THE SHOCK AND VIBRATION DIGEST

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WHOSE METHOD?

I'm sure this has happened to you. You are reading a technical paper and the author states that he has used "Abbadabba's" method to solve his problem. If you happen to be Abbadabba, or if you are familiar with his or her work, you continue to read the paper. If you are not familiar with that particular method, you come to an abrupt halt and look to see if the author has supplied a basic reference to the Abbadabba method. All too often the author has not taken the time to include a reference; and you, the reader, are left hanging. This is really a discourtesy to the reader and should be avoided. Instead of writing a paper for only a narrow field of specialists who are familiar with every subject item, authors should assume their readership to be made of people with a broad range of interests and write the paper accordingly. If a method is used as a basis for a technical paper, it is a good practice to cite a reference where the method is explained.

It is, however, a judgment call by the author as to which "methods" are common knowledge and which ones are more obscure. For instance, how many of the following "methods" are you familiar with?

- Andronow & Witt
- Bungetzianu
- Friedlander
- Frobenius
- Galerkin
- Guyan Reduction
- Holzer
- Kantorovich
- Kryloff-Bogoliuboff
- Kron
- Lyapunov
- Myklestad
- Newmark
- Rayleigh
- Stotola
- Van der Pol
- Wilson

These methods are all used as subject terms in the yearly index to the Shock and Vibration Digest. If your background is mechanical engineering, you certainly are familiar with the Holzer, Rayleigh and Ritz methods which are taught to every mechanical engineering undergraduate in any university today. With an ME degree, most of the terms above will look familiar. If your background is electrical engineering, or mathematics, or physics, then chances are that several of the names in the above list will be unfamiliar to you.

The problem, then, is where does one go to look for information when you are not familiar with a particular term? Unfortunately, there is no single reference work that can be consulted. I do have a few suggestions on what could be done, however.

What should a general reference contain and how should it be structured? Very common terms such as Newton-Raphson method or Runge-Kutta method probably do not need to be included in a general reference; but, for completeness, they could be. A good way to set up a general reference would be a glossary of terms with one or more references for each term. The more common methods such as Ritz or Holzer should be keyed to several standard engineering texts. For the rest of the methods, references to the open literature should be used. To be useful, the references cited should be the most readily available. Obscure texts and journals should not be used. It would also be useful to have an index where all similar terms are grouped. For example, one could list all eigenvalue extraction methods or energy methods.

I feel very strongly that such a glossary with subject index is needed in the shock and vibration community, and I am beginning the process of assembling material. If you know of any reference works that contain useful material which could be used in putting together such a glossary, please let me know about it.
PROFESSIONALISM IN ENGINEERING

About 10 years ago I wrote an editorial (June, 1973) on professionalism in engineering. At that time there was a lot of interest and discussion about professionalism in engineering. It appeared to me that in actual fact the concept was going nowhere. Today I believe engineers are developing as a profession; however, the motivations for this development have changed.

In the early 70s it was product liability that brought on the talk of professionalism in engineering. Then and today in many cases an engineer who had little control in the decision making process of the creation of a product could be held liable for misuse and/or inadequate design. Persons should be responsible for their actions; however, they should have control of how their works are modified and/or used in product development. This fact motivated a lot of talk about engineering professionalism. However, it was the motivations of technical independence and economic gain that caused professional engineering to progress.

More opportunities in the education, technical, and management areas now exist for engineers. For this reason I believe there is more independence among engineers. The promise of control over technical work and greater pay has increased the number of self-employed engineers and number of small engineering oriented companies. Most of these individuals and groups truly function as professional engineers.

It is not to say that an engineer who is employed by a company whose product is other than engineering services cannot function as a professional. It is a matter of whether or not that company will allow the engineer to operate as a professional.

R.L.E.
TURBULENT FLOW ANNULAR PUMP SEALS
A LITERATURE REVIEW

L.E. Barrett*

Abstract. This paper presents a review of the literature on turbulent flow annular seals including both theoretical and experimental work. Emphasis is placed on the application of these seals to main coolant pumps used in nuclear reactor facilities. A numerical example for calculating the dynamic force coefficients for rotor-dynamic response is presented together with design considerations relevant to main coolant pump applications.

Fine clearance annular seals are used in pumps primarily to prevent leakage between regions of different pressure within the pump. Two of the most typical arrangements are shown in Figure 1. One seal is located at the suction region of a shrouded centrifugal impeller and is used to reduce leakage between impeller shroud and case into the impeller inlet. Another is located at the back face of the impeller to prevent leakage between pump shaft and case from the higher pressure region of the next impeller. Although similar in appearance, there can be significant differences between these seals due to different lengths, radii, pressure drops across them, and velocity conditions of the fluid at the entrance.

Analysis of the fluid mechanics of flows within annular clearances is complicated because turbulence in the flows is pressure induced. Thus, normal thin-film turbulent hydrodynamic bearing analyses are usually not applicable, even for the relatively simple situation in which the shaft is perfectly centered within the case. A further complication is the presence of grooving patterns in the shaft surface. These grooves can either be a series of circumferential grooves or form a spiral pattern with various numbers of leads, as in worm gears.

Minimization of leakage is a very important consideration in annular seal design. Another important consideration is the development of significant forces on the shaft and impeller shroud by the fluid passing through the annulus as the shaft moves eccentrically within the clearance space. These forces are due to variation in the pressure distribution around the shaft circumference because of geometrically-induced variations in the flow path. The basic mechanism producing the generation of these forces can be described as follows.

The steady-state axial pressure distribution at any circumferential location within a seal is shown in Figure 2a for a simple case without shaft rotation. The pressure at the inlet of the seal is $P_s$ and that at the seal exit is $P_e$. As flow accelerates into the seal, a pressure drop occurs due to the Bernoulli effect. An additional decrease in pressure at the inlet region occurs due to the development of a turbulent flow velocity field into its fully developed form. The remainder of the pressure drop through the seal is very nearly linear. If the shaft becomes eccentric within the seal, the velocity at the top of the shaft increases because of the larger gap through which the fluid flows. Flow velocity at the bottom decreases because of the smaller gap height there. Thus, pressure drops at the seal entrance are flow-velocity

Figure 1. Typical Arrangements of Fine Clearance Annular Seals

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dependent and differ from top to bottom as shown in Figure 2b. At the top, the entrance pressure drop increases; at the bottom the entrance pressure drop decreases. Therefore, a net increase in pressure at the bottom of the seal produces an upward force tending to restore the shaft to its original, centered position. A similar situation occurs when the lateral velocity of the shaft changes.

The pressure distributions shown in Figure 2a and b are modified by shaft rotation and geometric variations within the seal, but the underlying principles governing pressure buildup within a seal remain the same. Successful application of annular seals to modern pump design and operation requires recognition of not only the efficiency aspects of seal design but also the forces exerted by the seal upon the shaft during dynamic motion. Both aspects, but primarily the latter, have been the subject of somewhat sporadic published research over the past 50 years. An overview of this research is presented in the following section.

ANNULAR SEAL LITERATURE REVIEW

The published literature on turbulent flow annular seals can be separated into four categories: (1) analytic determination of leakage rates; (2) analytic determination of dynamic force coefficients; (3) experimental measurement of flow rates and friction factors, and (4) experimental measurement of dynamic force coefficients. Within each category various geometries and ranges of operating conditions have been considered.

Calculation of leakage and pressure distributions within turbulent flow annular seals is universally based upon bulk flow analysis; empirically derived friction factors or wall shear stress are used. A number of experimental studies have addressed these measurements [4, 23, 41, 42, 46-55] and form the basis upon which most of the analytical work has been built. In particular, Nixon and Cairney [42], Tao and Donovan [47] and Yamada [52-54] have provided similar useful correlations for the friction factor between concentric cylinders with one or both surfaces rotating. These correlations include the effect of circumferential velocity of flow within the seal on the friction factor for axial seal flow velocity. These correlations assume fully developed turbulent flow in the circumferential as well as the axial directions. These correlations are of the general form

\[ \lambda = \frac{n_0 R_a^{m_0}}{R_b^{m_0}} \left( 1 + a \left( \frac{R_b}{R_a} \right)^2 \right)^b \]

and can be incorporated into a bulk flow analysis of seal flow.

Perhaps the first reference in the literature to the presence of dynamic forces in annular flow seals is attributable to Lomakin [38], who in 1958 presented a static analysis neglecting shaft rotation and lateral velocity; his analysis predicted the magnitude of stiffness developed by seal flow. However, it proved difficult to verify the predictions by measuring resonant frequencies and peak amplitudes in pumps because velocity-dependent damping forces neglected by Lomakin are also produced by seal flow [24, 45].
Beginning in 1969 Black produced a series of papers in which he developed an analysis of turbulent flow seals to include calculations of damping and inertia force coefficients as well as the effects of shaft rotation [6-13]. These papers also include results of several experimental studies and examine the effect of seals on the rotor-dynamic response of pumps. Because of its importance, Black's analysis is described in detail.

Black's analysis is based on a bulk flow formulation of the continuity and momentum equations for pressure-induced incompressible flow between two flat plates including a time-dependent gap height [6]. The bulk flow pressure gradient in the direction of fluid flow is therefore equated to bulk flow fluid inertia and to turbulent friction losses along the flow path. A perturbation analysis of this equation assumes that the change in film height is small during dynamic motion. The resulting differential equation is solved subject to the boundary conditions mentioned earlier; i.e., that there is a pressure drop at the entrance to the gap due to the Bernoulli effect on the flow accelerating into the gap and that additional losses are due to development of the flow velocity field.

Black argued that, for a nearly centered shaft within a seal, the above results are applicable. He integrated the pressure distribution over the shaft surface to obtain the resultant force exerted by flow on a shaft undergoing small displacement motion about the concentric position. This expression, which is linearized to give forces in terms of shaft displacement, velocity, and acceleration, directly yields stiffness, damping, and inertia force coefficients. The coefficients are direct because shaft rotation is neglected. Thus, the forces are in direct opposition to the motion. The linearized force coefficients are functions of shaft length and gap height, fluid density, and the friction factor for flow. The stiffness coefficient is identical to that previously developed by Lomakin.

Black applied his results to a rotating shaft by assuming first that the circumferential flow is fully developed turbulent Couette flow. Further assuming that circumferential flow remains essentially unchanged during small shaft motion, he argued that, in a one-half shaft speed reference frame attached to the shaft, the flow field appears nearly the same as in the non-rotating case previously described. Using a coordinate transformation back to a fixed frame of reference, he obtained a set of stiffness, damping, and inertia coefficients for the rotating case in terms of the nonrotating coefficients. Examination of these coefficients reveals that the direct stiffness is reduced by fluid inertia when shaft rotation is present. The direct damping and inertia coefficients are essentially unchanged. The presence of shaft rotation, however, gives rise to cross-coupled stiffness coefficients, as occurs in hydrodynamic journal bearings. These cross-coupled coefficients represent forces that are exerted on the shaft in a direction perpendicular to the motion producing the force. As in hydrodynamic journal bearings when the shaft is nearly centered, these cross-coupled stiffness forces are phased such that they promote dynamic instability of the shaft.

Limitations to Black's original analysis include small motion about the centered shaft position, small length to diameter ratios (implied by the assumption of undisturbed circumferential flow), plain seal surfaces, constant entrance flow development losses, constant friction factor throughout the flow, large ratios of axial to circumferential flow Reynolds numbers, and a one-half speed bulk flow circumferential inlet velocity. Some of these deficiencies were overcome in later publications.

Black and Murray [7] presented an overview of Black's previous seal work together with some experimental work on plain seals. They provided calculated comparisons to Stepanoff's leakage data [43] and load capacity comparisons for eccentric shaft operation showing turbulent transition flow nonlinearities. Yamada's friction factor correlation was used [48]. Black and Jenssen [8] presented Black's original analysis reformulated to include a variable friction factor during perturbation and comparisons to experimental load capacities that show improvement over the original theory. Black and Cochrane [12] presented a semi-empirical approach to calculating the stiffness and damping coefficients for serrated (circumferentially grooved) seals. This approach incorporates an effective seal length into finite length correction factors developed by Jenssen [36] for Black's original short seal theory. The effective length is calculated by assuming that the gap in the grooves is the same as that in the lands; circumferential viscosity there is altered, however, to give circumferential pressure gradients that would exist within
the grooves. In this analysis flow rate predictions are not changed from those for a non-serrated seal, but comparisons of predicted direct stiffness and inertia forces to measured values show reasonable agreement.

This body of work by Black and his colleagues represents a fundamental analysis of turbulent flow annular seals; little additional analytic work was done for several years. A resurgence of interest in seals occurred in 1976 because of instability problems encountered in the space shuttle engine high-pressure hydrogen fuel turbopumps [1, 14, 26]. Rotor-dynamic analysis indicated that improved stability could be achieved by redesign of the interstage seals to produce increased stiffness and damping, thereby increasing the natural frequency of the unstable mode and more effectively damping the unstable oscillations. These effects were confirmed by subsequent testing. In addition to rekindling analytic research interest, this particular problem has led to further experimental programs motivated by the extremely high Reynolds numbers occurring with liquid hydrogen flows. Allaire et al [1] and Allaire, Lee, and Gunter [3] presented analyses extending Black's work to eccentric operation of the shaft within the seal. Allaire and Lin [2] also presented a new analysis that relaxed Black's original assumption of large axial to circumferential flow Reynolds number ratios to incorporate a wider range of applicable operating conditions. This analysis is based on turbulent bulk flow equations of fluid motion developed by Hirs [31, 32] rather than the bulk flow equations of Black. These analyses are still restricted to plain seal surfaces, constant inlet loss coefficients, and fully developed inlet circumferential flow velocity.

The turbulent bulk flow equations of Hirs [33, 34] are developed from the premise that a relationship between wall shear stress and flow Reynolds number for pressure-induced turbulent flow exists that is similar to the more well known correlation for Couette or drag flow. Hirs then introduced a fictitious pressure gradient to represent the Couette portion of a general flow; he derived his bulk flow equations of motion by resolving into orthogonal components the shear stresses acting at the solid boundaries of the flow. He then eliminated the fictitious pressure from the equations of motion through algebraic manipulation. Mean flow convective and temporal inertia terms are added to the equations. As in Black's bulk flow model, recourse to empirical data is required to obtain the necessary constants in the relationships between wall shear stress and flow Reynolds number for drag and pressure-induced flow.

For the case of drag-induced turbulence, such as is generally found in hydrodynamic journal bearings, Hirs equations, neglecting inertia effects, give essentially the same results as the linearized turbulence theories of Constantinescu [22], Elrod and Ng [27], and Ng and Pan [43]. One advantage to the Hirs formulation is that it is more general than Black's and directly gives both axial and circumferential momentum equations. Black, Allaire, and Barrett [13], however, have developed a bulk flow circumferential momentum equation. They used it to examine the effect of circumferential inertia and variations in inlet circumferential swirl velocity of the fluid as it enters the seal. Consistent with Black's earlier analyses, it was assumed that axial flow velocity was much greater than that in the circumferential direction. The predominant effect of variation in the inlet swirl velocity was shown to alter the cross-coupled stiffness force coefficients. These coefficients are reduced in magnitude as swirl velocity is reduced. In fact, under proper circumstances of seal geometry, axial pressure drops, and inlet swirl velocity, the signs of the cross-coupled stiffness coefficients are reversed; cross-coupling promotes stability rather than instability.

Comparisons to the attitude angles for steady-state loads previously measured by Jenssen [36] show better correlation for cases in which the inlet swirl velocity of the tests was less than the one-half shaft speed velocity originally assumed by Black. Because the steady-state attitude angle of the shaft is directly attributable to cross-coupled forces, this comparison provides indirect verification of the accuracy of the coefficients. Because wide variations can occur in the inlet swirl velocity, depending upon where annular seals are installed in pumps, this analysis represents a needed improvement to the fundamental theory.

