ph.D., Lunds Universitet, Sweden, 8 pp (1972)
UM 1/2932c

Key Words: Journal bearings, Dynamic stability

The investigations presented here are the summaries of two papers, and concern the following: hydrodynamic lubrication of the circumferential groove and axial groove journal bearings. Locations of cavitation regions are determined by continuity-of-flow conditions. All bearing characteristics, including borderlines for dynamic stability are determined for a large variety of cases.

BLADES

78-973
The BARBEY Report. An Investigation into Controllable Pitch Propeller Failures from the Standpoint of Full-Scale Underway Propeller Measurements
C. Noonan, G. Antonides, A. Zaloumis, B. Corbin, and R. Schauer
David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD, Rept. No. DTNSRDC-77-0080, 293 pp (Aug 1977)
AD-A047 851/1GA

Key Words: Marine propellers, Propeller blades, Failure analysis, Experimental data

This report reviews experience with Controllable Pitch Propellers (CPP). Two ships of the FF-1052 class were fitted out with CPP's for test and evaluation.

78-974
Effect of Slip on Response of a Vibrating Compressor Blade
D.I.G. Jones
Wright-Patterson AFB, OH, ASME Paper No. 77-WA/GT-3

Key Words: Compressor blades, Vibrating structures, Modal analysis, Harmonic excitation

The aim of this paper is to develop a simple analytical model of a vibrating blade, using modal analysis and allowing for slip at the root and to show that the analysis accurately predicts the observed behavior of a specific blade under harmonic excitation. Criteria are obtained for determining the minimum frictional force needed to avoid infinite amplitudes under high level excitation.

CYLINDERS

78-975

Crossflow-Induced Vibration of a Row of Circular Cylinders in Water

H. Halle and W.P. Lawrence

Argonne National Lab., Argonne, IL, ASME Paper No. 77-JPGC-NE-4

Key Words: Cylinders, Submerged structures, Flow-induced vibration

A row of five flexible-cylindrical test elements was exposed to cross (transverse) flow of water as part of a program to study the dynamic response of heat exchanger tubes. The amplitudes and frequencies of the flow-induced vibrations were measured as a function of flow velocity. A total of nine test cases, obtained by combinations of different element spacings and element natural frequencies, were investigated.

78-976

Flow-Induced Vibrations of Circular Cylindrical Structures

S. Chen

Components Tech. Div., Argonne National Lab., Argonne, IL, Rept. No. ANL-CT-77-32, 47 pp (June 1977) 1 fig, 234 refs

Sponsored by Div. of Reactor Dev. and Demonstration, U.S. Energy Res. and Dev. Administration

Key Words: Circular cylinders, Fluid-induced excitation

This report reviews the problems of flow-induced vibrations of circular cylindrical structures. The general method of analysis and classification of structural responses is presented. Then, the presentation is broken up along the lines with stationary fluid, parallel flow, and cross flow. Finally, design considerations and future research needs are pointed out. Extensive references are included.

78-977

Beware of Resonance

J. Wajcfeld

Logetronics, Inc., Springfield, VA, Hydraulics & Pneumatics, 31 (2), pp 62-63 (Feb 1978)

Key Words: Cylinders, Beams, Resonant response

The effect of natural frequency is considered when selecting a cylinder in addition to compressive and buckling loads.

DUCTS

78-978

A Differential Microphone for In-Duct Acoustic Measurements

C.M.E. Riley

Dept. of Engrg., Cambridge Univ., UK, Rept. No. ARC-R/M-3799; ARC-36800, 17 pp (1977)

Sponsored by Min. of Defence, Rolls-Royce (1971), Ltd., and Sci. Res. Council

N78-14875

Key Words: Ducts, Acoustic measurement

A brief description is given of a technique using a differential microphone to measure the sound field structure within the duct of a rotor. The advantages and problems of direct in-duct, as opposed to far-field, measurement are discussed, and the present approach presented. The construction and calibration of the differential microphone are briefly described, and results from some of the experiments in which it was assessed are used to demonstrate its application.

FRAMES, ARCHES

78-979

Experiments on Dynamic Plastic Loading of Frames

S.R. Bodner and P.S. Symonds

Div. of Engrg., Brown Univ., Providence, RI, Rept. No. N0014-0860/4, 41 pp (July 1977)

AD-A048 687/8GA

Key Words: Frames, Beams, Dynamic plasticity, Pulse excitation

Tests are described on plane frames of mild steel and titanium (commercial purity) in which high intensity short duration pressure pulses were applied transversely to the beam member either uniformly over this member or concentrated at its center. The objective was to examine applications of two estimation techniques (upper bounds on deflections and the mode approximation technique) for major response features of pulse loaded structures at large deflections, taking account of strong plastic strain rate sensitivity. Loads over a range such as to cause final deflections up to about a third of the span were applied by detonating explosive sheet.

78-980

Large-Deflection Response of Square Frames to Concentrated Impulsive Loads

M.S.J. Hashmi and S.T.S. Al-Hassani

Dept. of Mech. and Production Engrg., Sheffield City Polytechnic, J. Mech. Engr. Sci., 19 (6), pp 243-250 (Dec 1977) 12 figs, 12 refs

Key Words: Frames, Explosion effects, Elastoplastic properties

A study is made of the elastic-plastic responses of portal and free square frames subjected to concentrated explosive impulses. A finite-difference method, which reduces the structure to small masses connected by light links, is used to solve the equations of motion of the deforming frames. The links are assumed to have the same strength properties as the material of the structure. Dynamic strain is measured experimentally, instantaneous profiles are obtained from high-speed photographs and the final deflections substantiate the predictions of the analytical method.

78-981

Numerical Simulation of Forced Vibration Tests on a Buried Arch

J. Isenberg, H.S. Levine, and S.H. Pang

Weidlinger Associates, Menlo Park, CA., Rept. No. 7712, DNA-4281F, SBIE-AD-E300 021, 98 pp (Mar 1, 1977)

AD-A047 386/8GA

Key Words: Arches, Underground structures, Vibration damping, Resonant response

Finite element simulation of a buried arch structure shows that the effective damping depends on backfill conditions. This information is used to explain the occurrence of resonance in forced vibration tests of buried rectangular structures and its absence in tests of the arch. Implications of the findings for developing single degree of freedom models of complex structures are examined.

MECHANICAL

78-982

Cam Mechanism Accuracy

B. Sandler

Ben-Gurion Univ. of the Negev, Beer Sheva, Israel, ASME Paper No. 77-WA/DE-19

Key Words: Cams, Geometric imperfection effects

This paper deals with the influence of cam profile accuracy on deviations in follower motion from that desired by the designer. The kinematic and dynamic approaches are discussed and a mode for decreasing non-desirable deviations is shown. An experimental device is described and the results of the experimental measurements are discussed. The spectral theory of stationary random functions is used for the theoretical consideration. Frequency analysis is used to the experimental measurements.

78-983

Vibrations of Cam Mechanisms and Their Consequences on the Design

M.P. Koster

Dissertation, Ph.D., Technische Hogeschool Eindhoven, Netherlands (1973)

UM 1/2928c

Key Words: Cams, Transient response, Design techniques

Cam mechanisms and their driving components, i.e., the camshaft, the reduction gear, and the driving asynchronous motor are investigated. Transient vibrations characterize the dynamic behavior of cam mechanisms. Several mathematical models have been developed and tested. Detailed analysis of machine vibrations can be obtained by means of a digitial simulation program based on a model with four degrees of freedom. Follower and shaft vibrations and the effects of nonlinear phenomena, i.e., backlash, squeeze, and impact are simulated. Based on a model with one degree of freedom a rule of design for the shaft and the other driving components is added to the existing rules concerning the follower linkage and the effects of backlash. Rules of design are formulated which can be used by a designer who is not a specialist in dynamics.

MEMBRANES, FILMS, AND WEBS

78-984

The Response of an Anisotropically Prestressed Thick Rectangular Membrane to Dynamic Loading

V.O.S. Olunloyo and K. Hutter
Faculty of Engrg., Univ. of Lagos, Lagos, Nigeria, Acta Mech., 28 (1-4), pp 295-311 (1977) 6 refs

Key Words: Rectangular membranes, Dynamic response, Perturbation theory

The dynamic response of a rectangular membrane to external time-dependent loading is investigated for the case when bending rigidity is small. Using singular perturbation techniques and multiple time scale solutions are constructed up to order e, where e measures a small bending rigidity. The perturbation procedure is counterchecked using an example whose exact solution can be found.

PIPES AND TUBES

(Also see Nos. 947, 1033)

78-985

Development of Interference Response Spectra for Lifelines Seismic Analysis

I. Nelson and P. Weidlinger
Weidlinger Associates, NY, Rept. No. IR-2, NSF/RA-770313, 47 pp (July 1, 1977)
PB-275 215/2GA

Key Words: Pipelines, Piping systems, Underground structures, Seismic design, Earthquake resistant structures

The authors contend that the dynamic response of a pipe network system may be determined by numerical integration of the appropriate equations of motion. An important criterion for failure of underground pipes subjected to seismic loading is the strain, or difference in displacement, between two points along the pipe. The concept of interference spectrum has been introduced to deal with this problem when dynamic effects are significant. The approach required to analyze a multi-degree of freedom pipe network is outlined. The case of only two connected pipes segments is treated in detail, and shown to be equivalent to a single degree of freedom system. The mathematical treatment is described in detail and the computer code developed is described. Numerical results are presented for both the El Centro 1940 and 15250 Ventura Boulevard 1971 input records.

78-986

Behaviour of Underground Lifelines in Seismic Environment

P. Weidlinger
Weidlinger Associates, NY, Rept. No. IR-4, NSF/RA-770315, 25 pp (July 1977)
PB-275 217/8GA

Key Words: Pipelines, Piping systems, Underground structures, Seismic design, Earthquake resistant structures

This research attempts to formulate a comprehensive procedure based on a consistent theory for the analysis and design of underground lifelines in seismic environment. Current procedures of engineering seismology are not sufficient for this purpose, and the detailed definition of the displacement field due to seismic motion needs to be extended to include spatial and temporal variations in a broader frequency range. The displacement field may interact weakly or strongly with a buried pipeline, depending on the pipe's dynamic characteristics as modified by the surrounding soil. The effect of this interaction is presented in a 'Interference Spectrum' which gives the peak response of a damped oscillator, subject to simultaneous excitation at two spatially separated points. Spectral amplitudes are used to determine the response of the system, in terms of a 'Damage Matrix' which quantifies the failure parameters of a system consisting of various types of pipes, joints and other details. For purposes of risk analysis, optimization and cost-benefit studies of existing or planned systems, covering large areas, a statistical method is developed which provides the expected value of free field gradients, as affected by subsurface and geology.

78-987

Waterhammer in Non-Rigid Pipes: Precursor Waves and Mechanical Damping

D.J. Williams
Dept. of Aeronautics and Fluid Mechanics, Glasgow Univ., UK, J. Mech. Engr. Sci., 19 (6), pp 237-242 (Dec 1977) 4 figs, 11 refs

Key Words: Pipes (tubes), Waterhammer

When a pipe can move, waterhammer effects are altered by the existence of precursor waves, i.e. longitudinal elastic strain waves in the pipe walls, modified by the presence of the fluid. Pipe motion caused mechanical damping of the waterhammer and was studied experimentally. Viscoelastic piping also gave rise to strong mechanical damping, even without pipe motion.

78-988

Pipe Rupture and Steam/Water Hammer Design Loads for Dynamic Analysis of Piping Systems

B.R. Strong, Jr. and R.J. Baschiere
Advanced Analysis Div., EDS Nuclear Inc., San Francisco, CA 94104, Nucl. Engr. Des., 45 (2), pp 419-428 (Feb 1978) 9 figs, 9 refs

Key Words: Piping systems, Nuclear power plants, Water hammer

The design of restraints and protection devices for nuclear Class I and Class II piping systems must consider severe pipe rupture and steam/water hammer loadings. Limited stress margins require that an accurate prediction of these loads be obtained with a minimum of conservatism in the loads. Methods are available currently for such fluid transient load development, but each method is severely restricted as to the complexity and/or the range of fluid state excursions which can be simulated. This paper presents a general technique for generation of pipe rupture and steam/water hammer design loads for dynamic analysis of nuclear piping systems which does not have the limitations of existing methods.

78-989

Nonlinear Attenuation of an N Wave Propagating in a Tube, Including Dissipation due to Wall Effects

A. Nakamura, R. Takeuchi, and S. Oie
The Inst. of Scientific and Industrial Res., Osaka Univ., Yamadakami, Suita, Osaka, Japan, J. Acoust. Soc. Amer., 63 (2), pp 346-352 (Feb 1978) 7 figs, 14 refs

Key Words: Sound waves, Wave attenuation, Tubes

Theoretical computations are made for the variation of waveform of an N wave propagating in a circular tube. The change with distance of the slope of the straight-line segment of the waveform at its axis crossing is calculated. Various assumptions are made in the calculation to isolate the separate contributions of weak-shock theory and tube-wall effects. The change in slope is as predicted by weak-shock theory.

78-990

Vibration of a Heat Exchanger Tube/Support Impact

Y.S. Shin, J.A. Jendrzejczyk, and M.W. Wambsganss
Argonne National Lab., Argonne, IL, ASME Paper No. 77-JPGC-NE-5

Key Words: Heat exchangers, Tubes, Resonant frequencies, Mode shapes, Damping

Experiments were performed to determine the effects of tube/support misalignment, tube/support-hole clearance, support thickness, exciting force amplitude, and support spacing on the vibrational characteristics (resonant frequencies, mode shapes, and damping) and displacement response amplitude of a heat exchanger tube. The test results were compared with analytical results based on a multi-span beam with simple intermittent supports.

78-991

Vibro-Impact Responses of a Tube with Tube-Baffle Interaction

Y.S. Shin, D.E. Sass, and J.A. Jendrzejczyk
Components Tech. Div., Argonne National Lab., Argonne, IL, Rept. No. ANL-CT-78-11, 62 pp (Jan 1978) 35 figs, 18 refs

Sponsored by Div. of Reactor Dev. and Demonstration, U.S. Energy Res. and Dev. Administration

Key Words: Heat exchangers, Tubes, Vibration response

The relatively small, inherent tube-to-baffle hole clearances associated with manufacturing tolerances in heat exchangers affect the vibrational characteristics and the response of the tube. Numerical studies were made to predict the vibro-impact response of a tube with tube-baffle interaction. The finite element method has been employed with a nonlinear elastic contact spring-dashpot to model the effect of the relative approach between the tube and the baffle plate.

PLATES AND SHELLS

(Also see Nos. 908, 947)

78-992

Random Vibrations of Orthotropic Plates Clamped or Simply Supported All Round

I. Elishakoff
Dept. of Aeronautical Engrg., Technion, I.I.T., Haifa, Israel, Acta Mech., 28 (1-4), pp 165-176 (1977) 25 refs

Key Words: Plates, Orthotropism, Random vibration

When the approximate method presented here is applied to cases capable of closed solutions (i.e. plates having a pair of opposite edges simply supported), the result coincides with that obtained by the classical normal-mode approach.

78-993

Free-Vibration Analysis of Rectangular Plates with Clamped-Simply Supported Edge Conditions by the Method of Superposition

D.J. Gorman
Dept. of Mech. Engrg., Univ. of Ottawa, Ottawa, Ontario, Canada, J. Appl. Mech., Trans. ASME, 44 (4), pp 743-749 (Dec 1977) 11 figs, 6 tables, 6 refs

Key Words: Rectangular plates, Transient response, Method of superposition

In this paper attention is focused on the free-vibration analysis of rectangular plates with combinations of clamped and simply supported edge conditions. Plates with at least two opposite edges simply supported are not considered as they have been analyzed in a separate paper.