The application of turbulent flow annular seals to the space shuttle main engine turbopumps motivated analytical and experimental research by Childs. His experimental data have been obtained from two test rigs. His first rig was designed for rather low Reynolds number turbulent flows [17, 18] and incorporated...
axial pressure transducers to determine the axial pressure distribution. Unlike Black's earlier rigs, Childs' rig incorporated controlled orbital motion of the shaft, thereby introducing dynamic pressures that he numerically integrated to obtain dynamic force coefficients. However, this method gives the combined dynamic forces represented by direct stiffness and inertia coefficients and by direct damping and cross-coupled stiffness coefficients. Preliminary results [17, 18] are somewhat inconclusive, however.

The extremely high Reynolds numbers experienced in the space shuttle fuel turbopumps prompted Childs to build a second test rig for high Reynolds number flows. As with the first rig, controlled motion of the shaft is provided and axial pressure measurements are taken. Unlike the first rig, however, the test section is designed for easy installation of different seal geometries. Halon is used as the working fluid to accommodate extremely high Reynolds number flows. To date, only preliminary results have been reported [20, 21].

Concurrent with experimental work, Childs has published a series of papers on the analysis of turbulent flow annular seals [15, 16, 19]. He presents an analysis of small length to diameter ratio seals [15]. His analysis is based upon Hirs bulk flow equations of motion and is similar to Black's analyses. Childs, however, retains additional fluid inertia terms in the momentum equations. His results are the same as those of Black when a one-half shaft speed swirl velocity is assumed. However, for other inlet swirl velocities, Childs predicts that inlet flow swirl affects not only the cross-coupled stiffness coefficients but also the direct stiffness coefficients. Childs analysis is also based on linearization of the governing equations using a small perturbation technique.

Childs has also presented an analysis of short tapered seals [19] and of finite length plain seals [16]. Both analyses are small perturbation linearizations of governing equations of motion. However, for small length-to-diameter ratios, Childs' finite length analysis does not reduce to the solution he obtained by imposing the assumption of a short seal [15]. Childs attributes this to a deficiency in Hirs governing turbulent bulk flow equations and suggests that similar problems can also occur for other thin-film pressure-induced turbulent flow models. These other models have not yet been expressly applied to the annular seal problem.

**APPLICATION TO PUMP DYNAMICS**

Most of the applications of turbulent flow annular seals to pump dynamics reported in the literature are for horizontal pumps, mostly in boiler feed service. Included are papers by Bedger [5], Black [11], Duncan [25], Lomakin [38], and Marcenkowskij [40]. References to applications to high pressure turbopumps include Childs [14], Ek [26], and Fleming [28, 29]. Discussions of applications to vertical pumps, particularly nuclear reactor main coolant pumps, is virtually nonexistent. It is clear from the above references that turbulent flow annular seals in multistage pump applications and in straddle-mounted single-stage pump applications have a dramatic effect on the dynamics of the machines. In fact, stiffness and damping properties provided by the seals represent the dominant forces exerted on pump shafts, excluding the fluid forces of flow through the impellers, particularly at part-flow operating conditions. For these systems the hydrodynamics of oil-lubricated journal bearings are also generally dominated by seal properties.

In typical applications shaft resonant critical speeds are rarely observed because of the tremendous damping capability afforded by seals. It is usually only when excessive wear occurs in seals that dynamics problems arise that can be attributed to the pump itself. These problems occur because of the decrease in dynamic forces exerted by the seals with increasing seal clearance.

The situation is not that different for single-stage vertical pumps such as nuclear reactor main coolant pumps. In most designs the pump impeller is not mounted between bearings but is cantilevered from the pump shaft bearing. Oil-lubricated bearings on the motor shaft are sufficiently removed from the impeller so that their effects on the dynamics of the pump shaft are limited due to motor and pump shaft flexibility and coupling flexibility. The pump shaft bearing, whether hydrodynamic or hydrostatic, is generally pressure fed with water from the impeller. Thus, under certain conditions, in which the pressure differential across the bearings can be reduced, the impeller seals are possibly the only significant source
of damping available to control the motion of the pump impeller.

Unlike multistage horizontal pumps, there are generally only two annular seals in main coolant pumps, one at the impeller suction and one between the impeller and the pump shaft bearing. For this type of design, the dynamic forces exerted by the seals can critically affect the dynamic behavior of the lower portion of the pump shaft. The reason is that seal forces can be of the same order of magnitude as dynamic forces generated by the pump shaft bearing. The geometry of the seals plays a crucial role in determining the dynamic forces; therefore, the geometry must be matched not only to leakage requirements of the pump but also to dynamic requirements. In this regard seal dynamic forces must be matched to those of the pump shaft bearing.

The effects of varying the dynamic forces on the lower portion of a main coolant pump shaft have been considered by Salamone and Gunter [44]. They analyzed undamped critical speeds and synchronous forced response of a pump. They considered the seal forces to be negligible although they included the pump shaft bearing.

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REFERENCES


APPENDIX

This Appendix presents an example calculation of the dynamic forces exerted by a pump impeller neck ring seal for a nuclear main coolant pump. The analysis of Black [8] is used because it involves the simplest calculations. It is assumed here that the bulk circumferential inlet flow swirl velocity is one-half the shaft surface speed and that the shaft is nearly centered in the seal.

The annular neck ring seal has the following geometric properties.

- Length = 50 mm
- Radius = 75 mm
- Radial clearance = 0.25 mm

At operating conditions the pressure difference across the axial length of the seal is \( P = 1.38 \times 10^6 \) Pa. The water properties are

- Viscosity = \( \mu = 4.14 \times 10^{-4} \) Pa\( \cdot \)s
- Density = \( \rho = 979 \) kg/m\(^3\)
- Pump operating speed is \( N = 1200 \) rpm

The relationship between the total axial pressure drop and the mean axial flow velocity is

\[
P = \frac{1}{2} \left( 1 + \xi + 2 \sigma \right) v^2
\]

where \( \xi = \text{inlet loss coefficient} \)

\( \sigma = \lambda L/c \)

The correlation between friction factor \( \lambda \) and the axial flow Reynolds number \( R_a \) used by Black is

\[
\lambda = 24 \frac{1}{R_a} \quad (\text{laminar flow}), \quad R_a \leq 3000
\]

\[
\lambda = 1.90 \times 10^{-5} R_a^{3/4} \quad (\text{transition flow}), \quad 3000 \leq R_a \leq 4200
\]

\[
\lambda = \frac{2.079}{R_a^{1/4}} \left[ 1 + \left( \frac{7R_r}{8R_a} \right)^2 \right]^{3/8} \quad R_a \leq 42000
\]

where

\[
R_a = \frac{2\rho v c}{\mu}
\]

and

\[
R_r = \frac{\rho R Owen}{\mu}
\]

Although Black used a friction factor correlation for laminar flow, the theory is valid only for turbulent flow and for axial Reynolds numbers much greater than the circumferential Reynolds number, i.e.,

\[
R_a \gg R_r
\]

After the analysis is performed, these conditions should be tested to determine the applicability of the analysis. Because \( \sigma \) is a nonlinear function of the mean velocity, the equations for \( P \) and \( \sigma \) must be solved interactively. Assume initially that the flow velocity is

\[
v = 25 \text{ m/s}
\]

The initial axial Reynolds number is

\[
R_a = \frac{(21)(979)(25)(0.00025)}{4.14 \times 10^{-4}} = 25559
\]
and

\[ R_r = \frac{(979)(0.075)(1200)(0.00025)}{(30)(4.14 \times 10^{-4})} = 5572 \]

Solving for \( \sigma \) gives

\[ \sigma = \frac{0.079}{25559^{3/4}} \left( 1 + \left[ \frac{3}{8} \left( \frac{5572}{25579} \right) \right]^2 \right)^{3/8} \]

\[ \left( \frac{0.05}{0.00025} \right) = 1.266 \]

Rewrite the equation for \( P \) as

\[ V = \sqrt{\frac{2P}{(1 + \xi + 2\alpha)}} \]

and solve for a new value of \( v \).

\[ V = \left[ \frac{(2)(1.38 \times 10^6)}{979(1 + 0.1 + (2)(1.266))} \right]^{3/8} = 27.86 \text{ m/s} \]

Repeat this process iteratively to obtain the mean flow velocity as

\[ V = 28.67 \text{ m/s} \]

Only three additional iterations are necessary.

The axial volumetric flow rate is

\[ Q = 2\pi Rcv \]

or

\[ Q = 2\pi(0.075)(0.00025)(28.67) = 3.38 \times 10^{-3} \text{ m}^3/\text{s} \]

The final value of axial Reynolds number is 33898. Thus the flow is fully turbulent.

The dynamic force coefficients for small motion of the shaft in the annular clearance are given as

\[ F_x = -\begin{bmatrix} k & k_c \\ -k_c & k \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} - \begin{bmatrix} c & c_c \\ -c_c & c \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} \]

\[ F_y = \begin{bmatrix} m_a & 0 \\ 0 & m_a \end{bmatrix} \begin{bmatrix} \ddot{x} \\ \ddot{y} \end{bmatrix} \]

where \( x \) and \( y \) are fixed coordinate displacements of the shaft and the dots are derivatives with respect to time.

The stiffness coefficients are

\[ k = \frac{\pi \lambda}{\lambda} \left( \mu_0 - \mu_0^2 T^2 / 4 \right) \]

\[ k_c = \frac{\pi \lambda}{\lambda} \left( \mu_1 \omega T / 2 \right) \]

The damping coefficients are

\[ c = \frac{\pi \lambda}{\lambda} \left( \mu_1 T \right) \]

\[ c_c = \frac{\pi \lambda}{\lambda} \left( \mu_2 \omega T^3 \right) \]

and the inertia coefficient is

\[ m_a = \frac{\pi \lambda}{\lambda} \mu_3 T^2 \]

The coefficients \( \mu \) are given by

\[ \mu_0 = \frac{(1 - \xi \alpha \omega)^2}{(1 + \xi + 2\alpha)^2} \]

\[ \mu_1 = \frac{(1 + \xi \alpha \omega^2 + 12\xi \alpha \omega^4 + 38\xi \alpha \omega^6 + 13\xi \alpha \omega^8 + 1.33\alpha \omega^{10}}{(1 + \xi + 2\alpha)^3} \]

\[ \mu_2 = \frac{0.33(1 + \xi \alpha \omega^2) - 1 / \alpha \omega + (1 + \xi)(1 + \xi \alpha \omega^2) + (1 + \xi \alpha \omega^4 + 1.33\alpha \omega^{10}}{(1 + \xi + 2\alpha)^4} \]

The mean passage time given is

\[ T = L/V \]
Substituting $\xi = 0.1$ and $\sigma = 1.266$ into the equations for $\mu_0$, $\mu_1$, and $\mu_2$ gives

$\mu_0 = 0.127$

$\mu_1 = 0.295$

$\mu_2 = 0.059$

Also

$T = 0.05/28.67 = 1.744 \times 10^{-3} \text{ s}$

and

$= 1200 \pi/30 = 125.7 \text{ s}^{-1}$

The force coefficients become

$k = \frac{\pi(0.075)(1.38 \times 10^6)}{5.8 \times 10^{-3}}$

$\left\{0.127 - (0.059)(125.7)^2 (1.744 \times 10^{-3})/4\right\}$

$= 7.080 \times 10^4 \text{ N/m}$

$k_c = \frac{\pi(0.075)(1.38 \times 10^6)}{5.8 \times 10^{-3}}$

$\left\{0.295(125.7)(1.744 \times 10^{-3})/2\right\}$

$= 1.813 \times 10^4 \text{ N/m}$

with the damping and inertia coefficients similarly calculated to be

$c = 2.884 \times 10^4 \text{ N-s/m}$

$c_c = 1.265 \times 10^3 \text{ N-s/m}$

$m_a = 1.006 \times 10^1 \text{ N-s}^2/\text{m}$
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.

This issue of the DIGEST contains an article about torsional vibration of crankshafts in reciprocating machines.

Dr. D.K. Rao, visiting scientist at Wright Patterson Air Force Base, Ohio (on leave from Indian Institute of Technology, Kharagpur, India) has written a review of current literature dealing with determination of torsional natural frequencies and vibratory stresses in reciprocating machinery shafting.
TORSIONAL VIBRATION OF CRANKSHAFTS IN RECIPROCATING MACHINES

D.K. Rao

Abstract. Crankshafts and connected shafting in reciprocating engine-driven systems such as ship propulsion drives, air compressors, diesel generator sets, and automobiles can fail if excessive torsional vibratory stresses are developed due to a torsional mismatch between driving and driven machinery. This paper reviews current literature dealing with determination of torsional natural frequencies and vibratory stresses in reciprocating machinery shafting.

This article is an update of a previous review [79] on current literature on free and forced torsional vibration responses of crankshafts and connected shafts in reciprocating machines. The topics reviewed include torsional model refinement, theoretical analysis, selection of dampers and couplings, applications, and program developments. Other reviews of similar topics have also appeared [81, 89, 93].

TORSIONAL MODEL REFINEMENT

Finite element method. In the standard model used to analyze torsional vibrations of reciprocating machine shafting the rotating shaft is replaced by a series of massless torsionally flexible shafts connected by rigid rotors. Attempts to improve this multi-rotor model with a finite element model (FEM) have been made [4, 5]. Bagci [6] concentrated on spatial elements each end of which can experience three displacements and three rotations. He compared the natural frequencies of a three throw crankshaft obtained by an FEM and conventional models with experimental data. Better correlation was obtained between FEM natural frequencies and experimental values.

Nagamatsu [58] used tetrahedral elements to model the crank arm and transfer matrix analysis to model the straight shaft part. He also computed the natural frequencies, modes, and dynamic response. His results also agreed well with experimental values. Kolenda [49] also used FEM to refine the natural frequency computation of crankshafts.

Coupled torsional-axial-bending vibrations. Analysis of torsional vibrations of a crankshaft can be refined by including the coupling between torsional, axial, and bending vibrations. Buckens [14] and Iida [40] concentrated on the coupling between torsional and flexural vibrations due to variation in transmission ratio. This variation is caused by changes in the central distances of gears, eccentricity, and/or mass imbalance. Their analysis showed how the natural frequencies shift due to coupling.

Kemper and Nesterova [44] used the method of initial parameters to determine the coupled torsional-axial frequencies of a marine crankshaft. Jeon and Tsuda [43] presented a method for estimating the resonant amplitudes of a marine diesel engine under combined torsional-axial vibrations. Coupled torsional-axial-bending frequencies of a tractor engine crankshaft were determined by Groza [34], who used a matrix method. His results compared favorably with experimental results. Coupled vibrations of crankshaft taking into account the elasticity of supports have been investigated [62]. Other vibrations have also been analyzed [18].

Variable inertia effects. Because the effective inertia of a crank varies with crank angle, secondary resonances occur as a result of variable inertia effects. Pasricha and Carnegie [70] investigated recent diesel crankshaft failures in the light of variable inertia effects. Krumm [52, 53] developed a theoretical analysis of variable inertia effects; Klier [47] dealt with experimental results. The effect of reciprocating mass on the torsional vibrations of a crankshaft has also been considered [36].

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THEORETICAL ANALYSIS

Natural frequencies and modes. Determination of natural frequencies by the Holzer method requires an estimated initial trial frequency as well as a frequency search increment. Some studies [20, 21] have involved improvement of the Holzer method; that is, a self-starting automatic root-search algorithm. Similar attempts to refine Holzer transfer matrix methods have been made [63, 73, 80, 86, 98]. A method for obtaining natural frequencies of a shaft with attached rotors that accounts exactly for distributed inertia of the shaft has been outlined [32]. The effect on natural frequencies of separately representing gears has been analyzed [63]. Methods for finding the lower bounds for fundamental natural frequencies have been developed [67, 84]. Bond graph techniques have been used to obtain natural frequencies [3, 92].

Detuning and model synthesis. The effects of changes in torsional stiffness and inertias on natural frequencies have been investigated [25]. Synthesis of a torsional model and its use in detuning diesel engine crankshafts have been discussed [64, 65]. Detuning of a fan motor by symmetrization and selection of appropriate inertias has been demonstrated [33, 85]. An associated problem, identifying system parameters from natural frequency data, has also been analyzed [87].

Excitation analysis. Complex amplitudes of disturbing forces for engines with complicated kinematic structure have been obtained by harmonic analysis [60]. Errors in measurement and approximation of indicator diagram by a Fourier series have been analyzed [55]. Such errors as leakage, piston deformations, and running clearances tend to displace the FTDC reference mark of excitation, but this displacement has been shown -- by a theoretical and experimental study -- not to greatly influence torsional vibration [83].

A method for estimating excitation from dynamic response measurements has been outlined [19]. Low frequency variations in angular speed of an Otto engine have been traced to the fuel mixture preparation [7]. Proper modeling of propeller-induced vibrations has been studied [15]. An experimental investigation into thermo-fluid-dynamic excitation sources for helicopter engine has been conducted [31]. The effect of torsional excitation on the stability of speed-controlled engines has been discussed [51]. The correlation between dynamic loads on gear teeth and torsional vibration has been analyzed [53]. Start-up excitation torques and their relation to actual shaft torques have been discussed [35].

APPLICATIONS

Automotive and railroad engines. Studies on torsional vibrations of vehicle engines have been conducted by a number of authors. Based on a series of road tests, high noise levels in passenger compartments of a European car were traced to a torsional resonance [16]. Correlation between a noise-generating mechanism and torsional vibrations in a car diesel engine at a single frequency has been studied [66]. The connection between the angular vibrations of a vehicle frame and the torsional vibrations of revolving masses due to a reduction gear on a propulsion shaft has been investigated [72], as have typical automotive gearbox torsional vibrations [77]. The effect of peripheral clearance of drive shafts on the torsional frequencies of vehicles has been analyzed [10], as has nonlinear model of torsional vibrations of a propulsion shaft with universal joints in an automobile [26]. Methods for eliminating undesirable torsional resonances were suggested for the latter case [26]. A linearized solution of similar automobile transmission torsional vibration problems has been studied [48].

The effect of Hooke's joints, backlash, and overload on torque inputs of the power takeoff (PTO) of a tractor on crankshaft torsional vibrations has been analyzed [17]. Coupled torsional vibrations of tractor engines have also been analyzed [34]. Torsional vibrations of helicopter engines due to irregular operation have been studied experimentally [31]. Permissible vibration limits in power transmission equipment as well as useful experimental methods for torsional vibrations have been discussed [27-29].

A complete analysis of torsional vibrations of hydraulic and mechanical coupled diesel rail car engines for operation up to 160 kph has been presented [71]. Performance standards for diesel locomotive crankshaft vibration dampers have been evaluated [38, 39].
Static measurements of machine tool gear drives have been shown to be useful [11, 12] in evaluating their dynamic behavior under operating conditions. The effects of gear manufacturing errors on the torsional vibration of machine tool drives have been investigated [45].

Compressors and motors. Excessive vibrations that have been observed after motor shutdown of a reciprocating compressor have been traced to torsional vibrations of a crankshaft connected to a large motor rotor by a comparatively slender shaft [41]. A laser-doppler system has been used [1] to measure the torsional vibrations of large compressors in petrochemical plants and ship engines; the sensitivity was 0.01 deg over a frequency range of 0-10 kHz. Transient torsional response of air compressors during starting and stopping have been investigated [75, 76]. An iterative analysis of a motor-driven system in which the motion of the input shaft dictates the driving torque, which, in turn, controls torsional vibrations, has been made [68]. Transient motor start-up torques and resulting torsional vibrations have been analyzed [35]. Torsional oscillation-induced insulation failures due to accumulated heat in electrical generators have been investigated [69]. The effect of shaft vibration on an electrical coupling between two identical generators feeding the same transmission lines has been analyzed [2]. Problems of fatigue strength and probability of failure of turbogenerator shafts in the presence of torsional vibrations have been discussed [96].

Ship engine shafts. An extensive literature exists on torsional vibrations of ship engine crankshafts. Bishop [9] considered the problem of controlling ship-engine vibration with a fluid drive. Results of full-scale experiments and the influence of the hull after body-induced propeller excitation on shafting have been discussed [15]. Coupled torsional-axial vibrations of marine engine shafting have been studied [43]. Marine shaft designs have been considered from a torsional vibration point of view [42, 50, 54]. Vibration tests on a twin screw container ship indicated that vibrations of bossings are mainly due to shafting [59]. Marine engines with large reduction gears that have severe torsional vibration problems have been studied [73]. Torsional stresses in marine engine shafts with and without dampers have been analyzed [102]. Correlation between dynamic loads on gears and torsional vibrations has been discussed [53].

Measurement and testing. A laser doppler system has been used to design a contactless torsional vibration measuring system [1]. A desk calculator has been used in the acquisition of torsional vibration measurement data [8]. Road test measurements of a car identified torsional resonance as a source of noise [16]. Field and laboratory measurements of torsional vibrations and related vibration standards have been described [27-29]. Shaft torques developed during startup have been measured and analyzed [35]. Results of experimental tests on marine engine shafting vibrations and comparison with theoretical torsional-axial natural frequencies have been presented [44]. Container ship vibration test measurement data have been reported [59].

DAMPERS AND COUPLINGS

A frequent problem faced by a designer has to do with choosing the best combination of dampers, couplings, and flywheels so as to minimize the maximum torsional stress developed in the shafting in the speed range of interest. Damper performance and analysis have been studied in great detail [9, 13], and formulas for determining the performance quality of friction dampers have been given [24]. Viscous dampers used for diesel locomotive shaft vibration control have been studied [38, 39]. Loss modulus and spring modulus of silicone oils used in dampers have been measured over a frequency range of 20-300 Hz at various temperatures [30].

Formulas for computing torsional vibrations taking into account internal damping have been presented [29]. Performance of a tuned vibration damper coupled to a diesel engine has been studied when one cylinder misfires [56] and when the engine is accelerating [57]. Problems associated with intermittent service and nonfiring of cylinders have been addressed [94, 95]. A calculation procedure for optimizing the damping capacity of a Holset-type friction damper has been outlined [82]. Low frequency vibration damping of a silicone damper in a marine engine has been analyzed [90]. A Voigt model was used to
simulate the stiffness and damping cycle of a rubber damper.

Wakabayashi [97] developed an approximate method for analysis of torsional vibrations in conjunction with transfer matrices. He corroborated his results with experimental evidence. Selection of torsionally flexible couplings to minimize torsional vibratory stresses has been described [37, 101], and selection of proper couplings to improve the torsional vibration characteristics has been considered [88].

**COMPUTER PROGRAM DEVELOPMENT**

Software dealing with analysis of torsional vibration of shafts (including crankshafts) using the multi-rotor model have been reviewed [74, 81, 89, 93]. These reviews cover application packages developed in the United States up to 1976. Further developments are given below.

A program for computing natural frequencies of machine tool drives has been described [11, 12]. Program HOLZER, developed by Dawson [22], uses the Holzer method to obtain torsional natural frequencies. A calculator-oriented program to determine the natural frequencies of a two-rotor model connected by a continuous shaft has been described [32]. A program using an extended Tuplin's method has been developed [98] to study natural frequencies.

Program TORVAR, developed by Rao [78], takes advantage of the finite element approach to reduce profile storage requirements. It uses efficient vector iterative methods to determine frequencies, modes, and vibratory stresses for in-line and branched shaft systems. Both damped and undamped vibrations including cylinder misfirings are covered by the program.

A program for calculating free and forced torsional vibrations has been described [46], as have programs to study the parametric excitation of crankshaft vibrations [52] and to find the torsional stresses in marine engines [102]. A desk calculator program has been developed [10] for use in measuring torsional vibrations.

**REFERENCES**


51. Kritzer, R., "Stability and Forced Torsional Vibrations of Speed Controlled Piston En-


THE PHYSICAL THEORY
OF ELECTROMECHANICAL SYSTEMS

D. Stanomir
Publishing House of the Romanian Academy
of Sciences, Bucharest
1982, 254 pages (In Romanian)

This book by D. Stanomir, a professor of electro-
acoustics at the Polytechnic Institute of Bucharest,
Romania, is a comprehensive text on the physical
behavior of electromechanical systems. The author
presents a unified treatment of the fundamental
concepts from system theory, electrical circuit
theory, and irreversible thermodynamics.

For members of the shock and vibration community
this text will be useful for accurate analyses of
different transducers and electrodynamic exciters.
It is recommended to anyone with a moderate math-
ematical background who wants to gain insight into
electromechanical analogies and access to the ad-
vanced literature on general dynamic systems.

The book is organized into seven chapters and an
appendix. The first chapter presents definitions and
properties of hybrid systems; that is, systems made
by coupled subsystems consisting of lumped elements
of the same kind (electrical, mechanical, or acousti-
cal). A four-sided functional diagram, based on a
classification suggested by Mie, is developed to
describe the possible constitutive relations between
primitive state variables and their time derivatives
called generalized velocities). Elementary one-
two-, and n-ports as well as hybrid n-ports are defined
 together with the constraints imposed upon their
functional relations. The Onsager-Casimir principle
for dissipative phenomena is used throughout.

Chapter 2 summarizes the main concepts and theo-
rems of the analytical mechanics used in the vari-
tional treatment of nonlinear electric circuits. La-
grange's equations of the second kind, Legendre's
transformation, and Hamilton's equations are briefly
presented. Energy functions are introduced for
hybrid systems. A new variational principle is sug-
gested to derive the equations of evolution for a
given class of hybrid systems with elements of the
same kind.

The third chapter is devoted to lumped parameter
electrical networks. Both the external description,
using the n-port formalism, and the internal (topo-
logical) description of their time evolution are treated
in detail.

Chapter 4 includes a Lagrangean description of
electrical networks with special reference to non-
linear time-invariant circuits. Energy functions of
electrical networks are presented. Stationarity theo-
rems are proved for resistive networks, and the
duality of the variational description of RLC net-
works is demonstrated. An important result states
that, in a variational description using nonhomogene-
ous basis (i.e., including voltages as well as currents),
a bilinear form in currents and voltages must be
included.

Chapter 5 is concerned with the derivation of the
state equations for nonlinear passive networks. Using
a Legendre transformation, the Brayton-Moser equa-
tions are obtained in an original way. A general form
of these equations is obtained that applies to net-
works including capacitive loops and inductive
cutsets.

Chapter 6 has to do with foundations of electro-
mechano-acoustical analogies using the theory of
conjugate variables given in Chapter 1. Some new
methods for constructing analogous electrical net-
works for mechanical and mechano-acoustical sys-
tems are presented.

Chapter 7 considers electromechanical transducers.
A general treatment is given to linear n-port trans-
ducers, including both electric and magnetic field
transducers. Nonlinear moving plate transducers
(variable reluctance, electrostatic loudspeakers) are
analyzed in detail. Two basic approaches are used:
n-port formalism and Lagrange equations. The formalism used in the book, called matrix functional calculus, is based on differential calculus and is explained in the Appendix.

This is a fine text. Highly theoretical, well organized, and clearly written it is addressed to researchers and engineers working or interested in electroacoustics, vibration measurement, vibration testing, and general dynamics. It should be accessible to advanced undergraduate and graduate students, research engineers, and scientists. The book provides a unified treatment of necessary concepts from dynamics, mechanical vibrations, electrical circuit theory, and automatic control.

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MECHANICS OF CONTINUOUS MEDIA AND ANALYSIS OF STRUCTURES

R. Valid
Vol. 26, Series in Applied Mathematics and Mechanics
North-Holland Publishing Co., Amsterdam
357 pages, 1981

Roger Valid is a Professor at the Ecole Centrale des Arts et Manufactures of Paris. He treats the general theory of mechanics of continuous media in abstract modern mathematical style. His approach to the subject is not common to English speaking scholars. It is recommended that the reader study first the appendix to acquaint himself with the concepts and terminology used in the book.

The book contains six chapters, the appendix, and seven lists of references. The first chapter deals with the mathematical theory of the mechanics of solid continuous media. The author did not provide any introduction or overview. The chapter begins with mathematical hypotheses and the definition of hyperelastic media. Such media are defined by the state at each point of the medium and depend on the immediate vicinity of the same point. An advanced treatment of stresses, deformations, and equilibrium equations is given and supported by mathematical interpretations of such special stress relations as Hermitian endomorphisms and the Piola-Kirchhoff stress and compatibility conditions. For nonpolarized media the author shows that the virtual deformation energy density is constant under pure rigid body rotations. The linear theory of elasticity is analyzed for isotropic medium. The stresses for isotropic and anisotropic media are defined in terms of the deformation energy volume density.

This chapter covers other topics: the variational principle for linear elastic medium and the reciprocity theorem for a linearized hyperelastic medium. The stability of the material (anisotropic linear medium) is measured by the sign of the specific energy. Under the title "stress functions" the author considers the problem of internally homogeneous equilibrium of continuous medium under surface-distributed external forces. The mathematical relations that characterize the polarized media are not accompanied by physical interpretations or discussions.

An excellent analytical treatment of the finite element method is presented in the second chapter. The author adopts the displacement method together with a piecewise Ritz method applied globally to complete structural systems. A triangular shaped element is chosen with the nodes placed at the apexes of each triangle. The static structural problem is converted to an algebraic set of equations in terms of the global stiffness matrix, displacements, and the generalized external static loads of the assembled system. Conformity is guaranteed in the assembly process because the displacements of nodes located on the sides common to two adjacent triangles are equal.

The author provides systematic discussions for such problems as the convergence of the method, overestimation of the stiffness in the displacement method, static reduction methods, rigid body displacements in static problems, and the patch test criterion when using nonconforming elements. Other types of elements and static problems examined include axisymmetrical three-dimensional bodies with axisymmetric loading and quadrilateral, rectangular, isoparametric quadrilaterals, and six node triangular elements. Applications to plates, beams, shells, and other structural systems are demonstrated.
Chapter 3 contains a compilation of a number of variational principles in problems of linear elasticity. The principles outlined are the principle of potential energy; principles of single, two, and three fields, and principle of virtual displacements and virtual stresses. The two-field principles include those due to Hellinger-Reissner (H-R) and Fraeijs de Veubeke. The single-field principle is a special case of the H-R method based on the principle of complimentary energy. These principles are employed to evaluate stress functions and to determine compatibility conditions. The author discusses the advantages and disadvantages of each principle when applied in the finite element method. In that regard the author adopts the principles of H-R and complementary energy for the purpose of illustration. The upper bound error incurred in the resulting solutions is analyzed for two methods. A remarkable result given in this chapter is that the saddle point is a solution satisfying the (H-R) principle using a search algorithm. The chapter ends by establishing the Legendre transformation for the H-R principle.

Chapter 4 contains the only material of the book dealing with the linear theory of structural dynamics. The free vibration of discretized structures is analyzed via the principle of virtual work, Hamilton's principle, and Lagrange's equation. A theorem pertaining to eigenvalues and eigenvectors for conservative systems is developed. The author also develops another theorem not common in this area, known as Riesz theorem, which establishes the spectrum of eigenvalues to linear continuous systems. The variational principles are then employed to determine the eigenvalues and eigenvectors (eigenmodes). The properties of the eigenvalues are defined by the maximum/minimum theorem based on the Rayleigh quotient.

The author introduces three methods for dynamic reduction of the structure degrees of freedom of a structure by decomposing it into substructures. The three methods are the mass coupling method, the stiffness coupling method, and the Guyan method. The Guyan method is based on a static reduction of the degrees of freedom applied to the mass matrix. The dynamic responses of linear structures to forced external excitation (harmonic, periodic, and stationary random) are briefly described.

Chapter 5 presents an advanced analysis of nonlinear deformation-buckling. The governing equations of large displacements are formulated from the natural state for hyperelastic medium and from a prestressed state for arbitrary medium. The author employs the usual discretization methods of any weak formulation to obtain a discretization of nonlinear problems. A number of methods for solving nonlinear static problems are outlined. New techniques such as the Wilson and Clough method, Newmark method (or B method), and Houbolt method are described in detail. The mechanisms of static buckling and its stability regimes (bifurcation and snap) are well presented. This section is extended to develop the criterion of static stability, its application, and the analyses of limit point and bifurcation point.