78-994

Eigenvalue Problems for the Plate Equation Under Determinate and Random Perturbations

F.D. Zaman

Dissertation, Ph.D., Cranfield Inst. of Tech., UK, 51 pp (1976)
UM 1/2845c

Key Words: Wave propagation, Rectangular plates, Eigenvalue problems, Natural frequencies, Normal modes

The solution to the problem of propagation of transverse waves in elastic rectangular plates which are both homogeneous and isotropic is well known for a variety of boundary conditions. Many real materials currently in use are neither isotropic nor homogeneous. The equations giving the natural frequencies and normal modes of vibration of such plates may sometimes be regarded as perturbations of the homogeneous isotropic equations by introducing a small parameter e which is a measure of the degree of anisotropy or inhomogeneity of the plate. Analytic perturbation theory may then be applied to obtain expressions for the natural frequencies and normal modes as power series in e and to give their range of validity. These results are applied to vibrations of two distinct types of composite plate. An orthotropic plate with clamped boundary conditions is considered. A plate with random inhomogeneities, under simply supported boundary conditions is studied.

78-995

Sound Radiation from a Simply Supported Rectangular Plate Vibrating under Complex Modes

S.P. Nigam, G.K. Grover, and S. Lal

Government Engrg. College, Jabalpur, (M.P), India, Israel J. Tech., 15 (3), pp 123-129 (1977) 6 figs, 13 refs

Key Words: Rectangular plates, Vibrating structures, Sound waves

Sound radiation from a simply supported rectangular plate vibrating under complex resonant or non-resonant modes is studied. The average radiation efficiency and sound power radiated is defined and evaluated under such conditions. Rayleigh's integral is formulated and the far-field acoustic pressure evaluated after giving due consideration to the modal phase shifts. The results of the analytical computations are presented and discussed.

78-996

Dynamic Plastic Analysis Using Stress Resultant Finite Element Formulation

P. Lukkunaprasit and J. Kelly

Earthquake Engrg. Res. Center, California Univ., Richmond, CA., Rept. No. UCB/EERC-77/21, 61 pp (Sept 1977)
PB-275 453/9GA

Key Words: Spherical shells, Plates, Dynamic plasticity, Finite element technique

A stress resultant finite element formulation is developed for the dynamic plastic analysis of plates and shells of revolution undergoing moderate deformation. A nonlinear elastic-viscoplastic constitutive relation simulates the behavior of rate-sensitive and -insensitive materials.

78-997

Axi-symmetric Proper Vibrations of a Conical Shell Made of the Compressible Nonlinear Elastic Material

F. Twardosz and T. Wegner

Dept. Tech. Mechanics, Tech. Univ., Piotrowo 3, 61-138 Poznan, Poland, Bull. Acad. Polon. Sci., Ser. Sci. Tech., 25 (10), pp 225-233, 533-541 (1977) 6 refs

Key Words: Conical shells, Axisymmetric vibrations

The paper presents an analysis of axi-symmetric proper vibrations of a thin-walled truncated conical shell. It is assumed that the shell is free supported, and made of isotropic, homogeneous, compressible and nonlinear elastic material. The considerations are limited to the small vibration analysis. Under such a restriction it appeared possible to use the geometrical linear relations. As a result the set of two nonlinear partial differential equations of the fourth order, describing longitudinal and transversal vibrations, was obtained. The set of equations was reduced to ordinary differential equations with the help of the Bubnov-Galerkin method.

78-998

Dynamic Analysis of Shallow Shells Using Finite Element Mixed Models

S.F. Abbas

Ph.D. Thesis, Univ. of Toronto (Canada) (1975)

Key Words: Dynamic structural analysis, Shells, Finite element technique

In this work, a Finite Element dynamic analysis of shallow shells has been successfully performed using Mixed models. The underlying principle used to derive the models was Karnopp's extension of Reissner's principle to elastodynamics. A development similar to that of Prato's in elastostatics was performed so as to reduce the final variables to moments and displacements only.

78-999

Transient Response of Shells with Internally Attached Structures

D. Ranlet and F.L. DiMaggio

Weidlinger Associates, NY, Rept. No. TR-21, 25 pp (Aug 1977)

AD-A048 167/1GA

Key Words: Transient response, Shells, Equations of motion, Shock response, Submerged structures

Equations of motion are derived for the transient response, to a shock wave, of a submerged shell with internal structures. A substructuring procedure, which does not require calculation of a system stiffness matrix, is employed to obtain these equations in a general manner for arbitrary internal structures approximated by finite elements.

78-1000

Dynamic Response of a Submerged Elastic Structure with Elastic Structures Attached to It by Inelastic Springs

F.L. DiMaggio

Weidlinger Associates, NY, 15 pp (Aug 1977)

AD-A048 166/3GA

Key Words: Shells, Submerged structures, Shock response

A procedure is described which may be used to obtain the dynamic response to shock loading of a submerged shell with internal structure attached to it by nonlinear mountings.

SPRINGS

78-1001

Spring Equivalent of Flywheel for Reciprocating Engines

N.G. Vaidya and P.S. Gokhale

Government Polytechnic, Bombay, India, J. Inst. Engr. (India), 58 (ME1), pp 36-37 (July 1977) 4 figs, 2 refs

Key Words: Reciprocating engines, Energy absorption

Flywheel of any reciprocating engine acts as a rotating energy reservoir and helps to control the cyclic fluctuations of speed of the engine. Equivalent springs can be used in an identical manner to achieve the same objective. This paper gives an account of the work carried out in applying the principle to a double acting steam engine. Application to I C engines is also briefly discussed.

STRUCTURAL

(See Nos. 920, 925)

TIRES

(Also see No. 955)

78-1002

The Effect of Hydroplaning on the Dynamic Characteristics of Car, Truck and Bus Tires

H. Sakai, O. Kanaya, and T. Okayama

Japan Automobile Research Inst., Inc., SAE Paper No. 780195, 24 pp, 61 figs, 9 refs

Key Words: Tires, Tire characteristics, Ride dynamics

This report deals with the tests made on the hydroplaning phenomenon of car, truck and bus tires using the interior of a dynamic tire testing machine. For car tires, the relationship between braking force and slip ratio and between cornering force and slip angle as affected by hydroplaning were investigated. Studies were also made of the influence of the difference between radial-ply and cross-ply tires, inner pressure, load, thickness of the water film, etc.. Next, a study was conducted concerning the effect of hydroplaning on the cornering properties of truck and bus tires.

SYSTEMS

ABSORBER

(Also see No. 922)

78-1003

On the Dynamic Vibration Damped Absorber of the Vibration System

T. Ioi and K. Ikeda

Chiba Inst. of Tech., Narashino, Japan, Bull. JSME, 21 (151), pp 64-71 (Jan 1978) 10 figs, 4 refs

Key Words: Dynamic vibration absorption (equipment)

This paper analyzes the prevention of forced vibration of a vibration system with positive or negative damping by means of a damped dynamic absorber. Three cases are treated: the alternative exciting force of a constant magnitude is acting on the mass of the main system, the alternative exciting force whose magnitude is proportional to the square of its frequency, is acting on the mass of the main system, and the alternative displacement is given to the foundation of the main system.

NOISE REDUCTION

78-1004

Muffler for Pneumatic Drill

A. Visnapuu and S.E. Lay

Dept. of the Interior, Washington, D.C., PAT-APPL-815 127/GA, 14 pp (July 1977)

Key Words: Mufflers, Pneumatic tools, Rock drills

This invention relates to mufflers for the exhaust of pneumatic tools in general, and more particularly for mechanized, jumbo mounted percussive rock drills employed in the mining industry. The muffler consists of a casing of general prismatic shape, adapted for mounting on the drill.

78-1005

Investigation of Noise Reduction on a 100 kVA Transformer Tank by Means of Active Methods

N. Hesselmann

Institut f. Technische Akustik, 51 Aachen, Templergraben 55, West Germany, Appl. Acoust., 11 (1), pp 27-34 (Jan 1978) 6 figs, 7 refs

Key Words: *Noise reduction*

This paper describes experiments in reducing transformer noise by acoustical compensation. For this purpose, two loudspeakers have been arranged close to a 100 kVA transformer and fed by a suitable compensation signal. As a result, the noise level in the far field fell by between 20 and 38 dB, depending on the direction of observation.

78-1006

Sound Pressure-Level Prediction in Large Rooms Containing Barriers

T.H. Aishton, M.J. Moran, and L.L. Faulkner

Dept. of Mech. Engrg., The Ohio State Univ., Columbus, OH, Appl. Acoust., 11 (1), pp 67-72 (Jan 1978)

Key Words: Noise barriers, Noise prediction

A simple-to-use graphical method for estimating the sound pressure level in the shadow zone of a rigid straight-edged barrier for sound radiated from a point source located in a large room is presented and discussed. Also presented is a means based on the graphs introduced for evaluating the noise reduction potential of a barrier in a room or factory work space.

78-1007

The Contribution of Heavy Vehicles to Urban Traffic Noise

B. Bodsworth and A. Lawrence

School of Engrg. and Architecture, Deakin Univ., Geelong, Australia, Appl. Acoust., 11 (1), pp 57-65 (Jan 1978) 1 fig, 4 tables

Key Words: Traffic noise, Noise reduction

The dominating influence of road traffic on the noise climate of the world's cities is established and attempts to reduce the problem follow. The first involves ameliorating the effects of traffic stream noise; the second an attack on the noise levels of individual vehicles.

78-1008

Materials for Noise Reduction in Food Processing Environments

S.A. Waggoner, J.F. Shackelford, F.F. Robbins, Jr., and T.H. Burkhardt

Dept. of Agricultural Engrg. and Materials and Devices Res. Group and Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, Appl. Acoust., 11 (1), pp 1-20 (Jan 1978) 16 figs, 7 tables, 11 refs

Key Words: Industrial facilities, Noise reduction

Government standards for noise levels in industrial environments including the food processing industry have led to a program of materials selection for noise reduction. In addition to traditional architectural considerations, the constraints of sanitation and cost were factors. Primary materials systems studied were: metal/polymer composites for impact noise reduction, polymer film/foam composites for sound absorption and transparent polymer barrier/enclosures.

AIRCRAFT

(Also see Nos. 927, 929)

78-1009

Investigation of Acoustic Properties of a Rigid Foam with Application to Noise Reduction in Light Aircraft

C.I. Holmer

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. NASA-CR-132333; Rept-2558, 79 pp (1972)

N78-13851

Key Words: Aircraft noise, Noise reduction, Foams

An analytic model of sound transmission into an aircraft cabin was developed as well as test procedures which appropriately rank order properties which affect sound transmission.

78-1010

A Parametric Investigation of an Existing Supersonic Relative Tip Speed Propeller Noise Model

J.H. Dittmar

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-73816; E-9405, 25 pp (Nov 1977)

N78-13854

Key Words: Aircraft noise, Noise reduction

A high tip speed turboprop is being considered as a future energy conservative airplane. The noise reduction possibilities of decreasing relative Mach number were further investigated during the interdependent variations.

78-1011

Description of Noise Measurement and Analysis Procedures Developed for Light General Aviation Aircraft

D.W. Andrews and D.W. Durenberger

Dept. of Aerospace Engrg., Technische Hogeschool, Delft, Netherlands, Rept. No. VTH-LR-246, 82 pp (Apr 1977)

N78-14874

Key Words: Aircraft noise, Noise measurement

The equipment, flight test procedures, and analysis methods used in the aircraft noise research program at the university are described.

78-1012

Investigation of Interior Noise in a Twin-Engine Light Aircraft

J.S. Mixson, C.K. Barton, and R. Vaicaitis

Langley Res. Center, NASA, Hampton, VA, J. Aircraft, 15 (4), pp 227-233 (Apr 1978) 15 figs, 26 refs

Key Words: Aircraft noise, Interior noise, Noise reduction

This paper describes experimental studies of interior noise in a twin-engine, propeller-driven, light aircraft. An analytical model for this type of aircraft is also discussed.

78-1013

Flight-Effects on Predicted Fan Fly-By Noise

M.F. Heidmann and B.J. Clark

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-73798, 24 pp (1977)

N78-13060

Key Words: Aircraft noise, Engine noise, Fans

The impact on PNLT (Perceived Noise Level, Tone corrected) and Fly-by EPNL (Effective Perceived Noise Level) when forward motion reduces the noise generated by the bypass fan of an aircraft engine was studied. Calculated noise spectra for a typical subsonic tip speed fan designed for blade passage frequency (BPF) tone cutoff were translated in frequency by systematically varying the BPF from 0.5 to 8 kHz.

78-1014

Methodology for Determining, Isolating, and Correcting Runway Roughness

D.R. Seeman and J.P. Nielsen

Civil Engrg. Research Facility, Rept. No. AD-A044-328/3; CERF-AP-24; FAA-RD-75-110-2, 33 pp (June 1977)

N78-13078

Key Words: Runway roughness, Aircraft response

Elevation and acceleration profiles were generated to determine the relationship between runway roughness and aircraft response. The aircraft response is specified in terms of pilotstation vertical accelerations, which are determined from computer simulation. Corrections to the profiles are then made to reduce the aircraft response.

78-1015

Analytical and Experimental Fatigue Program for the Kfir Main and Nose Landing Gears

B. Abraham

Israel Aircraft Industries Ltd., Lod, Israel, Israel J. Tech., 15 (1-2), pp 70-78 (1977) 12 figs, 6 tables, 9 refs

Key Words: Aircraft equipment, Landing gear, Fatigue tests

This paper describes the program that was carried out on the Kfir main and nose landing gears in order to insure adequate service life. The fatigue program began in the detail design phase; next came the development of loading spectra used for analysis and test. A fatigue analysis was then performed for several suspected critical locations on both gears. A flight-by-flight fatigue test was performed on both landing gears with the aim of demonstrating four service-lifetimes of operation. Design modifications were introduced, based on the results of these tests. Finally, rational inspection and replacement intervals were established for the main and nose gear, some of which require monitoring of aircraft operations.

78-1016

An Asymptotic Method for Predicting Amplitudes of Nonlinear Wheel Shimmy

J.T. Gordon, Jr. and H.C. Merchant

Science Applications, Inc., Oakland, CA, J. Aircraft, 15 (3), pp 155-159 (Mar 1978) 5 figs, 10 refs

Key Words: Landing gear, Wheel shimmy, Amplitude analysis, Nonlinear analysis

An asymptotic method involving the multiple-time-scale perturbation technique is presented for nonlinear stability analysis of landing gear wheel shimmy models that include a velocity-squared damper. General expressions for the limit cycle amplitude and frequency are obtained, with the stability of the limit cycles determined by the sign of a computed coefficient.

78-1017

Determination of Dynamic Characteristics from Flight Test Data

M. Marchand

Abt. Flugmechanik der Flaechenflugzeuge, Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Brunswick, West Germany, Rept. No. DLR-FB-77-26, 23 pp (June 20, 1977)
(In German)
N78-14044

Key Words: Aircraft, Dynamic properties, Computer programs

An evaluation procedure for the determination of dynamic characteristics from flight test data was developed. The procedure uses a gradient method for the evaluation of eigenvalues and a regression method for the calculation of eigenvectors. The procedure was programmed in FORTRAN and was successfully applied during a handling qualities assessment of a fighter aircraft. The procedure is described and some results from both simulation and flight testing are presented.

BIOENGINEERING

78-1018

Compliance of the Human Ankle Joint

G.C. Agarwal and C.L. Gottlieb

Univ. of Illinois at Chicago Circle, Chicago, IL, ASME Paper No. 77-WA/Bio-2

Key Words: Bioengineering, Ankles, Dynamic response

The dynamic response of the human ankle joint to a band-limited (0 to 50 Hz) gaussian torque disturbance superimposed on a constant bias torque is observed at different levels of voluntary contraction of the leg muscles acting about the ankle. The compliance of the ankle joint, defined as the ratio of the joint rotation and applied torque is modeled by a second-order, linear dynamic model.

BRIDGES

78-1019

An Analysis of the Dynamic Characteristics of a Suspension Bridge by Ambient Vibration Measurements

A.M. Abdel-Ghaffar and G.W. Housner

Earthquake Engrg. Res. Lab., California Inst. of Tech., Pasadena, CA, Rept. No. EERL-77-01, 86 pp (Jan 1977)

PB-275 063/6GA

Key Words: Suspension bridges, Natural frequencies, Mode shapes, Traffic-induced vibrations, Experimental data

Extensive experimental investigations were conducted on the Vincent-Thomas Suspension Bridge at Los Angeles Harbor to determine natural frequencies and mode shapes of vertical, torsional and lateral vibrations of the structure. These ambient vibration tests involved the simultaneous measurements of both vertical and lateral vibrational motions caused by traffic. Measurements were made at selected points on different cross sections of the stiffening structure.