The last chapter presents a comprehensive analysis pertaining to the general theory of shells. The author points out the main difficulties and controversies encountered by different workers. The definition of the main mathematical notations and operations together with the kinematic hypotheses (with, w, and without transverse shear, wo) are given. The equilibrium equations corresponding to the two kinematic hypotheses w and wo are derived. The linearized deformations for w and wo cases and the conditions of compatibility in terms of the generalized deformations are established. The author outlines the formulation of nonlinear surface deformation (known as the Riemann-Christoffel curvature tensor). The subject is extended to determine indeterminate stresses, symmetrical stresses, and stress functions for w and wo cases. The applications of variational principles, linear surface constitutive laws, and the theory of shells of revolution are mathematically examined. For shells of arbitrary shapes the classical discretization method, the Ritz or Galerkin method, the finite difference method, and the finite element method are considered.

The appendix includes notations and formulas used in the six chapters. These include mapping, matrix keys, representation of linear mapping, tensors, gages, change of tensor variance on an Euclidian space, external derivatives, differentiable Riemann and integral manifolds, Stokes formula, and Lagrangian multipliers.
Pipe support analysis has matured in design approaches and methodologies in the last 15 years. The reason is the need for elaborate pipe supports in nuclear power plants as well as strict regulatory requirements.

This volume includes applied aspects and theoretical studies. It contains 11 papers. The first paper considers bolt location tolerance in base plate analysis. The paper provides simple equations for predicting bolt tension when bolt and attached member locations are changed during base plate installation. The second paper contains derivations of equations for a base plate subjected to direct pull. The effect of plate flexibility is included; the derivations are based on the concept of a beam resting on an elastic foundation. The third paper considers some of the factors overlooked in the design of pipe restraint end attachments (snubbers). The FE method accounts for these features and furnishes a cost effective solution.

The fourth paper treats the problem of rigid struts used as restraints in a piping system. The authors employ COSMIC and BPSTRUT computer programs; they show that the former is in excellent agreement with test results for rigid struts that fail elastically.

The fifth paper contains a computerized pipe support graphics system that is cost effective and efficient. The sixth paper presents an analytical procedure for determining the stresses from loads that cause weak axis bending and torsion in an angle clip in addition to strong axis bending. The seventh paper treats the criteria for evaluating stepped beam columns that support nuclear piping systems. It focuses on various aspects of the ASME Boiler and Pressure Vessel Code Section III, subsection NF.

The eighth paper considers the development of a nonlinear frequency and load-dependent model for velocity-sensitive hydraulic snubbers. The dynamic snubber model is based on fluid mechanics and includes the effect of fluid compressibility. Force displacement results compare favorably with experimental data. In the reviewer’s opinion, this is probably the most informative paper of the volume.

The ninth paper focuses on load deflection characteristics of small bare insulated pipe design. Test and analysis are compared for a special insulated clamp containing a Belleville spring arrangement. The latter compensates for thermal expansion of the pipe. Tests confirmed significant variations in clamp spring rate with changes of clamping preload associated with preload induced compression of the Belleville washer.

The final paper discusses load capacities of a pipe riser clamp. A closed form solution of biaxial stresses produced in the clamp is impractical. The finite element method is used to calculate the load capacities for a wide range of pipe and clamp sizes.

In summary, this volume contains many applications as well as theoretical analyses.

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SPECIAL APPLICATIONS IN PIPING DYNAMIC ANALYSIS

E. Van Stijgeren, editor
ASME Publ. PVP-67, New York, NY
1982, 80 pages

This volume contains papers ranging from practical applications to theoretical investigations. The initial
paper considers the design of LMFBR primary hot leg piping and its applications to minimizing the number of snubbers. Simple pivotal links, in-line supports, and cold-springing were used to reduce the number of snubbers in a specific primary leg by 75%.

The second paper contains a comprehensive approach to the use of nonorthogonal rigid restraints in the design of plant loads. The straightforward method for positioning the nonorthogonal restraints reduces computer costs. The application of varied curved surfaces for support attachment is considered in detail.

The third paper describes a test series in which one in. diameter pipes were subjected to dynamic (seismic) testing. Approximately 40 ft of schedule 40 pipe with bends and risers were supported from a rigid test frame. Variations of the pipe support configurations were tested. Analytical predictions for each configuration were compared with measured results.

The next paper presents the capability of DYNAPRO-4, a fluid systems and frame analysis computer program. It is a riser-oriented specialized computer program capable of analyzing three-dimensional linear elastic piping systems as frames for static loads, dynamic earthquake loads as represented by acceleration response spectra, transient dynamic loads, and time history forcing functions.

The fifth paper contains proposals of design guidelines for PWR pressurizer safety and relief valve discharge piping in order to minimize potential operating and piping qualification programs. Potential system operating problems that can arise from improper design are included.

The sixth paper is a report of nonlinear piping restraints in pipe stress analysis. The author's model employs simulation techniques, i.e., unclamped pipe on a rack and a box beam support with gaps. The author employs the computer program PIPELINE for example results.

The last two papers consider the experimental study of dynamic behavior of piping systems under maximal load conditions. Small piping systems, typical of those installed in a nuclear plant, were tested on a shaker table. The purpose was to determine their capability of surviving extreme low and high frequency loads in which large displacements and accelerations occur in the presence of plastic strains. The tests indicated that existing installations without backfitting and simplifying fixtures are necessary.

Although piping dynamics analysis has made great strides, further combined testing and analysis are required.

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COMPUTATIONAL METHODS IN STRUCTURAL AND CONTINUUM MECHANICS

C.R.T. Ross
John Wiley & Sons, New York, NY
1982, 176 pages, $49.95

This book is a collection of 14 computer programs written in BASIC for the Commodore PET personal computer. The programs cover problems mainly in the area of solid mechanics; one program has to do with continuum mechanics. The book fills a gap between theoretical texts in structural mechanics and the sophisticated codes currently used on large computers. One program, supported by a number of examples, is described in each chapter. However, the author provides incomplete lists for the symbols used in each program and it is thus difficult, especially for beginners, to follow the sequence of the programs.

The basic idea of the finite element method is outlined in the introduction. The first and fourth chapters describe programs to determine nodal displacements as well as forces in plane and three-dimensional pin-jointed trusses subjected to concentrated loads at their nodes. The second and third chapters present two programs to calculate nodal displacements and bending moments in beams and in rigid-jointed plane frames.

The eigenvalues and eigenvectors of plane trusses, continuous beams of different sectional properties,
rigid-jointed plane frames, and three-dimensional pin-jointed trusses are programmed in chapters five through eight. Chapter nine describes a program to determine forces and moments in three-dimensional rigid-jointed space frames. The bending moments in grillages and in bulkheads are determined by the programs of chapters ten and eleven. The program described in Chapter 10 is suitable for the analysis of flat, horizontal, cross-stiffened grids subjected to vertical loads. The grids can be skew or orthogonal with irregular internal and external boundaries. The method of matrix displacement is employed in the analysis. For the case of bulkheads described in Chapter 11, the grids are subjected to hydrostatic loading together with concentrated loads at the nodes.

Chapter 12 describes a program to calculate axisymmetric displacements and stresses for thin-walled axisymmetric shells under axial and lateral pressure. The lateral pressure can be uniform, stepped, or hydrostatic. The author is aware of one deficiency of this program: the lateral pressure stresses and the end fixing force stresses have not been superimposed to give the net value. The determination of stresses and strains in plates under in-plane forces are programmed in Chapter 13. The author adopts a constant stress element of triangular shape.

Chapter 14 describes two-dimensional field problems of the Laplace and Poisson types with reference to applications such as irrotational flow of fluid, heat transfer, and ground water flow.

Future edition of this book should include lists of definitions of all symbols used in each program. The book would then be a valuable source of self-education for beginners.

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SHORT COURSES

MARCH

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION
Dates: March 5-9, 1984
Place: Washington, DC
Dates: June 4-8, 1984
Place: Santa Barbara, California
Dates: August 27-31, 1984
Place: Santa Barbara, California
Dates: September, 1984
Place: Ottawa, Ontario
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis, also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 - (805) 682-7171.

MEASUREMENT SYSTEMS ENGINEERING
Dates: March 12-16, 1984
Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS
Dates: March 19-23, 1984
Place: Phoenix, Arizona

Objective: Program emphasis is on how to increase productivity and cost-effectiveness for data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists and managers of industrial, governmental and educational organizations who are concerned with planning, executing, or interpreting experimental data and measurements. The emphasis is on electrical measurements of mechanical and thermal quantities.

Contact: Peter K. Stein, Director, Stein Engineering Services, Inc., 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

DYNAMIC BALANCING SEMINAR/WORKSHOP
Dates: March 21-22, 1984
April 18-19, 1984
May 23-24, 1984
Place: Columbus, Ohio
Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single, two and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels, etc., with emphasis on reducing costs and improving quality in balancing operations.

Contact: R.E. Ellis, IRD Mechanalysis, Inc., 6150 Huntley Rd., Columbus, OH 43229 - (614) 885-5376.

APRIL

MODAL TESTING
Dates: April 3-6, 1984
Place: San Diego, California
Dates: August 14-17, 1984
Place: New Orleans, Louisiana
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.
ROTOR DYNAMICS
Dates: April 30 - May 4, 1984
Place: Syria, Virginia
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics: fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

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

FOURIER AND SPECTRAL ANALYSIS IN DYNAMIC SYSTEMS
Dates: April 30 - May 4, 1984
Place: Austin, Texas
Objective: This five day course will enable the participant to understand and apply the basic Fourier transform theory required to utilize the new digitally based Fourier and spectral analysis equipment. Lecture, demonstrations, discussions and lab will place emphasis upon a basic understanding of the digital processing of signals, including time and frequency domain characteristics, effects of sampling, windowing, statistical averaging, and some of the pitfalls present in collecting, processing, and interpreting data. Applications of the theory which will be discussed and/or demonstrated include dynamic system identification, signature analysis, random vibration, transfer function identification, experimental modal analysis, acoustics, and noise characterization and transmission.

Contact: Continuing Engineering Studies, College of Engineering, The University of Texas at Austin, Austin, TX 78712 - (512) 471-3506.

ELECTROEXPLOSIVES DEVICES
Dates: May 15-17, 1984
Place: Philadelphia, Pennsylvania
Objective: Topics will include but not be limited to the following: history of explosives and definitions; types of pyrotechnics, explosives and propellants; types of EEDs, explosive trains and systems, fuzes, safe-arm devices; sensitivity and functioning mechanisms; output and applications; safety versus reliability; hazard sources: lightning, static electricity, electromagnetic energy (RF, EMP, light, etc.), heat, flame, impact, vibration, friction, shock, blast, ionizing radiation, hostile environments, human error; precautions, safe practices, standard operating procedures: grounding, shorting, shielding; inspection techniques, system check-out trouble shooting and problem solving; safety devices, packaging and transportation; specifications, documentation, information sources, record keeping; tagging, detection and identification of clandestine explosives; reaction mechanisms, solid state reactions; chemical deactivation, disposal methods and problems, toxic effects; laboratory analytical techniques and instrumentation; surface chemistry.


MACHINERY VIBRATION ANALYSIS

MAY

Dates: May 15-18, 1984
Place: Nashville, Tennessee
Dates: August 14-17, 1984
Place: New Orleans, Louisiana
Dates: October 9-12, 1984
Place: Houston, Texas
Dates: November 27-30, 1984
Place: Chicago, Illinois

Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures...
on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

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

MACHINERY VIBRATION ENGINEERING

Dates: May 15-18, 1984
Place: Nashville, Tennessee

Dates: August 14-17, 1984
Place: New Orleans, Louisiana

Dates: October 9-12, 1984
Place: Houston, Texas

Dates: November 27-30, 1984
Place: Chicago, Illinois

Objective: Techniques for the solution of machinery vibration problems will be discussed. These techniques are based on the knowledge of the dynamics of machinery; vibration measurement, computation, and analysis; and machinery characteristics. The techniques will be illustrated with case histories involving field and design problems. Familiarity with the methods will be gained by participants in the workshops. The course will include lectures on natural frequency, resonance, and critical speed determination for rotating and reciprocating equipment using test and computational techniques; equipment evaluation techniques including test equipment; vibration analysis of general equipment including bearings and gears using the time and frequency domains; vibratory forces in rotating and reciprocating equipment; torsional vibration measurement, analysis, and computation on systems involving engines, compressors, pumps, and motors; basic rotor dynamics including fluid film bearing characteristics, critical speeds, instabilities, and mass imbalance response; and vibration control including isolation and damping of equipment installation.

Contact: The Vibration Institute, 101 West 55th Street, Clarendon Hills IL 60514 - (312) 654-2254.

JUNE

VIBRATION DAMPING

Dates: June 17-21, 1984
Place: Dayton, Ohio

Objective: The utilization of the vibration damping properties of viscoelastic materials to reduce structural vibration and noise has become well developed and successfully demonstrated in recent years. The course is intended to give the participant an understanding of the principles of vibration damping necessary for the successful application of this technology. Topics included are: damping fundamentals, damping behavior of materials, response measurements of damped systems, layered damping treatments, tuned dampers, finite element techniques, case histories, problem solving sessions.

Contact: Michael L. Drake, Jesse Philips Center 36, 300 College Park Avenue, Dayton, OH 45469 - (513) 229-2644.
SECOND INTERNATIONAL CONFERENCE
ON RECENT ADVANCES IN STRUCTURAL
DYNAMICS
April 9-13, 1984
Southampton, England

In recent years, considerable advances have been made in both theoretical and experimental techniques for solving problems in structural dynamics. In addition, a great deal of experience has been gained in applying these techniques to practical situations. This conference aims to bring together researchers and practicing engineers from the different branches of engineering, so that these techniques should receive the widest dissemination.

The conference is being organized by the Institute of Sound and Vibration Research, with the support of the Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base and the European Office of Aerospace Research and Development, London, England.

The conference is separated into a linear vibration section, with sessions in analytical methods, finite element and boundary element methods, testing techniques, damping, aerospace structures and/or fatigue, surface vehicles, machinery, vibration control; and a nonlinear vibration section with sessions in analysis techniques, modal and data analysis, dynamics of beams, dynamics of plates and response to seismic excitation. Invited papers will be given by Prof. J.D. Robson, Dr. G. Maidanik, Dr. S.L. Grassie, Mr. A. Bertram, and Prof. A. Leissa.

For further information, please contact: H.F. Wolfe, AFWAL/FIBED, Wright-Patterson Air Force Base, OH 45433 - (513) 255-5753.

STRENGTH OF MATERIALS AND STRUCTURAL COMPONENTS AT SONIC AND ULTRASONIC LOADING FREQUENCIES

This international symposium will be held on May 22-25, 1984 at the Institute for Problems of Strength, Kiev, USSR.

The symposium goals are:

- fatigue of structural materials at high loading frequencies
- acoustic fatigue of flying vehicles structural components and devices in the intensive sonic fields
- strength of acoustically active materials (piezoelectric and magnetostrictive)
- change of mechanical properties and strength of materials and devices on exposure to sonic and ultrasonic vibrations
- new experimental procedures and equipment for tests at high loading frequencies

The working languages of the symposium will be Russian and English. Simultaneous translation in both languages will be provided.

Proposals for papers should be presented by the authors to the Organizing Committee in the form of 200 - 400 word abstracts (without figures) before March 1, 1984. Proposals without abstracts will not be considered. The full manuscripts should be presented at the symposium for the purpose of publishing its Proceedings. Abstracts arriving after the deadline will be considered for additional poster presentation.

The participants and accompanying persons will be offered an extensive program of technical tours and excursions to local sites of attraction and interest, visits to theaters, museums, etc.

To receive an information bulletin, write to: Organizing Committee, USSR 252014 Kiev 14, Timiryazevskaya str., 2, Institute for Problems of Strength.
**ABSTRACTS FROM THE CURRENT LITERATURE**

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**35**
AVAILABILITY OF PUBLICATIONS ABSTRACTED

Government Reports: NTIS
Springfield, VA 22151
(unless otherwise indicated)

Ph.D. Dissertations: University Microfilms International
300 N. Zeeb Rd.
Ann Arbor, MI 48106

U.S. Patents: Commissioner of Patents
Washington, DC 20231

Chinese Publications (CSTA): International Information Service, Ltd.
P.O. Box 24683
ABD Post Office
Hong Kong
(In Chinese or in English translation)

In all cases appropriate order numbers should be used (last line of citation).

When not available in local libraries, copies of the majority of papers or articles may be obtained at Engineering Societies Center, 345 E. 47th St., New York, NY 10017, or Library of Congress, Washington, DC.

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

A list of periodicals scanned in published in issues 1, 6, and 12.
MECHANICAL SYSTEMS

ROTATING MACHINES
(Also see No. 373)

84-245
Definition of Forces on Turbomachinery Rotors, Task A
D.W. Childs
Texas A&M Univ., College Station, TX, Rept. No. NASA-CR-170780, 83 pp (Feb 17, 1983) N83-28451

Key Words: Rotors, Seals, Damping coefficient

Pump seals, unshrouded turbines, shrouded turbines with tip seals, gas labyrinth seals, gas seals with constant-clearance and convergent-tapers geometries, impeller forces, rolling-element bearings, and spline-interfaces to develop internal rotor damping are addressed.

84-246
Response in Passing through Critical Speed of Arbitrarily Distributed Flexible Rotor System (Part 1, Case without Gyroscopic Effect)
K. Nonami
Chiba Univ., 1-33 Yayoi-cho Chiba-shi, Japan, Bull. JSME, 26 (217), pp 1198-1204 (July 1983) 8 figs, 1 table, 18 refs

Key Words: Rotors, Flexible rotors, Critical speeds, Resonance pass through

The characteristics of responses of flexible rotor systems with arbitrarily distributed mass passing through several critical speeds are clarified sequentially using numerical solutions obtained from the transition matrix method. It is shown that the maximum amplitudes in transition through each critical speed are not influenced by the starting point of acceleration and are close to those in the accelerated cases from the state of nonrotation.

84-247
Response in Passing through Critical Speed of Arbitrarily Distributed Flexible Rotor System (Part 2, Case with Gyroscopic Effect)

K. Nonami
Chiba Univ., 1-33 Yayoi-cho Chiba-shi, Japan, Bull. JSME, 26 (217), pp 1205-1212 (July 1983) 10 figs, 21 refs

Key Words: Rotors, Flexible rotors, Critical speeds, Resonance pass through

Considering gyroscopic effects, approximate equations of responses in passing through critical speeds for distributed mass rotor systems on isotropic or anisotropic supports are derived by an asymptotic method. For flexible rotors on anisotropic supports, the nonstationary vibration in passing through two neighboring critical speeds is computed and coupling phenomena are discussed. The whirling directions in transient vibrations of a fundamental rotor on anisotropic supports are made clear by numerical solutions.

84-248
Test Simulation of Turbomachinery Rotor/Stator Interactions
W.D. Marscher
Creare Incorporated, Hanover, NH 03755, Lubric. Engrg., 39 (9), pp 577-583 (Sept 1983) 10 figs, 12 refs

Key Words: Interaction: rotor-stator, Turbomachinery, Wear

There is often occasion for transient interference in rotating machinery of various sorts, and hence rubbing between rotating and static components. It is important to minimize the wear damage which results, both in terms of performance loss and deteriorated structural integrity. To guide the design process, testing is often performed on prototype materials and configurations in machinery simulation rigs. Often these rigs involve constant load, constant rub conditions, and are performed in an ambient environment. It is shown in this paper that constant interaction rate, intermittent rubbing is just as easy to simulate and is far more representative of the majority of rotor/stator interactions. The importance of environmental conditions is also discussed.

RECIPROCATING MACHINES
(Also see No. 351)

84-249
Acoustical Source Characterization Studies on a Multi-Cylinder Engine Exhaust System
M.G. Prasad and M.J. Crocker
Characterization of the acoustic source in an exhaust muffler system is of utmost importance in the proper evaluation of the acoustic performance of the muffler. This paper describes the use of a transfer function method (with a random excitation source) for measurement of the internal source impedance of an eight-cylinder engine under running conditions. The results obtained agree well with those obtained by the standing wave method.

METAL WORKING AND FORMING

84-250
Special Aspects of Chatter in Milling
J. Tlsty and F. Ismail

Key Words: Chatter, Machine tools

Characteristics of chatter in milling are discussed including the lobing effect and the effect of process damping on vibration at different cutting speeds and frequencies. For the effects of the periodic variation of chip thickness and of the directional orientation on the boundary between stable and unstable milling, an original analysis is presented based on digital simulation of the development of chatter.

84-251
Dynamic Cutting Stiffness - A Measure for the Chatter of the Cutting Process (Dynamische Schnittsteifigkeiten — ein Maß für das Ratterverhalten des Schleifprozesses)
H. Follinger
Industrie Anzeiger, 105 (46), pp 30-31 (1983) 4 figs, 6 refs
(In German)

Key Words: Simulation, Cutting, Machine tools

A simulation method for quantizing transmission behavior of individual components during a grinding process is presented. Using various models the effect of the values at machine locations, or the combination of grinding disk-workpiece material is investigated. The results show that for the grinding process under investigation the purely geometric method for the determination of polar frequency response locus is promising only for the first approximation. The height displacement of the active cutters with respect to each other and the strain building mechanism should not be neglected.

MATERIALS HANDLING EQUIPMENT

84-252
Research on the Interaction between Power Source and Machinery. Part 3, Vibrating Lift Made by Utilizing the Principle of Self-Synchronization
J. Inoue, A. Sueoka, and S. Nishiwaki
Kyushu Univ., Hakozaki, Higashi-ku, Fukuoka-shi, Japan, Bull. JSME, 26 (219), pp 1649-1653 (Sept 1983) 8 figs, 4 refs

Key Words: Vibrators (machinery), Conveyors

A new type of vibrating lift made by utilizing the principle of self synchronization of mechanical vibrators is investigated. Vibrations of the spiral trough are measured for various values of set parameters of the unbalanced rotors. Traveling speeds of products in the spiral trough are also measured.

STRUCTURAL SYSTEMS

84-253
Fatigue Behavior of Weathered Steel Bridge Components
P. Albrecht
Dept. of Civil Engrg., Univ. of Maryland, College Park, MD, Rept. No. FHWA/MD-81/02, 177 pp (Dec 1982) PB83-227165

Key Words: Bridges, Steel, Fatigue tests

A total of 176 specimens with transverse stiffeners or 102-mm (4-in) attachments were fatigue tested as they were
originally fabricated, after they were weathered two years and four years, respectively. It was found that weathering reduced the fatigue life of the stiffeners as much as 22 percent, and the life of the attachments as much as 10 percent, as compared to their nonweathered counterparts.

84-254
Bridge Response with Tractor-Trailer Vehicle Loading
N. L. Mulcahy

Key Words: Bridges, Moving loads, Tractors, Trailers, Articulated vehicles

A method for the calculation of dynamic response and loading of single span multigirder bridges due to vehicle loads is described. The analysis takes account of vehicle acceleration or braking, road surface roughness and eccentric placement of the vehicle on the bridge. The analysis is presented for a three-axle tractor-trailer vehicle and the bridge is modeled as an orthotropic plate using higher order finite strips.

BUILDINGS
(Also see No. 426)

84-255
Vibration Control of Tall Buildings
P. C. Wang, F. Kozin, and F. Amini

Key Words: Buildings, Multistory buildings, Active vibration control, Successive approximation method

Objectionable vibrations have been experienced in modern tall buildings. To alleviate the vibrations active control devices may be used which provide control forces based on the feedback control theory. This paper presents a systematic approach which first reduces a multistory structure to a simpler equivalent system, then develops a pole placement method to obtain the control forces. A successive approximation method is used to reduce the responses to permissible magnitudes. An example is presented to demonstrate the feasibility of the method.

84-256
Analysis of Multi-Correlated Wind-Excited Vibrations of Structures Using the Covariance Method
E. Gossmann and H. Waller
Institut f. Mechanik, Ruhr-Universität Bochum, Universitätsstrasse 150, Gebäude JA 01/127, Bochum, W. Germany, Engrg. Struc., 5 (4), pp 264-272 (Oct 1983) 8 figs, 14 refs

Key Words: Buildings, Wind-induced excitation, Covariance function

Multi-correlated stochastic processes that can be found in nature are described using stochastic differential equations. The power spectral density matrix is evaluated first; then all of the power spectra are approximated by rational functions. By a series of transformations of the power spectral density matrix, a matrix of the transfer functions can be restored. Then by means of minimal realization methods from control theory, the differential equation is evaluated that connects the real excitation process with so-called white noise.

84-257
Modern Developments in Wind Engineering: Part 4
E. Simiu

Key Words: Buildings, Wind-induced excitation, Reviews

This is the fourth in a series of review papers devoted to the state-of-the-art in wind engineering. The first three parts of the series were published in October 1981 and March 1982.

84-258
Hysteresis Identification of Existing Structures
S. Toussi and J. T. P. Yao

Key Words: Buildings, Multistory buildings, Reinforced concrete, Seismic analysis, System identification technique, Hysteretic damping
A method is presented for the identification of dynamic properties such as energy dissipation, permanent deformation and strength deterioration of damaged structures. The proposed method is formulated in detail. It is then applied to identify the inter-story hysteresis behavior of two one-tenth scale and 10-story reinforced concrete structures which were subjected to repeated earthquake loads in the laboratory.

84-259
The Comparative Performance of Seismic Response Spectrum Combination Rules in Building Analysis
B.F. Maison, C.F. Neuss, and K. Kasai

Key Words: Buildings, Multistory buildings, Seismic analysis, Seismic response spectra

The peak dynamic responses of two mathematical models of a fifteen-story steel moment resisting frame building subjected to three earthquake excitations are computed by the response spectrum and time history methods. Four response spectrum model combination rules are discussed and are used to predict the peak responses. The response spectrum results are compared to the corresponding peak time history values to evaluate the accuracy of the different combination rules.

TOWERS

84-260
Shell Elements for Cooling Tower Analysis
T.Y. Yang and R.K. Kapania
Purdue Univ., West Lafayette, IN, ASCE J. Engrg. Mech., 109 (5), pp 1270-1289 (Oct 1983) 8 figs, 2 tables, 29 refs

Key Words: Towers, Cooling towers, Seismic response, Shells, Finite element technique

To achieve optimum finite element modeling of column supported cooling towers for seismic response studies according to the distributions of dominating bending and membrane stresses and to model the vulnerable shell-column region using discrete column elements and quadrilateral shell elements, a set of elements is adopted, modified or extended. Examples are given to evaluate a single type, combined types, and the whole set of elements with results in good agreement with alternative solutions.

84-261
Ductile Anchor Bolts for Tall Chimneys
S.J. Powell and A.H. Bryant
Auckland Regional Authority, Auckland, New Zealand, ASCE J. Struct, Engrg., 109 (9), pp 2148-2158 (Sept 1983) 4 figs, 6 tables, 13 refs

Key Words: Chimneys, Seismic design, Bolts

The design and testing of holding down bolts of the type used at the base of large industrial chimney stacks are described. The bolts provide a ductile mechanism whereby large earthquake induced vibrations, displacements and forces can be absorbed and so isolate the rest of the structure from the bulk of the input energy.

84-262
Wind Tunnel Tests on Model Crane Structures
J.F. Eden, A.J. Butler, and J. Patient

Key Words: Cranes (hoists), Towers, Wind-induced excitation, Wind tunnel testing

Wind-tunnel tests on model latticed and telescopic crane jibs and the model of a complete mobile crane are described. The patterns of forces and moments on the two types of jib are compared and tentative methods of calculation proposed.

FOUNDATIONS
(Also see No. 374)

84-263
Modeling of Dynamic Deformation Mechanisms for Granular Material
Ching-Liang Kuo
Ph.D. Thesis, Univ. of Massachusetts, 222 pp (1983) DA8317479
Key Words: Granular materials, Soils, Sand, Seismic response

The prediction of dynamic soil behavior is a problem of considerable importance in geotechnical engineering due to the increasing need to understand the response of soil under earthquake and offshore wave loadings. A new constitutive model based on the concepts of particulate mechanics and thermodynamics has been developed to model the cyclic behavior of granular material. Several drained and undrained cyclic triaxial tests and simple shear tests are predicted using the model, and the results are compared with the experimental results.

84-264
Application of Wave Equations to Pile Driving Analysis
A. Hejazi

Key Words: Pile driving, Computer programs

The analysis completed in this dissertation was undertaken to provide a comprehensive understanding of the behavior of piles during and after driving by means of dynamic analysis. Two computer based analysis programs were selected for this study. The approach used in this evaluation consisted of the comparisons of the analytical results obtained from the computer programs with referee data obtained from actual field pile tests.

84-265
Decoupling Approximation to the Evaluation of Earthquake-Induced Plastic Slip in Earth Dams
Jeen-Shiang Lin and R.V. Whitman

Key Words: Dams, Seismic response

Newmark's sliding block analysis for evaluating earthquake-induced permanent displacements of earth dams and slopes did not consider the effects of elastic dynamic response. Makdisi and Seed extended the analysis to include such effects, using the simplifying assumption that the computation of dynamic response and plastic slip can be decoupled. This paper examines the error introduced by this assumption, using three idealized lumped-mass models for a dam. Both sinusoidal and synthetic earthquake motions are employed.

POWER PLANTS

(Also see Nos. 311, 344, 421)

84-266
Seismic Qualifications Using a Combined Modal Test and Finite Element Procedure
J.B. Steedman and A. Edelstein

Key Words: Nuclear power plants, Nuclear reactor components, Seismic tests, Modal tests, Finite element technique

A case study is presented where the combined model test and finite element procedure is used to determine the seismic response of a control panel to be used in a nuclear power generating station.

84-267
Flow-Induced Vibration Qualification Program for the Babcock & Wilcox 205-Fuel Assembly Prototype Reactor Internals
M.K. Au-Yang and D.E. Thoren
Babcock & Wilcox, Lynchburg, VA, ASME Paper No. 83-PVP-74

Key Words: Nuclear reactor components, Vibration tests

A brief description is presented on an overall vibration qualification program with emphasis on the post phase -- the preoperational vibration test of the program. This paper illustrates the magnitude (in time and expenditure) of the vibration qualification of a large engineering project.

OFF-SHORE STRUCTURES

84-268
Hydrodynamic Energy Transfer in Shallow Water Ship Impacts
D.J. Ball and A. Markham

41
Experiments are described in which a model ship was pushed sideways onto a single, centrally placed, elastic fender to represent a 100,000 DWT oil tanker berthing on a fender of average stiffness. Underkeel clearance, the position of a solid quay wall, and the history of ship motion before impact are shown to be important factors in determining the amount of energy transferred from the water to the fender in addition to the transfer of the kinetic energy of the ship.

84-269
Nonlinear Analysis of a Dynamical System Being Pulled by Cables
J.A.P. Aranha and C.A. Martins
Instituto de Pesquisas Tecnologicas, Cidade Universita, Sao Paulo, Brazil, J. Appl. Mech., Trans. ASME, 50 (3), pp 652-656 (Sept 1983) 5 refs

Key Words: Cables, Towed systems, Off-shore structures, Pipelines, Wave forces

Offshore pipelines must, in certain situations, be pulled by means of cables placed in a barge. An important nonlinear aspect of the wave-induced dynamic motion is the fact that the cable can become loose. This paper analyzes a simplified dynamical model whose steady state is obtained analytically.

84-270
Coupled Dynamics of Tensioned Buoyant Platforms and Mooring Tethers
M.H. Patel and E.J. Lynch

Key Words: Off-shore structures, Moorings

A mathematical model is presented of the coupled dynamics of a tensioned buoyant surface platform and the lateral dynamics of its taut mooring tethers. A finite element model of the lateral mooring tether dynamics is extended to take account of nonlinear square law fluid damping by a simple global whole tether linearization and an alternative computationally more expensive element-by-element linearization scheme. The resultant finite element model is combined with the surface platform dynamic analysis and the coupled dynamic model is used to investigate the effects of water depth, surface platform mass and tether mass per unit length on the tether displacements and bending stresses as well as the resultant surface platform displacements.