BUILDING

(Also see No. 929)

78-1020

Design of an Elastic Wind Tunnel Model of a Tall Office Building Using a Finite Element Computer Code

M.P. Felix and W.A. Eckerle

General Dynamics/Convair, San Diego, CA, ASME Paper No. 77-WA/DE-6

Key Words: Multistory buildings, Test models, Wind tunnel tests, Mathematical models, Finite element technique, Computer programs

A dynamic structural model of a 274-m (900-ft) office building was designed and built for test in a low speed wind tunnel. The design of the model was aided by a finite element computer code (SAP IV). The design was based upon bending and torsional elastic curves of the proposed full-scale building supplied by the structural architects.

78-1021

Design of Excavation Blasts to Prevent Damage

Y.S. Chae

Rutgers Univ., New Brunswick, NJ, Civ. Engr. (N.Y.), 48 (4), pp 77-79 (Apr 1978) 4 figs

Key Words: Blast-resistant structures, Buildings

The July, 1968, issue of Civil Engineering included an article stating criteria for designing excavation blasts to avoid damaging nearby structures. Blasts causing particle velocities not greater than 2 in./sec were considered safe. Ten years of additional experience has shown that the 2 in./sec criteria was too rigid; some structures have been damaged at smaller values, some have withstood larger blasts. The author recommends that blast design take into consideration the condition of nearby structures and states that humans, because they are more sensitive to vibration than are structures, can be the controlling factor in blast design.

78-1022

Some Uniqueness Results Related to Building Structural Identification

F.E. Udwadia and D.K. Sharma

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA 90007, SIAM J. Appl. Math., 34 (1), pp 104-118 (Jan 1978) 1 fig, 1 table, 12 refs

Key Words: Seismic design, Buildings, Parameter identification techniques

This paper studies the nature of uniqueness in the identification of building structural systems subjected to strong ground shaking. Characterization of the stiffness distribution in the structure from a knowledge of response of one of the floors to a base excitation is investigated.

78-1023

Inelastic Behavior of Eccentrically Braced Steel Frames Under Cyclic Loadings

C.W. Roeder and E.P. Popov

Earthquake Engrg. Res. Center., California Univ., Richmond, CA, Rept. No. UCB/EERC-77/18, 329 pp (Aug 1977)

PB-275 526/2GA

Key Words: Framed structures, Building, Seismic design, Earthquake resistant structures

A unique, practical structural system, the eccentric bracing system, which possesses many advantages in the seismic design of steel structures, is described in this work.

78-1024

A Methodology for Seismic Design and Construction of Single-Family Dwellings

Applied Technology Council, Palo Alto, CA, Rept. No. HUD-PDR-248-1, 476 pp (Sept 1976)

PB-275 099/0GA

Key Words: Buildings, Seismic design

This report presents the results of an in-depth effort to develop design and construction practices for single-family residences that minimize the potential economic loss and the life-loss risk associated with earthquakes. The report:

discusses the ways structures behave when subject to seismic forces; sets forth suggested design criteria for conventional layouts of dwellings constructed of conventional materials; presents construction details that do not require the designer to perform analytical calculations; suggests procedures for efficient plan-checking; and presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

78-1025

A Methodology for Seismic Design and Construction of Single-Family Dwellings; Supplementary Engineering Analysis Report

Applied Technology Council, Palo Alto, CA, Rept. No. HUD-PDR-248-2, HUD/RES-208, 126 pp (Jan 1977)

PB-275 100/6GA

Key Words: Buildings, Seismic design

This report presents the engineering basis for the Report titled, 'A Methodology for Seismic Design and Construction of Single-Family Dwellings' (PB-275 099). The purpose of that report was to develop seismic-resistive design and construction recommendations to reduce future probable earthquake caused damage and hazards for single-family residences. Included in this report are the engineering calculations, reasoning and/or reports of field observations that form the basis for the design and construction procedures recommended in the Methodology. The theory and design calculations given in this report include considerations of the overall structure, as well as specific construction details.

78-1026

Seismic Shears and Overturning Moments in Buildings

R. Smilowitz and N.M. Newmark

Dept. of Civil Engrg., Illinois Univ. at Urbana-Champaign, IL, Rept. No. STRUCTURAL RESEARCH SER-441, UILU-ENG-77-2011, NSF/RA-770317, 145 pp (July 1977)

PB-275 678/1GA

Key Words: Buildings, Seismic response

Seismic force distributions for simplified computation of shears and over-turning moment for preliminary design of buildings have been generated. A parameter study of the significant variables has been made to determine the applicability of the proposed distributions. The results of the study along with the explanation of the methods by which they were obtained are presented. Tabular and graphic material are included.

ISOLATION

78-1027

Helicopter Rotor Isolation Evaluation Utilizing the Dynamic Antiresonant Vibration Isolator

A.D. Rita, J.H. McGarvey, and R. Jones

Kaman Aerospace Corp., J. Amer. Helicopter Soc., 23 (1), pp 22-29 (Jan 1978) 10 figs, 2 tables, 7 refs

Key Words: Dynamic antiresonant vibration isolator (DAVI), Helicopter rotors

This paper includes the results of the analysis, design, ground tests and flight test phases that were conducted on an Army furnished UH-1H helicopter modified with a Dynamic Antiresonant Vibration Isolator (DAVI) rotor isolation system.

78-1028

The Damping Characteristics of Vibration Isolators Used in Gas Turbines

R. Holmes

School of Engrg. and Appl. Sciences, Univ. of Sussex, UK, J. Mech. Engr. Sci., 19 (6), pp 271-277 (Dec 1977) 4 figs, 6 refs

Key Words: Gas turbines, Vibration isolators, Squeeze film bearings, Damping coefficients

The linear and nonlinear damping performance of a common type of gas-turbine vibration isolator, consisting of a squeeze-film journal bearing in parallel with a linear retainer spring, is computed and used to prescribe limits to the use of linear damping coefficients.

PUMPS, TURBINES, FANS, COMPRESSORS

78-1029

Transient Speed Response of a Gas Turbine

A.K. Mohanty and H.M. Balasubramanya

IIT, Kharagpur, J. Inst. Engrs. (India), 58 (ME1), pp 49-53 (July 1977) 7 figs, 1 table, 6 refs

Key Words: Gas turbines, Dynamic response

This paper presents a simple analysis of a gas turbine power plant under transient operating conditions - in particular, the acceleration at constant load torque. Comparable results of experiments performed on laboratory model gas turbine are also discussed.

78-1030

Noise Reduction by Suitable Choice of Displacement-Type Pumps and Their Parameters

P. Wuesthof

British Library Lending Div., Boston Spa, UK, Rept. No. BLL-NEL-TT-2719 (6075.461), 17 pp (1977) (Engl. transl. from Oelhydraulic and Pneumatic, 20 (7), pp 457-461, 1976)

N78-14404

Key Words: Pumps, Noise reduction

An attempt was made to examine the noise output of different patterns of pump comparatively as a function of pressure, reaction speed and displaced volume. It was found that as a rule a reduction of reaction speed and a division of the total oil flow into smaller units are particularly effective.

78-1031

Effect of the Design of External Gear Pumps on the Noise Emitted by Them in Service

S. Stryczek

British Library Lending Div., Boston Spa, UK, Rept. No. BLL-NEL-TT-2732 (6075.461), 11 pp (1977) (Engl. trans. from Oelhydraulic and Pneumatic, 20 (12), pp 813-815, 1976)

N78-14406

Key Words: Pumps, Gears, Noise generation

Various shapes and sizes of key elements in a gear pump were used in a test pump constructed to identify and locate the most important pump noise sources, thus enabling effective noise reduction during pump design. Factors studied include the effects of different numbers of teeth of a gear pair, the end and radial clearances, and the bearing of the gears on the pump casing.