84-271
Longitudinal Resonant Behavior of Very Deep Water Risers
C.P. Sparks, J.P. Cabillic, and J.-C. Schawann
Institut Francais du Petrole, Cedex, France, J. Energy Resources Tech., Trans ASME, 105 (3), pp 282-289 (Sept 1983) 8 figs, 5 refs

Key Words: Off-shore structures, Marine risers, Natural frequencies, Hydrodynamic damping, Resonant response

The problem of longitudinal resonant vibration of a 3000-m-long disconnected riser is considered. Theoretical investigations of natural frequencies and induced displacements and dynamic tensions are presented, as well as practical investigations of riser longitudinal hydrodynamic damping and of short period heave excitation, likely to be communicated to such a riser, by a typical drillship.

84-272
Simple Models to Evaluate Dynamic Guyed Tower Response
D.G. Morrison and S.A. Will

Key Words: Off-shore structures, Towers, Guyed structures, Single degree of freedom systems

The guyed tower is a system designed for use in relatively deep waters (more than 1000 ft (300 m)). A model is described that mimics the response of the tower. This model calculates the response by a single degree of freedom. The properties of the simple model are derived from stiffness, mass and hydrodynamic properties of more detailed models. The simple model is used to evaluate different mooring system configurations, and to determine the influence of dynamic mooring system properties on overall dynamic tower response.
**84-273**

**Dynamic Interaction of a Guyed Tower with Its Guying System**

C.R. Brinkmann
Exxon Production Res. Co., Houston, TX 77001,
J. Energy Resources Tech., Trans. ASME, **105**(3), pp 290-295 (Sept 1983) 10 figs, 4 refs

Key Words: Off-shore structures, Towers, Guyed structures, Drilling platforms

One of the key aspects of designing a guyed tower is the selection of a guying system that can adequately resist the anticipated environmental forces. Inclusion of guyline dynamics in an analysis of guyed tower motions is necessary to accurately predict maximum tower tilt and maximum guyline tensions in the design storm conditions when the clump weights are lifted completely off the sea bottom. The inclusion of dynamic loads on the guylines will increase the maximum tension in the guylines and reduce the maximum tower tilt induced in the platform by environmental forces.

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**VEHICLE SYSTEMS**

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**GROUND VEHICLES**

(Also see Nos. 299, 300, 301)

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**84-274**

**Protection of Car Occupants in Frontal Impacts with Heavy Lorries: Frontal Structures**

W. Johnson and A.C. Walton

Key Words: Collision research (automotive)

A review of head-on impacts between lorries and motor cars is given. This type of collision results in a number of fatalities than is caused by cars colliding into the rear of a lorry. It is maintained that to protect car occupants it is necessary to modify current lorry frontal structural design. Some suggestions pertinent to this are given.

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**AIRCRAFT**

(Also see No. 295)

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**84-277**

**On the Energy Characteristics of the Aerodynamic Matrix and the Relationship to Possible Flutter**

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**SHIPS**

(Also see Nos. 268, 296)

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**84-275**

**Mechanics of Minor Ship Collisions**

K.A. Reckling

Key Words: Ships, Collision research (ships), Energy absorption

A structural method is presented by which the critical velocity for a minor collision of a ship striking another ship midships at right angles can be determined with a minimum of computational effort. The proposed method takes into account the deformability of both collision opponents. The energies absorbed in both ships, up to rupture of the struck ship hull, are computed using internal collision mechanics. The critical velocity can then be determined using external collision mechanics.

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84-276

A Proposed Method of Predicting Ship Collision Damage

K. Hagiwara, H. Takanabe, and H. Kawano

Key Words: Ships, Ship hulls, Collision research (ships), Plates

A method is proposed for predicting ship collision damage using three combined experiments: a fundamental test determining the initiation of plate fracture; a local structural model test evaluating the effects of structural details; and a structural model test investigating the deformation of a ship hull. This paper reviews, by way of example, some results of these experimental studies.
J.G. Jones  

Key Words: Aircraft wings, Forced vibration, Flutter, Aerodynamic excitation

The problem of energy transfer between an airstream and a wing in sinusoidal motion has been investigated extensively. In this paper the author reconsiders the energy characteristics of the aerodynamic matrix in terms of the network concepts of resistive and reactive elements, corresponding to energy dissipation and energy storage, respectively. A dual formulation of Nissim's method is described and an extension proposed that takes account of aerodynamic energy storage in addition to aerodynamic energy dissipation.

84-278  
Aerelastic Response of an Aircraft Wing to Random Loads (Response Aerélastique d'une Alle D'Aeronef a des Charges Aleatoires)  
B.H.K. Lee  
AD-A130 476

Key Words: Aircraft wings, Random excitation, Aerodynamic excitation

A method for the prediction of the response of an elastic wing to random loads at flight conditions using rigid model wind tunnel pressure fluctuation measurements is presented. The importance of the unsteady aerodynamic loads induced by the vibration of the wing and input load representation is illustrated by comparing theoretical predictions with results from flight tests.

84-279  
Suppression of Interference Flutter by Composite Tailoring  
T.N. Bakthavathsalam  
Ph.D. Thesis, Univ. of Texas at Austin, 120 pp (1983)  
DA8319557

Key Words: Aircraft wings, Flutter

To study the nature and mechanism of interference flutter phenomenon as well as to devise ways and means to alleviate this type of flutter, a wing-tail flutter model was designed and constructed along the lines of the AFFDL wind tunnel model. This report deals with the composite tailoring aspect of design and analysis for suppression of interference flutter.

84-280  
Evaluation of Four Subcritical Response Methods for On-Line Prediction of Flutter Onset in Wind Tunnel Tests  
C.L. Ruhlin, J.J. Watson, R.H. Ricketts, and R.V. Doggett, Jr.  

Key Words: Aircraft wings, Wind tunnel testing, Flutter

Four subcritical response methods were evaluated for on-line use in transonic wind-tunnel tests where the flutter model is excited solely by airstream turbulence. The methods were: randomdec, power-spectral-density, peak-hold, and cross-spectrum. Subcritical response data were obtained during tests of a cantilevered flutter model wing.

84-281  
Effects of Angle of Attack on Transonic Flutter of a Supercritical Wing  
E.C. Yates, Jr., E.C. Wynne, and M.G. Farmer  

Key Words: Aircraft wings, Flutter

Flutter calculations were made by modified strip analysis employing steady-state aerodynamic parameters obtained from published wind tunnel pressure distributions. The results indicate that increasing angle of attack from zero can produce substantial changes in the transonic flutter characteristics that are favorable or unfavorable depending on Mach number and angle of attack. These results correlate well, in a qualitative sense, with the known aerodynamic behavior.

84-282  
Aeroservoelasticity in the Time Domain  
M.A. Cutchins, J.W. Purvis, and R.W. Bunton
84-283
Correction of Fan Noise for Effects of Forward Flight
R.K. Amiet

Key Words: Fan noise, Aircraft noise

When acoustic measurements are made on a static engine test stand, the data must be corrected for the effects of forward flight to predict correctly the noise characteristics of the engine in flight. A ray tracing approach is used here to relate the static test case to the flight case. The assumptions of isentropic irrotational flow into the fan inlet and a cylindrical shear layer at the fan exhaust lead to slightly different methods for correcting inlet noise and exhaust noise.

84-284
Propeller Tone Bursts
G.P. Succi, D.H. Munro, and K.U. Ingard
Bolt Beranek and Newman, Inc., 50 Moulton St., Cambridge, MA 02238, J. Sound Vib., 89 (2), pp 145-153 (July 22, 1983) 7 figs, 9 refs

Key Words: Aircraft noise, Propeller noise

Intense high frequency (25-38 kHz) tone bursts have been observed in acoustic tests of a scale model of a general aviation propeller. The amplitude of the tone burst is approximately equal to the amplitude of the propeller noise signature. The conditions necessary for the production of these tone bursts are described.

84-285
Interior Noise Considerations for Advanced High-Speed Turboprop Aircraft
J.S. Mixson, F. Farassat, J.D. Leatherwood, R. Prydz, and J.D. Revel
NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 20 (9), pp 791-797 (Sept 1983) 14 figs, 3 tables, 27 refs

Key Words: Aircraft noise, Propeller noise, Interior noise

Recent research on noise generated by high-speed propellers, on noise transmission through acoustically treated aircraft sidewalls, and on subjective response to simulated turboprop noise is described. Propeller noise discussion focuses on theoretical prediction methods for complex blade shapes designed for low noise at Mach = 0.8 flight and on comparisons with experimental test results.

84-286
Model Test and Full-Scale Checkout of Dry-Cooled Jet Runup Sound Suppressors
J.L. Grunnet and E. Ference

Key Words: Aircraft noise, Noise reduction

Jet aircraft runup sound suppressors featuring complete enclosure of the aircraft, dry cooling of the exhaust sound suppressor (even during afterburner operation), and adaptability to a variety of aircraft types are now employed at a number of U.S. Navy and Air Force airfields. The design, model testing, and full-scale checkout of the existing U.S. Navy hush house is described. Extension of the hush house concept to unusual aircraft designs and to dry-cooled jet engine test cells is also covered.

84-287
Assessment of the Importance of Small Crack Growth to Aircraft Design
R.F.W. Anstee
Key Words: Aircraft, Crashworthiness

A special program of investigation has been undertaken that will provide the real-world data necessary to establish an envelope of typical general aviation accident impact deceleration loads and to describe crash scenarios for a range of general aviation accidents for which design for passenger survivability is feasible. This report explains the crashworthiness program, its objective, and its goals. It presents a description of the crashworthiness analysis methodology used, demonstrates its validity, and provides an example demonstrating its application.

84-289
Analysis of Aircraft Dynamic Behavior in a Crash Environment
G. Wittlin
Lockheed-California Co., Burbank, CA, J. Aircraft, 20 (9), pp 762-769 (Sept 1983) 16 figs, 5 tables, 19 refs

Key Words: Crash research (aircraft)

Differences in the crash environments and design aspects that influence occupant survivability in military and commercial aircraft are discussed. Available analytical techniques for assessing structural behavior during a crash are described. The application of a hybrid technique in assessing aircraft structural behavior and trends in crash environments is provided. Representative mathematical simulations of aircraft crash tests and correlation with light fixed-wing and rotary-wing aircraft test results are shown.

84-290
Rotor Blade with Passive Tuned Tab
T.G. Campbell

Key Words: Helicopters, Propeller blades, Vibration control

The patent application relates to a structure for reducing vibratory airloading in a rotor blade with a leading edge and a trailing edge which includes a cut-out portion at the trailing edge. A substantially wedge shaped cross-section, inertially deflectable tab, also having a leading edge and a trailing edge is pivotally mounted in the cut-out portion.

84-291
Added Fluid Mass and the Equations of Motion of a Parachute
J.A. Eaton

Key Words: Parachutes, Stability, Added mass effects

The concept of added fluid mass is outlined and some general conditions for its significance are presented. Its implementation in the parachute equations of motion is reviewed, and equations used in previous treatments are shown to be erroneous. A general method for finding the equivalent external forces and moments due to added mass is given, and the correct, anisotropic forms of the added mass tensor are derived for the six degree-of-freedom motion in an ideal fluid of rigid body shapes with planar-, twofold- and axisymmetry. These derivations may also be useful in dynamic stability studies of other low relative density bodies such as airships, balloons, submarines and torpedoes.

MISSILES AND SPACECRAFT

84-292
Control of Reflector Vibrations in Large Spaceborne Antennas by Means of Movable Dampers
P.K.C. Wang and J.C. Sarina
A simple approach to the design of feedback controls for damping the vibrations in large spaceborne antennas with flexible dish reflectors is proposed. The feedback controls consist of movable velocity-feedback dampers whose positions are determined by minimizing the rate of change of total vibrational energy at any time. The performance of the proposed feedback controls is studied via computer simulations.

84-295
Aircraft Trajectories for Reduced Noise Impact
R.G. Melton and I.D. Jacobson
Pennsylvania State Univ., University Park, PA, J. Aircraft, 20 (9), pp 798-804 (Sept 1983) 15 figs, 1 table, 13 refs

Key Words: Aircraft noise, Noise reduction, Human response

A method is developed for studying the feasibility of reducing annoyance due to aircraft noise by modifying the flight trajectories over a community. Numerical optimization is used to compute the optimum flight paths based upon a parametric form of the trajectories that implicitly includes some of the problem restrictions.

84-294
Truck Cab Vibrations and Highway Safety

Key Words: Trucks, Vibration excitation, Human response

Experimental data obtained in this project demonstrate that truck vibration level is related to road roughness from which it may be inferred that the vibration levels will increase in the future if the highway system continues to deteriorate.

84-293
Truck Cab Vibrations and Highway Safety
Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSR-82-9/1, FHWA/RD-82/093, 205 pp (Mar 1982) PB83-229526

Key Words: Trucks, Vibration excitation, Human response

This document reports the findings of a research project in which the state-of-knowledge on the links between the truck ride vibration environment and accident involvement was critically reviewed by a panel of experts in an effort to evaluate its significance as a public safety issue.

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jected to impact by a rigid body is described. Plasticity is treated using the Mises yield criterion and the Prandtl-Reuss flow rule, and strain-rate effects on yielding are incorporated by allowing the yield surface to expand or contract depending on the current strain-rate.

84-297
Piping Seismic Test with Energy-Absorbing Devices. Final Report (PWR; BWR)
S. Schneider, H.M. Lee, and W.G. Godden
College of Engrg., Univ. of California, Berkeley, CA, Rept. No. EPRI-NP-2902, 175 pp (Mar 1983)
DE8304275

Key Words: Piping systems, Energy absorption, Seismic response

Results of an investigation into the behavior of a complex spatial piping system under simulated seismic and thermal loading are presented. The control of seismic response by steel energy absorbing devices is studied and compared with equivalent response controlled by shock arrestors. The concept is based on previous work on booth plane and spatial piping systems.

84-298
Vibration Isolation Using Feedback Control and Compound Dynamic Absorber for Portable Vibrating Tools
K. Kanada and K. Seto
Daido Inst. of Tech., Daido-cho Minami-ku Nagoya, Japan, Bull. JSME, 26 (217), pp 1219-1225 (July 1983) 5 figs, 2 tables, 6 refs

Key Words: Dynamic absorbers, Vibration isolators, Tools

Various isolators made of springs or rubber for portable vibrating tools are not always effective in reducing vibration. A feedback controller adapted for keeping a constant operating frequency and a compound dynamic absorber has been developed. The absorber consists of several parallel nominally undamped absorbers with appropriate dispersion of their natural frequencies.

84-299
The Crush Analysis of Vehicle Structures
H.C. Wang and D. Meredith


Key Words: Energy absorption, Ground vehicles, Automobiles, Collision research (automotive), Finite difference technique, Computer programs

This survey paper reports on the application of the MENTOR-III finite-difference computer program to a variety of vehicle crush analysis problems, many of which have not proven to be analyzable in any rigorous sense by alternate predictive methods.

84-300
Impact Response of Thin-Walled Plane Frame Structures
S.-I. Ishiyama, T. Nishimura, and Y. Tsuchiya

Key Words: Energy absorption, Automobiles, Ground vehicles, Collision research (automotive)

A numerical study of the impact response of plane frame structures with thin-walled members was performed to predict the deformation and absorbed energy of automobiles under crash loading. The collapse characteristics of thin-walled members under axial compression or bending loads are considered. Crash tests on simplified plane frame models impacted against a flat barrier were performed to verify the proposed method.

84-301
An Experimental Investigation of the Energy Dissipation of a Number of Car Bumpers under Quasi-Static Lateral Loads
W. Johnson and A.C. Walton

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

Experiments were performed to determine the load-deflection characteristic and the energy which could be dissipated plastically by the bumpers of ten common passenger cars marketed about 10 years ago.
84-302
The Effective Crushing Distance in Axially Compressed Thin-Walled Metal Columns
W. Abramowicz

Key Words: Energy absorption, Compressive strength, Columns
The effective crushing distance of thin-walled box columns is examined. A simplified theoretical model of a compressed rigid-linearly strain-hardening metal strip is studied and a closed-form solution is derived for the crushing distance of unstiffened as well as transversely stiffened box columns.

84-303
Axial Crushing of Square Tubes
Q. Meng, S.T.S. Al-Hassani, and P.D. Soden

Key Words: Energy absorption, Tubes, Compressive strength
The mechanics of the large deformation of a square tube under axial load is discussed. Theoretical results are substantiated by experimental results.

84-304
Long Stroke Energy Dissipation in Splitting Tubes
W.J. Stronge, T.X. Yu, and W. Johnson

Key Words: Energy absorption, Tubes
A passive crashworthy system that dissipates impact energy by fracture and plastic deformation of metal tubes is analyzed. The energy dissipating component is a square tube that is pressed axially against a die where it splits at the corners and curls outward.

84-305
Energy Absorbing Capacities of Braced Metal Tubes
S.R. Reid, S.L.K. Drew, and J.F. Carney, III

Key Words: Energy absorption, Tubes, Collision research (automotive)
The collapse and energy dissipation characteristics of metal tubes braced with tension members are considered experimentally and load bounding techniques are employed to estimate collapse loads of such tubes. The results are applied in the full scale crash testing of a vehicle impact attenuation device composed of clusters of steel tubes and subjected to high speed roadway collisions.

84-306
Classification of the Axial Collapse of Cylindrical Tubes under Quasi-Static Loading

Key Words: Energy absorption, Tubes, Compressive strength, Experimental test data
The results of an experimental investigation of the axial crushing modes and energy absorption properties of quasi-statically compressed aluminium alloy tubes are presented. The influence of tube length on these properties is discussed and quantified and a classification chart presented.

84-307
Crushing Analysis of Metal Honeycombs
T. Wierzbicki

Key Words: Energy absorption, Honeycomb structures, Compressive strength
A method for determining the crushing strength of hexagonal cell structures subjected to axial loading is given. The method is based on energy considerations in conjunction with a minimum principle in plasticity. The purpose of this study...
was to provide a simple and rational means by which hexagonal cell structures can be designed for use as energy absorbers in impact or impulsive loading situations.

Key Words: Base isolation, Seismic isolation, Seismic response, Experimental test data

This report describes the base isolation experiment of the SIMQUAKE II test in which the isolation system was subjected to two distinct ground motions.

84-308  
**Examination of Mechanical Snubbers from TM1-2.**  
**Final Report**  
F.L. Wadsworth, R.S. Walker, and E.P. Kurdziel  
DE83901978

Key Words: Snubbers, Shock absorbers

This report documents the status of the mechanical snubber examination project sponsored by the Electric Power Research Institute's Three Mile Island Unit 2 Mechanical Component Information and Examination Program (MCI and EP). Five mechanical snubbers were the first components removed from containment for examination under the MCI and EP. They were transported to Wyle Laboratories for inspection and for functional and dynamic testing.

84-309  
**Structure-Borne Sound Transfer Functions of a Phoenix Megikone 786027S5 Mounting**  
B. Vandergraaf  
N83-28463

Key Words: Mountings, Silencers, Exhaust systems

The static and dynamic tests on a mounting used for the exhaust silencers connected to the diesel generator sets aboard navy ships are described.

84-310  
**Testing of a Natural-Rubber-Base Isolation System by an Explosively Simulated Earthquake.**  
**Final Report**  
J.M. Kelly  
Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Rept. No. EPRI-NP-2917, 49 pp (Mar 1983)  
DE83902298

Key Words: Active vibration control, Fatigue life

The active control strategy for reducing the vibrations of elastic structures is sought. Optimal model-following is applied, and the control-system-synthesis method is used to make the actual system behave like a specified ideal model. The actual vibrating elastic structure with control forces and random disturbance is described with a system of first-order linear differential equations.
BLADES

84-313
Rotor Noise Due to Blade-Turbulence Interaction
K. Ishimaru
AD-A129 757

Key Words: Blades, Rotor blades (turbomachinery), Noise generation, Blade passing frequency

The time-averaged intensity density function of the acoustic radiation from rotating blades is derived by replacing blades with rotating dipoles. This derivation is done under the following turbulent inflow conditions: turbulent ingestion with no inlet strut wakes, inflow turbulence elongation and contraction with no inlet strut wakes, and inlet strut wakes.

BEARINGS

84-314
Determination and Analysis of the Dynamic Properties of Ball Bearings in Precision Instrument Technology (Bestimmung und Analyse der dynamischen Eigenschaften von Kugellagern für die Feingerätetechnik)
A. Jurkauskas and A. Palionis
Kaunas Polytechnic Institute, Kaunas, Lithuanian SSR, Feingerätetechnik, 32 (8), pp 347-349 (1983) 7 figs, 4 refs (In German)

Key Words: Bearings, Ball bearings, Friction excitation

Friction moment variations are dependent on oscillations and geometrical errors of ball grooves. The friction moment was measured and determined by means of correlation spectral analysis.

FASTENERS

(See No. 380)

VALVES

(Also see No. 421)

84-315
Designing to Reduce Noise in Control Valve Applications
A.K. Shea
Copes-Vulcan, Lake City, PA, ASME Paper No. 83-PVP-79

Key Words: Valves, Noise reduction

The sources of noise in control valves are identified and methods of controlling valve noise are discussed.

84-316
Knocking from Valve Hammer in Triplex Pumps
S.L. Collier

Key Words: Valves, Hydraulic valves

This paper investigates valve hammer as opposed to water hammer in triplex pumps, both of which produce knocking under certain distinctly different hydraulic operations. The occurrence of water hammer is reviewed and the development of valve hammer is discussed and documented.

SEALS

84-317
Damping Seal for Turbomachinery
G.L. Vonpragenau
A damping seal between a high speed rotor member and stator member that separates pressurized fluid compartments is described.

### STRUCTURAL COMPONENTS

#### CABLES
(See No. 269)

#### BARS AND RODS
(Also see No. 356)

84-318
The Differential Equations of Uniform Skew-Curved Bars in Harmonic Motion
P.S. Theocaris and D.E. Panayotounakos

Key Words: Bars, Harmonic response, Transverse shear deformation effects, Rotatory inertia effects

An analytical treatment for the formulation of the differential equations governing the harmonic motion of a uniform skew-curved bar is presented. Each differential element of the bar has six degrees of freedom; i.e., three translations and three rotations. The influences of transverse shear deformation and rotatory inertia are included in the analysis and the problem of harmonic motion of planar curved bars is examined.

#### BEAMS

84-319
The Application of Sinusoidally Derived Beam Receptances to Calculation of Transient Responses for Damped Composite Systems

R.G. Jacquot

Key Words: Beams, Transient response, Damped structures, Composite structures, Bernoulli-Euler method

A method in which transcendental sinusoidal beam receptances are employed for calculation of transient responses of composite systems containing Bernoulli-Euler beams is given. In the actual response calculations the Gaver-Stehfest algorithm is employed for inverting the transcendental functions of the complex s variable. Several example applications are given.

84-320
Two-Dimensional Analysis of Natural Frequencies and Mode Shapes of a Wide Beam: Application to the Determination of Mechanical Characteristics of Viscoelastic Materials
G. Ledon and J. Derouet
Laboratoire de Mécanique des Solides, Equipe de Recherche Associée au CNRS, 40, avenue du Recteur Pineau, 86022 Poitiers Cedex, France, J. Sound Vib., 89 (2), pp 155-167 (July 22, 1983) 6 figs, 1 table, 20 refs

Key Words: Beams, Rectangular beams, Natural frequencies, Mode shapes, Viscoelastic properties

The theory of plane elastodynamics is used to provide a simple method for calculating the natural frequencies and the normal mode shapes of a wide rectangular beam. The boundary conditions at both ends are prescribed in a mean-value sense.

84-321
The Dynamic Behaviour of Slender Structures with Cross-Sectional Cracks
P. Gudmundson

Key Words: Beams, Cracked media

A dynamic model for beams with cross-sectional cracks is discussed. It is shown that a crack can be represented by a
consistent, static flexibility matrix. Two different methods for the determination of the flexibility matrix are discussed.

84-322
Flutter Loads of a Timoshenko Beam-Column under a Follower Force Governed by Two Variants of Equations of Motion
J.T. Katsikadelis and A.N. Kounadis

Key Words: Beam-columns, Columns, Follower forces, Transverse shear deformation effects, Flutter

In the technical literature one may observe two variants of the equation of motion for a vibrating Timoshenko column subjected to a follower compressive force at its end. The objective of this analysis is to compare the flutter loads and flutter frequencies obtained on the basis of these two variants. A partially fixed Timoshenko beam carrying concentrated masses at its ends under the action of a compressive follower force is considered.

84-323
Vibration Characteristics of a Deployable Controllable-Geometry Truss Boom
J.T. Dorsey

Key Words: Trusses, Cantilever beams, Fundamental frequency

An analytical study was made to evaluate changes in the fundamental frequency of a two dimensional cantilevered truss boom at various stages of deployment. The truss could be axially deployed or retracted and undergo a variety of controlled geometry changes by shortening or lengthening the telescoping diagonal members in each bay. Both untapered and tapered versions of the truss boom were modeled and analyzed by using the finite element method.

84-324
Torsional Impact of a Layer or a Cylinder Bonded to an Elastic Half-Space

R.S. Dhaliwal, B.M. Singh, and J. Vrbik

Key Words: Cylinders, Elastic half-space, Torsional response

Two torsional impact problems are considered. The first problem deals with the solution of a layer bonded to an elastic half-space when the layer is driven by the torsional impact over a bonded rigid circular disc. In the second problem sudden torsion by a rigid disc attached over the plane face of a circular cylinder is considered and the rest of the plane surface of the cylinder is stress free.

COLUMNS
(Also see Nos. 322, 358)

84-325
Impact-Induced Vibrations of a Simple Viscoelastic Column Model
L.X. Ren and B. Lundberg

Key Words: Columns, Cantilever beams, Viscoelastic properties, Impact excitation, Vibration response

A two-degree-of-freedom model for an almost-axially impacted viscoelastic cantilever column is analyzed. The impact load is produced by a mass striking the free end of the column. Under the assumption of small displacements two second-order nonlinear ordinary differential equations for the coupled longitudinal and transverse vibrations of the column are derived.

MEMBRANES, FILMS, AND WEBS

84-326
Observations on the Steady-State Solution of an Extremely Flexible Spinning Disk with a Transverse Load
R.C. Benson
The steady deflection of a transversely loaded, extremely flexible, spinning disk is studied. Membrane theory is used to predict the shapes and locations of waves that dominate the response. It is found that waves in disconnected regions are possible. Some results are presented to show how disk stiffness moderates the membrane waves.

84-327
Nonlinear Panel Flutter Using High-Order Triangular Finite Elements
A.D. Han and T.Y. Yang
Purdue Univ., West Lafayette, IN, AIAA J., 21 (10), pp 1453-1461 (Oct 1983) 12 figs, 38 refs

Key Words: Panels, Flutter, Finite element technique

A 54 degree-of-freedom, high-order triangular plate finite element extended for geometrically nonlinear static and dynamic analysis is used to formulate and analyze supersonic nonlinear panel flutter problems. The finite element formulation is based on Kirchhoff's theory of thin plates. The quasisteady aerodynamic theory is used. Numerical solution procedures are presented.

84-328
Low-Velocity Impact Response of Laminated Plates
R.L. Ramkumar and P.C. Chen
Northrop Corp., Hawthorne, CA, AIAA J., 21 (10), pp 1448-1452 (Oct 1983) 4 figs, 5 tables, 13 refs

Key Words: Plates, Layered materials, Anisotropy, Impact response, Transverse shear deformation effects

An analysis is presented to predict the response of anisotropic laminated plates to low-velocity impact by a rigid object. Transverse shear deformation in the plates is accounted for using Mindlin's theory and the governing equations are solved using Fourier integral transforms, assuming infinite planform dimensions for the plate.

84-329
Stability of Transverse Vibration of a Circular Plate Subjected to a Periodically Varying Torque
J. Zajaczkowski
Lodz Technical Univ., Lodz, Zwirki 36, Poland, J. Sound Vib., 89 (2), pp 273-286 (July 22, 1983) 7 figs, 7 tables, 9 refs

Key Words: Plates, Circular plates, Flexural vibration, Torquinal excitation, Time-dependent excitation

Transverse vibration of a circular plate subjected to periodically varying torsion is studied. The instability regions are found and plotted for the plate under a tangent uniform load and a tangent concentrated force.

84-330
Sound Radiation from a Housing Containing a Vibration Source
K. Urnezawa, M. Futakawa, and H. Houjoh
Tokyo Inst. of Tech., Nagatsuta, Midori-ku, Yokohama, Japan, Bull. JSME, 26 (217), pp 1213-1218 (July 1983) 16 figs, 1 table, 7 refs

Key Words: Plates, Housings, Sound waves

The behavior of the sound radiation from the plates of a housing being excited with each made frequency is studied theoretically and experimentally from a viewpoint of directivity and by means of acoustical holography.

84-331
Thermal Effect on Frequencies of an Orthotropic Rectangular Plate of Linearly Varying Thickness
J.S. Tomar and A. K. Gupta
Dept. of Mathematics, Univ. of Roorkee, Roorkee-247 672, India, J. Sound Vib., 90 (3), pp 325-331 (Oct 8, 1983) 2 figs, 8 refs

Key Words: Plates, Rectangular plates, Variable cross section, Temperature effects, Natural frequencies

An analysis is presented of the effect of a constant thermal gradient on free axisymmetric vibrations of an orthotropic elastic rectangular plate of linearly varying thickness. The governing differential equation of motion is solved by Frobenius’ method.
84-332
Generation of Waves in an Elastic Plate by a Vertical Force and by a Moment in the Vertical Plane
S. Ljunggren

Key Words: Plates, Periodic excitation

An approximate solution is determined for the motion of an infinite elastic plate, excited by a vertical force (normal to the plate) and by a moment in the vertical plane (with the axis of the moment parallel to the plate). The driving force and moment are sinusoidal in time and applied to a small, rigid indenter with a circular base, fixed to the plate.

84-333
Vibratory Control of Thermally Stressed Discs by Means of Intermediate Heating
D.G. Gorman and J.P. Huissoon

Key Words: Disks, Tuning, Flexural vibration, Finite element technique

The finite element technique is used to study the possibilities of thermal detuning of the modes of free transverse vibration associated with annular discs while subjected to heating at the outside peripheral radius. The detuning (or increasing the fundamental mode of vibration) is induced by the addition of heat at some intermediate radius of the disc. The changes in the natural frequencies are noted for varying degrees of intermediate heating at various intermediate radii.

SHELLS
(Also see Nos. 260, 359)

84-334
Seismic Response of Large Suspended Tanks
D.C. Ma, J. Gvildys, and Y.W. Chang
Argonne Natl. Lab., Argonne, IL, ASME Paper No. 83-PVP-70

Key Words: Tanks (containers), Fluid-filled containers, Seismic response

The response of the large-diametered liquid-filled tank under seismic disturbances is studied with the emphasis on the effects of the bottom plate vibration on fluid dynamic pressure and free-surface sloshing.

84-335
Free Vibration of a Circular Cylindrical Shell Elastically Restrained by Axially Spaced Strings
T. Irie, G. Yamada, and Y. Muramoto

Key Words: Shells, Circular shells, Cylindrical shells, Natural frequencies, Mode shapes

An analysis is presented for the free vibration of a circular cylindrical shell restrained by axially spaced elastic springs. The method is applied to circular cylindrical shells supported by axially equispaced springs of the same stiffness, and the natural frequencies and the mode shapes of vibration are calculated numerically.