78-1032

Pumping Phenomenon of Compressors and Turbopumps as Nonlinear Oscillation (Der Pumpvorgang von Verdichtern und Kreiselpumpen als nichtlineare Schwingung)

A.J.T. Horvath

Inst. de Thermique Appliquee, Ecole Polytechnique Federale de Lausanne, Switzerland, Rept. No. EPFL-ITA-3, 136 pp (1976)

(In German)

N78-14407

Key Words: Surges, Compressors, Pumps, Turbomachinery

Unsteady flow phenomena, so-called surging, are known to occur in duct systems comprising turbopumps, turbocompressors or fans if the volume flow rate being delivered falls below a certain limit. Surging is associated with self-excited fluctuations of pressure and flow rate of definite periodicities. A mathematical description of a surging process is presented in the form of a non-linear differential equation which is an extended form of the equation of Van der Pol. Application of the theory to several systems investigated experimentally by other authors (involving axial and centrifugal compressors and centrifugal pumps) shows very good agreement of surging frequencies, amplitudes and waveforms. The analogies between the self-exciting behavior of tunnel (Esaki) diodes, gas compressors, and hydraulic pumps are also considered.

78-1033

First-Order Pump Surge Behavior

P.H. Rothe and P.W. Runstadler, Jr.

Creare, Inc., Hanover, NH, ASME Paper No. 77-WA/FE-12

Key Words: Pumps, Piping, Fluid-induced excitation

This paper presents the results of an empirical study undertaken to assess the appropriateness and applicability of a simple, analytical model of pump-piping system flow instability. The analysis is used to describe behavior actually observed in a well defined, simple, pump-piping system. The frequency and amplitude of the flow oscillations observed during pump surge and the range of the pump-piping system characteristic parameters for which unstable flow oscillations occurred are in good agreement with the behavior predicted by the analysis. The results of this work provide a quantitative basis for investigating modifications to the lumped-parameter model in order to make it also appropriate for the analysis of more complex pump or compressor systems. Although the analytical model displayed here is not new, a direct comparison of model predictions against similar measurements of first-order pump surge has not been published prior to this work.

RAIL

78-1034

Techniques for Measuring Wheel/Rail Forces with Trackside Instrumentation

D.R. Ahlbeck and H.D. Harrison
Battelle-Columbus Laboratories, Columbus, OH, ASME Paper No. 77-WA/RT-9

Key Words: Interaction: rail-wheel, Measurement techniques

In this paper, techniques for the measurement of wheel/rail loads using trackside instrumentation are discussed, based on experience accrued over two years of field measurements. These trackside measurements have provided a basis for the evaluation by Amtrak of new locomotives and passenger equipment, and were used in a Department of Transportation-sponsored program for evaluating loads on concrete-tie track. Wheel/rail load data representative of freight and passenger traffic are presented to illustrate an application of the measurement techniques.

REACTORS

(Also see Nos. 916, 945, 988)

78-1035

The Analysis of Dynamically Loaded Non-Linear Structures

I. Davidson and J.N. Bradbury
9 Dale Lane, Appleton, Warrington, UK, Nucl. Engr. Des., 45 (2), pp 399-410 (Feb 1978) 6 figs, 7 refs

Key Words: Nuclear reactors, Containment structures, Dynamic tests, Computer programs

Small models of a proposed prestressed concrete containment structure for a sodium cooled fast breeder reactor have been made and tested. They were partly filled with water and loaded internally by detonating explosive charges. Prior to the tests the model was analyzed by an axisymmetric dynamic relaxation computer program.

78-1036

Seismic Model Test of the GCFR Core and Core Support Structure

L.E. Penzes and R.L. Bedore
General Atomic Co., P.O. Box 81608, San Diego, CA 92138, Nucl. Engr. Des., 45 (2), pp 471-480 (Feb 1978) 5 figs, 3 tables, 8 refs

Key Words: Nuclear reactors, Seismic excitation, Resonant frequencies, Mode shapes, Model testing

A 15% scale model was constructed to study the dynamic structural behavior of the GCFR (gas cooled fast breeder reactor) core support structure during seismic excitation. The model contains a perforated aluminum plate with a diameter of 20 in. and 265 model core elements constructed from 7/8 in.-diameter aluminum tubes. The proper frequency and mass ratios of the core elements and the perforated plate was ensured by placing steel inserts in the tubes. The natural frequencies, mode shapes and damping factors were individually measured for each of the components and for the complete system. Harmonic and simplified seismic forcing functions were applied to study the dynamic behavior of the core and its support structure. The test results were compared with both analytical and computer code results.

78-1037

Dynamic Analysis of a Pressurized Water Reactor Coolant System Subjected to Postulated Loss-of-Coolant Accident Transient Loads

R.E. Mathews, B.F. Saffell, Jr., and R.K. Mattu
EG & G Idaho, Inc., Idaho Falls, ID, ASME Paper No. 77-WA/DE-23

Key Words: Nuclear reactors, Piping, Transient response

An independent, time history, dynamic analysis of a three-loop pressurized water reactor (PWR) has been performed for a postulated rupture of the cold leg primary coolant piping at the reactor pressure vessel nozzle. This postulated, instantaneous (less than 0.020 s) rupture of a reactor system primary coolant pipe is a loss-of-coolant accident (LOCA). Such an event causes large magnitude short-duration mechanical loads on piping components, and component supports. The structural response of the primary coolant system is defined by first formulating a finite element representation of the loop piping, major components in the piping loops, reactor vessel with internals, and the major component supports. The transient forcing functions which are utilized to excite the system are developed from plant hydraulic analyses.

78-1038

Standardized Seismic Design Spectra for Nuclear Plant Equipment

N.C. Tsai and W.S. Tseng
Bechtel Power Corp., San Francisco, CA 94119, Nucl. Engr. Des., 45 (2), pp 481-488 (Feb 1978) 8 figs, 1 table, 4 refs

Key Words: Nuclear power plants, Seismic design

Standardized seismic design spectra were developed for the nuclear plant equipment. Presented here are idealized design spectrum peak envelopes for different types of structure materials and for both the SSE and OBE conditions. Procedures are also provided for the application of the design spectrum peak envelopes to the seismic qualification of equipment either by dynamic analysis or testing.

78-1039

Proving Test of Earthquake-Resistant Pipings, Equipment and Active Components

H. Shibata

Inst. of Industrial Science, Univ. of Tokyo, 22-1, Roppongi 7, Minato-ku, Tokyo 106, Japan, Nucl. Engr. Des., 46 (1), pp 169-178 (Mar 1978) 5 figs, 1 table, 6 refs

Key Words: Nuclear power plants, Earthquake resistant structures, Test facilities

A shaking table for testing earthquake-resistant properties of key items in nuclear power stations is described.

78-1040

Regulatory Requirements for Blast Effects from Accidental Explosions

J. O'Brien

Nuclear Regulatory Commission, Washington, DC 20555, Nucl. Engr. Des., 46 (1), pp 145-150 (Mar 1978) 3 figs, 9 refs

Key Words: Nuclear power plants, Explosion effects

Procedures and criteria acceptable to the USNRC for verifying the adequacy of nuclear power plant structures, systems and components to resist the effects of accidental explosions outside the plant are presented. A method of computing the probability of an accidental explosion is also given. The relative importance of blast generated missiles, wind, overpressure and ground shock is treated. The inherent strength of Nuclear Power Plants to resist blast effects due to imposed design requirements for other extreme environmental loads, such as tornadoes, is considered. Shortcomings in the previous practice of comparing air blasts with tornadoes are outlined.

78-1041

Non-Linear Lateral Mechanical Response of Pressurized Water Reactor Fuel Assemblies

R.L. Grubb and B.F. Seffel, Jr.

EG & G Idaho, Inc., Idaho Falls, ID, ASME Paper No. 77-WA/DE-18

Key Words: Nuclear fuel elements, Nonlinear response

Mechanical response analysis of 15 adjacent fuel assemblies subjected to postulated loss-of-coolant accident (LOCA) loadings is described in this paper. A structural and mass model is developed for each fuel assembly. The gaps between adjacent fuel assemblies and between the fuel and baffle plates are included in the structural representation. Spacer grid impact forces are defined within these gap elements by springs which become active when contact is made between adjacent grids.

78-1042

Environmental Noise Study for a Nuclear Power Plant

E.E. Dennison, R.E. Maier, J.W. McGaughey, and S.P. Ying

Gilbert/Commonwealth, Commonwealth Associates, Inc., 209 E. Washington Ave., Jackson, MI 49201, Noise Control Engr., 10 (1), pp 33-39 (Jan/Feb 1978) 7 figs, 31 refs

Key Words: Nuclear power plants, Noise reduction, Standards and codes

This paper describes an environmental noise impact technique intended to fulfill federal, state, and local requirements for constructing a large nuclear power plant in the United States.

78-1043

In SITU Dynamic Tests and Seismic Records on the RHR System Building ENEL IV Nuclear Plant/Caorso, Italy

A. Castoldi, M. Casirati, and F.L. Scotto

Dynamic Dept. ISMES (Istituto Sperimentale Modelli e Strutture), Bergamo, Italy, Nucl. Engr. Des., 45 (2), pp 497-506 (Feb 1978) 10 figs, 1 table

Key Words: Nuclear power plants, Buildings, Dynamic tests, Testing techniques, Seismic excitation

The tests on the RHR Building of the Caorso Nuclear Plant are part of a program of dynamic tests on large structures sponsored by ENEL, which ISMES is presently carrying out. The main purposes of this program are to collect information on the effectiveness of different excitation methods, set up the most suitable recording and processing technique, and compare the experimental results with the computed ones, in view of the validation of the adopted computing schemes.

78-1044

Seismic Analysis and Design of Electrical Cable Trays and Support Systems

R.M. Shahin, R. Manuelyan, and C. Jan

Gibbs & Hill, Inc., 393 7th Ave., New York, NY 10001, Nucl. Engr. Des., 45 (2), pp 515-522 (Feb 1978) 3 figs, 5 refs

Key Words: Nuclear power plants, Seismic design, Transmission lines

Most cable trays in nuclear power plants are classified as seismic category I components. Current safety requirements dictate that all such components be adequately designed in order to remain functional during and after the most severe possible earthquake, so that a safe and orderly plant shut-down can be ensured. The design aspects of electrical cable trays and support systems are discussed from the seismic and structural standpoint. The effects of the inherent flexibility of commonly used cable trays is considered. A procedure for the selection of trays and the design of their support structure is recommended.

RECIPROCATING MACHINE

(Also see No. 1001)

78-1045

Wind-Tunnel Investigation of the Aerodynamic Performance, Steady and Vibratory Loads, Surface Temperatures and Acoustic Characteristics of a Large-Scale Twin-Engine Upper-Surface Blown Jet-Flap Configuration

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-X-72794, 163 pp (Nov 1975) N78-14031

Key Words: Turbofan engines, Wind tunnel tests

Tests have been conducted in full-scale tunnel to determine the aerodynamic performance, steady and vibratory aerodynamic loads, surface temperatures, and acoustic characteristics of a large scale, twin turbofan engine, upper surface blown jet-flap configuration. The tests were made for an angle of attack range from -6 deg to 28 deg and a thrust coefficient range from 0 to 4 for trailing edge flap deflections of 32 deg and 72 deg.

78-1046

High Frequency Dynamic Engine Simulation

J.A. Schuerman, K.E. Fischer, and P.W. McLaughlin

Commercial Products Div., Pratt & Whitney Aircraft Group, East Hartford, CT, Rept. No. NASA-CR-135313; PWA-5543, 166 pp (July 1977) N78-13059

Key Words: Turbofan engines, Digital simulation, Dynamic properties

A digital computer simulation of a mixed flow, twin spool turbofan engine was assembled to evaluate and improve the dynamic characteristics of the engine simulation to disturbance frequencies of at least 100 Hz. One dimensional forms of the dynamic mass, momentum and energy equations were used to model the engine. A TF30 engine was simulated so that dynamic characteristics could be evaluated against results obtained from testing of the TF30 engine at the NASA Lewis Research Center.

78-1047

An Example of Additive Damping as a Cost Savings Alternative to Redesign

M.L. Drake and J.D. Sharp

Univ. of Dayton Research Inst., Dayton, OH, ASME Paper No. 77-WA/GT-2

Key Words: Engine vibration, Vibration damping, Testing techniques, Resonant frequencies, Mode shapes, Fast Fourier transform

As a cost savings alternative to complete redesign of the TF-41 engine inlet extension, the Air Force Materials Laboratory, in conjunction with the University of Dayton Research Institute, conducted a program demonstrating the practicality of applying a multi-layer damping treatment to the existing inlet extension to replace the current fiberglass wrap. The fiberglass wrap was designed to eliminate high cycle fatigue failures in the extension; however, the wrap incurs disbonds and delaminations which in turn cause local high temperature spots resulting from frictional heating. This paper describes in detail the experimental methods used to determine dynamic characteristics of both the damped and undamped structure, including digital fast-fourier analysis for determination of resonant frequencies and mode shapes, the techniques used to damping treatment optimization, and correlation of test cell and laboratory data.

ROAD

(Also see Nos. 918, 921, 922, 1014)

78-1048

The Performance of Conventional and Energy Absorbing Restraints in Simulated Crash Tests

S.R. Sarrailhe and N.D. Hearn

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC.359, 35 pp (Sept 1975)
AD-A047 532/7GA

Key Words: Dynamic tests, Collision research (automotive), Seat belts, Energy absorption

Dynamic tests were done using conventional lap sash seat belt restraints, and assemblies incorporating energy absorbers in the sash strap. Three restraint geometries, rigid and cushioned seats and assemblies with the straps slack, tight and preloaded were tested.

78-1049

Response of Belted Dummy and Cadaver to Rear Impact

A.S. Hu, S.P. Bean, and R.M. Zimmerman
Physical Science Lab., New Mexico State Univ., University Park, NM, Rept. No. PSL-PR00848, DOT-HS-803 028, 444 pp (June 1976)
PB-275 472/9GA

Key Words: Collision research (automotive), Anthropomorphic dummies

Sled impact tests were conducted to simulate the motion of a standard size car at rest impacted from the rear by a second car of equal weight travelling at 32 mph. The test subjects were anthropomorphic dummies and unembalmed cadavers. They were seated in a bench seat (headrest in its down position) and were three-point belted.

ROTORS

(Also see Nos. 951, 958, 1027)

78-1050

Problem of Rotor Passing Through Critical Speed with Gyroscopic Effect (Analysis by Asymptotic Method and Experiments)

K. Nonami and M. Miyashita
Faculty of Engrg., Tokyo Metropolitan Univ., Setagaya-ku, Tokyo, Japan, Bull. JSME, 21 (151), pp 56-63 (Jan 1978) 19 figs, 13 refs

Key Words: Rotors, Critical speeds, Gyroscopic effects

The nonstationary vibration of a rotor with a gyroscopic effect in passing through its critical speed is studied by using the asymptotic method. Two cases are examined in detail: a constant acceleration and the interaction between the driving source and the vibration system. The effect of internal damping on the stability is also studied.

78-1051

Influence of Oil Squeeze-Film Damping on Steady-State Response of Flexible Rotor Operating to Supercritical Speeds

R.E. Cunningham
Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TP-1094; E-9091, 44 pp (Dec 1977)
N78-13064

Key Words: Squeeze-film dampers, Flexible rotors, Periodic response, Unbalanced mass response

Experimental data were obtained for the unbalance response of a flexible rotor to speeds above the third lateral bending critical. Squeeze-film damping coefficients calculated from measured data showed good agreement with short-journal-bearing approximations over a frequency range from 5000 to 31,000 cpm. Response of a rotor to varying amounts of unbalance was investigated. A very lightly damped rotor was compared with one where oil-squeeze dampers were applied.

78-1052

Analysis of the Noise Generated by Axial Ventilators Resulting from Rotor-Stator Interaction

J. Jedryszek
Dissertation, Ph.D., Polytechnika Wroclaswka, Poland, 138 pp (1976)
(In Polish)
UM 1/2906c

Key Words: Interaction: rotor-stator, Noise generation, Noise reduction, Computer programs

An analysis of the noise generated in an axial ventilator by rotors and stators blade is presented in this dissertation. The ventilator's acoustical model is given. Stator blade altitude are received like geometrical spot of acoustical dipol source.

SHIP

(See No. 917)

SPACECRAFT

78-1053

Some Aspects of the Dynamics and Stability of Spinning Flexible Spacecraft

R.K. Williamson
Engrg. Science Operations, Aerospace Corp., El Segundo, CA, Rept. No. TR-0077 (2901-03)-8, SAM-SO-TR-77-210, 63 pp (Sept 12, 1977)
AD-A047 502/0GA

Key Words: Spacecraft, Rotating structures, Wobble, Dynamic stability

The hybrid coordinate approach combines discrete coordinates describing the translations and rotations of some bodies or reference frames of the system with distributed or modal coordinates describing the small relative motions of other parts of the system. This approach is illustrated by application to a simplified spinning spacecraft system.

78-1054
Stability and Control of Flexible Spacecraft with Parametric Excitation
C.J. Harris
Engrg. Lab., Oxford Univ., UK, Rept. No. OUEL-1193/77, 22 pp (Apr 1977)
N78-13120

Key Words: Spacecraft, Lumped parameter method, Mathematical models, Parametric excitation

The analysis and control of flexible spacecraft has attracted considerable attention in recent years; with ever increasing demands for fine pointing accuracy and larger and more complex vehicles, this problem is becoming more significant. The lumped parameter modeling approach is used to find a simple but representative three-dimensional mathematical model of a generalized flexible satellite with momentum exchange and body fixed gas jet reactor attitude controllers.

78-1055
Dynamic Model of a Three Axis Stabilized Geostationary Satellite with Flexible Solar Arrays in Normal Operation
G.K. Heimbold
Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Oberpfaffenhofen, West Germany, Rept. No. DLR-IB-552-77/7, 129 pp (Mar 16, 1977) (In German)
N78-14082

Key Words: Satellites, Dynamic structural analysis, Mathematical models

The equations of motion were derived from the total system energy by application of Lagrange's method. Structural flexibility was introduced into the system equations in a hybrid coordinate formulation, i.e., a combination of discrete and distributed (modal) coordinates. Some simulation results of the whole system using a digital computer numerical integration are shown.

78-1056
Resonant Behavior of a Symmetric Missile Having Roll Orientation-Dependent Aerodynamics
T.R. Pepitone
Ph.D. Thesis, Univ. of Virginia, 179 pp (1977)
UM 7800425

Key Words: Resonant response, Missiles

The transient response of a symmetric, cruciform missile, having roll orientation - dependent aerodynamics, is studied. The asymptotic method of Bogoliubov and Mitropolsky is employed, in the case of missle planar motion, to investigate the parametric resonance instability which exists at one-half the fundamental resonance roll rate.

USEFUL APPLICATION

78-1057
Dynamic Techniques for Detecting and Tracing Tunnel Complexes
R.F. Ballard, Jr.
Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES-MP-S-77-25, 17 pp (Dec 1977)
AD-A048 415/4GA

Key Words: Tunnels, Detection, Vibratory techniques, Acoustic techniques

The purpose of this investigation was to determine the feasibility of using various types of dynamic test techniques to detect and trace tunnel complexes.

AUTHOR INDEX

TECHNICAL NOTES

L.A. Month and R.H. Rand
The Stability of Bifurcating Periodic Solutions in a Two-Degree-of-Freedom Nonlinear System
J. Appl. Mech., Trans. ASME, 44 (4), pp 782-784 (Dec 1977) 4 figs, 8 refs

I. Elishakoff and M. Charmats
Godunov-Conte Method for Solution of Eigenvalue Problems and Its Applications
J. Appl. Mech., Trans. ASME, 44 (4), pp 776-779 (Dec 1977) 5 tables, 19 refs

P.T. Lewis
The Noise Generated by Single Vehicles in Freely Flowing Traffic -- Some Further Comments
J. Sound Vib., 55 (3), pp 472-473 (Dec 8, 1977) 1 table, 3 refs

C.V.S. Kameswara Rao
Creep Damage Under Stationary Random Loading
J. Appl. Mech., Trans. ASME, 44 (4), pp 763-764 (Dec 1977) 6 refs

Y. Tatara
Effects of External Force on Contacting Times and Coefficients of Restitution in a Periodic Collision
J. Appl. Mech., Trans. ASME, 44 (4), pp 773-774 (Dec 1977) 3 figs, 2 refs

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Response of Nonclassically Damped Linear Systems to Stationary Random Excitation
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Natural Frequencies of a Cantilever with an Asymmetrically Attached Tip Mass
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Elastic-Plastic Response of Simply Supported 1018 Steel Beams to Impulse Loads
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Simple Linear Formulas for Critical Frequencies for Cantilever Circular Cylindrical Shells
J. Sound Vib., 55 (3), pp 467-471 (Dec 8, 1977) 3 tables, 4 refs

L.E. Luisoni, P.A.A. Laura, and R. Grossi
Antisymmetric Modes of Vibration of a Circular Plate Elastically Restrained Against Rotation and of Linearly Varying Thickness
J. Sound Vib., 55 (3), pp 461-466 (Dec 8, 1977) 1 fig, 5 tables, 3 refs

J.F. Wilson and D.P. Garg
Frequencies of Annular Plate and Curved Beam Elements
AIAA J., 16 (3), pp 270-272 (Mar 1978) 3 figs, 8 refs

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Vibration of Plates Considering Shear and Rotatory Inertia
AIAA J., 16 (3), pp 285-286 (Mar 1978) 1 fig, 2 refs

H. Saito and H. Wada
Forced Vibrations of a Mass Connected to an Elastic Half Space by a Spring
J. Appl. Mech., Trans. ASME, 44 (4), pp 788-789 (Dec 1977) 2 figs, 3 refs

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A Further Note on the Poincare-Lighthill-Kuo Method and Non-Linear Hyperbolic Waves
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Shear-Damping Reduction Effects in Sandwich Beams
J. Sound Vib., 55 (4), pp 591-593 (Dec 22, 1977) 1 fig, 3 refs

SEPTEMBER 1978

11-13 **IUTAM Symposium on Variational Methods in the Mechanics of Solids,** [U.S. Army Research Office & National Science Foundation & Northwestern University] Evanston, IL *(Prof. S. Nemat-Nasser, Dept. of Civil Engrg., Northwestern Univ., Evanston, IL 60201 - Tel. (312) 492-5513.)*

11-14 **Off-Highway Meeting and Exposition,** [SAE] MECCA, Milwaukee, WI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - (412) 776-4841)*

24-27 **Design Engineering Technical Conference,** [ASME] Minenapolis, MN *(ASME Hq.)*

OCTOBER 1978

8-11 **Diesel and Gas Engine Power Conference and Exhibit,** [ASME] Houston, TX *(ASME Hq.)*

8-11 **Petroleum Mechanical Engineering Conference,** [ASME] Houston, TX *(ASME Hq.)*

17-19 **49th Shock and Vibration Symposium,** [U.S. Naval Research Lab.] Washington, D.C. *(H.C. Pusey, Director, The Shock and Vibration Info. Ctr., Code 8404, Naval Res. Lab., Washington, D.C. 20375 - Tel. (202) 767-3306)*

17-19 **Joint Lubrication Conference,** [ASME] Minneapolis, MN *(ASME Hq.)*

NOVEMBER 1978

26-30 **Acoustical Society of America** [ASA] Salt Lake City, UT *(ASA Hq.)*

26-Dec 1 **Acoustical Society of America, Fall Meeting,** [ASA] Honolulu, Hawaii *(ASA Hq.)*

27-30 **Aerospace Meeting,** [SAE] Town & Country, San Diego, CA *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - (412) 776-4841)*

DECEMBER 1978

4-6 **15th Annual Meeting of the Society of Engineering Science, Inc.,** [SES] Gainesville, FL *(Prof. R.L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603)*

10-15 **Winter Annual Meeting,** [ASME] San Francisco, CA *(ASME Hq.)*

11-14 **Truck Meeting,** [SAE] Hyatt Regency, Dearborn, MI, *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - (412) 776-4841)*

JUNE 1979

11-15 **Acoustical Society of America, Spring Meeting,** [ASA] Cambridge, MA *(ASA Hq.)*

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