84-336
A Case Study of the Seismic Response of Fluid-Coupled-Flexible Cylinders
S.J. Brown and M. Chu
Quest Engineering and Development Corp., Houston, TX, Exptl. Mech., 23 (3), pp 270-281 (Sept 1983) 11 figs, 6 tables, 18 refs

Key Words: Shells, Cylindrical shells, Coaxial structures, Fluid-filled containers, Natural frequencies, Mode shapes, Damping coefficients, Seismic response

An experimental and theoretical study of the seismic time history and RMS response of a series of fluid-coupled-coaxial-flexible cylinders is presented. The influence of annular clearance and viscous effects is considered.

84-337
An Experimental Study on the Dynamic Axial Plastic Buckling of Cylindrical Shells
W. Ren, H. Mingbao, H. Zhuping, and Y. Qingchun

Key Words: Shells, Cylindrical shells, Dynamic buckling

An experimental study on the dynamic plastic post-buckling behavior of a stationary AMT aluminium alloy cylindrical shell under axial impact is discussed.

84-3,41
Nonlinear Shell Dynamics – Intrinsic and Semi-Intrinsic Approaches
A. Libai

Key Words: Shells, Boundary condition effects

The intrinsic approach to the nonlinear dynamics of shells is reviewed and extended by the addition of appropriate initial and boundary conditions of the dynamic and kinematic types to the field equations. The alternative semi-intrinsic velocity approaches are also presented. Both linear and rotational velocity forms are included. The relative merits of these approaches to shell dynamics are discussed and compared with extrinsic approaches.

84-339
The Effect of Viscosity on the Forced Vibrations of a Fluid-Filled Elastic Shell
T.C. Su

Key Words: Shells, Spherical shells, Fluid-filled containers, Forced vibration, Viscosity effects

The effect of viscosity on the axisymmetric, forced vibrations of a fluid-filled, elastic, spherical shell is studied analytically. Necessary theory, using boundary layer approximation for the fluid as developed in a previous paper for free vibrations, has been extended to incorporate an external forcing excitation. Shell response, fluid loading, and energy dissipation rate are computed for radial, tangential, and combined force excitations.

84-340
Nonlinear Responses of Sloshing in Rectangular Tanks (1st Report, Nonlinear Responses of Surface Elevation)
S. Hayama, K. Aruga, and T. Watanabe
Univ. of Tokyo, Hongo, Bunkyo-ku, Tokyo, Japan, Bull. JSME, 26 (219), pp 1641-1648 (Sept 1983) 7 figs, 12 refs

Key Words: Tanks (containers), Fluid-filled containers, Sloshing

An analytical solution to represent the nonlinear responses of sloshing in a rectangular tank is obtained, using the perturbation method. Under the assumption of potential flow for the liquid, it is compared with experiments and results are presented.

PIPPES AND TUBES
(Also see Nos. 269, 297, 376, 401)

84-341
Flow-Induced Vibration of Tubes in a Once-Through Steam Generator
J.C. Simonis and D. A. Steininger
Southwest Res. Inst., San Antonio, TX, ASME Paper No. 83-PVP-76

Key Words: Tubes, Fluid-induced excitation, Boilers

The results of tests performed at Oconee Unit 2 are reported and compared to those obtained from Three Mile Island Unit-2 (TMI-2).

84-342
Impact – Response Behavior of Offshore Pipelines
P.G. Bergan and E. Mollestad

Key Words: Pipelines, Underwater pipelines, Off-shore structures, Impact response

A method for analyzing the dynamic behavior of marine pipelines subjected to impact loads or sudden forced move-
ments is outlined. Examples show computed dynamic response for pipelines lying on the sea floor and for a pipe section freely submerged in water when subjected to various force and displacement histories.

Key Words: Piping systems, Seismic analysis, Supports
A comparison of dynamic responses of piping systems subject to independent-support excitation using the response spectrum and time-history methods is presented. The BNL finite-element computer code PSAFE2 is used to perform the analyses.

84-343
Seismic Design of Piping Systems in the Flexible Range
P.O. Svenson, F.B. Braun, and G.C. Slagis
EDS Nuclear Inc., Walnut Creek, CA, ASME Paper No. 83-PVP-68

Key Words: Piping systems, Seismic design
A preliminary study has been performed on both simplified and actual piping systems to evaluate seismic design in the flexible range. Based on this study, it is feasible to design piping systems with the first fundamental frequency in the 1-3 Hz range and meet seismic stress allowables. Guidelines for selection of support spacing and applicability of the flexible concept are discussed.

84-344
Nuclear Power Plant Piping Damping Parametric Effects
A.G. Ware

Key Words: Piping systems, Nuclear power plants, Damping effects
Current state-of-the-art knowledge in the U.S. on parameters that influence piping system damping is presented. Examples of inconsistencies in the data and areas of uncertainty are explained.

84-345
Seismic Analysis of Piping Systems Subjected to Independent-Support Excitation
M. Subudhi and P. Bezler
DEB3012215

84-346
A Numerical Model of Acoustic Choking, Part 1: Shock Free Solutions
N.J. Walkington and W. Eversman
Dept. of Mech. and Aerospace Engrg., Univ. of Missouri-Rolla, Rolla, MO 65401. J. Sound Vib., 90 (4), pp 509-526 (Oct 22, 1983), 9 figs, 6 tables, 24 refs

Key Words: Ducts, Shock waves, Wave propagation
The one dimensional gas dynamic equations for an ideal gas are utilized to investigate the phenomenon of acoustic choking in near sonic flows. This approach eliminates the need to make the classical small disturbance assumption. A finite difference scheme is developed to approximate these equations.

84-347
Modeling and Analysis of Induction Machines Containing Space Harmonics, Part I: Modeling and Transformation
H.R. Fudehand C.M. Ong
School of Electrical Engrg., Purdue Univ., West Lafayette, IN 47907, Power Apparatus Syst., IEEE Trans., PAS-102 (8), pp 2608-2615 (Aug 1983) 1 fig, 14 refs

ELECTRIC COMPONENTS
MOTORS
Key Words: Induction motors, Harmonic analysis, Mathematical models

The coupled-circuit approach is used to derive a mathematical model of a general m-n winding induction machine in which all MMF harmonics are taken into account. The model, which is applicable to both squirrel cage and phase-wound rotors, has provision for cage rotors with non-integral number of rotor bars per stator pole-pair.

**DYNAMIC ENVIRONMENT**

**ACOUSTIC EXCITATION**

(Also see Nos. 249, 284, 309, 424)

84-348  
**Modeling and Analysis of Induction Machines Containing Space Harmonics, Part II: Analysis of Asynchronous and Synchronous Actions**
H.R. Fudehand C.M. Ong  
School of Electrical Engrg., Purdue Univ., West Lafayette, IN 47907, Power Apparatus Syst., IEEE Trans., PAS-102 (8), pp 2616-2620 (Aug 1983) 8 refs

Key Words: Induction motors, Harmonic analysis, Nonsynchronous vibration, Synchronous vibration

The steady-state equations which describe the asynchronous and synchronous actions in a general polyphase induction machine are derived. The conditions for synchronous action at standstill and at some finite rotor speed between two harmonics are identified.

84-349  
**Modeling and Analysis of Induction Machines Containing Space Harmonics, Part III: Three-Phase Cage Rotor Induction Machines**
H.R. Fudehand C.M. Ong  
School of Electrical Engrg., Purdue Univ., West Lafayette, IN 47907, Power Apparatus Syst., IEEE Trans., PAS-102 (8), pp 2621-2628 (Aug 1983) 27 figs, 4 tables, 5 refs

Key Words: Induction motors, Harmonic analysis, Mathematical models

This part of the paper deals with the application of the general model and equations derived in Parts I and II to the common three-phase, cage rotor induction machines. It describes the procedure used to identify the significant harmonics for a reasonable representation with a low order model. The effects of MMF harmonics on the steady-state and transient behaviors of three sample cage rotor induction machines that have rotors designed to give varying amounts of asynchronous and synchronous torques are examined.

84-350  
**Sound Radiation from Periodically Connected Double-Plate Structures**
D. Takahashi  

Key Words: Acoustic waves, Wave propagation, Buildings, Noise reduction

The problem of sound radiation from periodically connected infinite double-plate structures excited by a harmonic point force is investigated theoretically. Point connected, point connected with rib-stiffening, and rib-connected structures are discussed.

84-351  
**Studies of Acoustical Performance of a Multi-Cylinder Engine Exhaust Muffler System**
M.G. Prasad and M.J. Crocker  

Key Words: Exhaust systems, Mufflers, Noise reduction, Internal combustion engines

Among the various descriptors of a multi-cylinder engine exhaust muffler system performance, it is evident that insertion loss and radiated sound pressure are the most useful. This paper describes a theoretical acoustical model to predict insertion loss and radiated sound pressure levels, in which the source impedance is obtained from measurement and from which the source strength is estimated. Both flow and temperature gradient effects are included in the analysis.
84-352
Sound Generation by Turbulence Near an Elastic Wall
A.P. Dowling
5 figs, 11 refs

Key Words: Turbulence, Noise generation

The Lighthill theory has been extended to describe the sound generated by turbulence near an elastic wall. The case of a thin elastic slab with identical fluid in contact with both faces is investigated in detail by solving the elastic equations in the slab together with the acoustic boundary-layer equations in the fluid, with all stresses and displacements continuous across the fluid-elastic interface. The low-wavenumber elements of the pressure spectrum under the plate are determined, and it is found that the surface pressure spectrum has considerable structure which is not predicted by simple bending plate theory.

84-353
Transmission Loss Characteristics of Expansion-Chamber Silencers with Tapered Connectors
S. Murakami and S. Hagi
Tokai Univ., 1117, Kitakaname, Hiratsuka-shi, Kanagawa, Japan, Bull. JSME, 26 (217), pp 1139-1145 (July 1983) 12 figs, 3 refs

Key Words: Silencers, Ventilation, Ducts, Sound transmission loss

This paper describes the transmission loss characteristics and acoustical overall performance of expansion-chamber silencers with tapered connectors at either or both ends of the chambers which are widely used in ventilation systems.

84-354
Scattering of Sound by an Elastic Plate with Flow
I.D. Abrahams
Dept. of Mathematics, The University, Manchester M13 9PL, UK, J. Sound Vib., 89 (2), pp 213-231 (July 22, 1983) 8 refs

Key Words: Wave scattering, Sound waves, Plates

An elastic plate, set in an infinite baffle and immersed in a fluid moving with a uniform subsonic velocity, is excited by an acoustic source. The scattered sound field is analyzed when fluid-plate coupling is large, and a solution is found by the use of matched asymptotic expansions. The far field is found to approximate to the solution obtained when the elastic plate is absent.

84-355
Dynamic Pulse Buckling – Theory and Experiment
H.E. Lindberg and A.L. Florence

Key Words: Dynamic buckling

This monograph brings together research results on dynamic buckling from reports and technical papers produced during the past two decades by the authors and their co-workers at SRI International (formerly Stanford Research Institute). Emphasis is on developing an understanding of the buckling processes and on making available practical theory that can be used for estimating buckling strengths of structural elements (bars, plates, rings, shells) under a variety of pulse loadings.

84-356
Longitudinal Collision of Rod-Rigid Element Systems
A. Mioduchowski, M.G. Faulkner, A. Pielorz, and W. Nadolski

Key Words: Rods, Impact response

One-dimensional wave propagation theory is used to investigate the forces, velocities, and displacements in a series of elastic rods connected to rigid elements. The method is applied to the case of two subsystems that collide. The technique allows the calculations to be done during a short-lived event such as a collision.

84-357
Convergence to Mode Form Solutions in Impulsively Loaded Piecewise Linear Rigid-Plastic Structures
J.B. Martin
Key Words: Impact response, Rigid-plastic properties

Models in load and velocity space which illustrate the behavior of impulsively loaded piecewise linear rigid-plastic structures are considered. Attention is focused on the question of determining onto which mode a particular initial velocity field will converge, or conversely, what initial velocity fields converge onto a particular mode. Some answers to this question are provided, and links with the determination of the optimal time bound and with a recently presented algorithm for determining mode shapes are established.

84-358
Convergence to Higher Symmetric Modes in Impulsively Loaded Rigid-Plastic Beams
J.B. Martin and A.R. Lloyd

Key Words: Impact response, Beams, Rigid-plastic properties

The question of convergence onto higher modes in impulsively loaded rigid, perfectly plastic beams is considered. Two specific examples are studied: a fixed end and a simply supported beam in which the velocity field is symmetric and in which there are three hinges in the interior of the span.

84-359
Structural Plastic Shock Model for One-Dimensional Ring Systems
S.R. Reid, W.W. Bell, and R.A. Barr

Key Words: Shock wave propagation, Rings

Previously reported experiments indicated that when a line of rings is subjected to end impact the deformation proceeds from one ring to the next in a wave-like manner. In this paper a shock theory is constructed analogous to that for waves in a solid cylinder. The model is used to examine three different systems and extensions of the theory are discussed.

84-360
Research on Upgrading Structures for Host and Risk Area Shelters, Phase II
R.S. Tansley, R.D. Bernard, G.J. Cuzner, and C. Wilton

Key Words: Protective shelters, Blast resistant structures

A summary of the work conducted during the second year of a five-year program is presented. This research effort provides the engineering basis and guidance for the development of upgrading for host and risk area shelters.

84-361
Blast Loading of Closures for Use on Shelters
G.A. Coulter

Key Words: Protective shelters, Closures, Doors, Blast loads, Blast resistant structures

Results are presented for the blast loading of wood beams/plywood closures, steel grating/plywood, and steel doors. Ultimate failures for the closures and doors were determined for long duration blast loads. Loading and deflection data are presented for the test closures.

84-362
Evaluation of the Inelastic Spectrum Design Method for Two Degree-of-Freedom Structures under Earthquake Loading
J.F. Baggett and J.B. Martin

Key Words: Seismic design

An extension of the design spectrum method, making use of the concept of ductility under earthquake loading has been suggested. Depending on the anticipated ductility of
the structure, the elastic design spectrum is modified to be less severe, and the structure is designed elastically on the basis of the modified spectrum. Several studies of tall steel frames are carried out, and show that caution must be exercised in the application of the method. Information is given on the way in which the unconservatism introduced varies with the parameters of the problem, and on how it compares with other sources of error.

84-363
Seismic Spectral Analysis for Structures Subject to Nonuniform Excitation
K.M. Vashi
Key Words: Seismic analysis, Spectrum analysis, Dynamic structural analysis
Numerous investigations have studied the subject of computation of seismic response of structural systems subject to nonuniform excitation represented by response spectra. This paper examines the theory and formulation of these studies and makes an evaluation of the advantages and limitations associated with the approaches taken.

VIBRATION EXCITATION

84-364
Combination Resonances in the Non-Linear Response of Bowed Structures to a Harmonic Excitation
A.H. Nayfeh
Key Words: Harmonic excitation, Combination resonance
A second-order uniform expansion is obtained for the response of a bowed structure (systems with quadratic and cubic nonlinearities) to a combination resonance. The results show that combination resonances of the difference type can never be excited.

84-365
Forced Nonlinear Oscillations of an Autoparametric System - Part 1: Periodic Responses
H. Hatwal, A.K. Mallik, and A. Ghosh
Univ. of Calgary, 2500 University Dr., N.W., Calgary, Alberta, Canada T2N 1N4, J. Appl. Mech., Trans. ASME, 50 (3), pp 657-662 (Sept 1983) 7 figs, 10 refs
Key Words: Forced vibration, Autoparametric response, Harmonic balance method
Forced oscillations of a two degree-of-freedom autoparametric system are studied with moderately high excitations. The approximate results obtained by the method of harmonic balance are found to be satisfactory by comparison with those obtained by numerical integration.

84-366
Forced Nonlinear Oscillations of an Autoparametric System, Part 2: Chaotic Responses
H. Hatwal, A.K. Mallik, and A. Ghosh
Univ. of Calgary, 2500 University Dr., N.W., Calgary, Alberta, Canada T2N 1N4, J. Appl. Mech., Trans. ASME, 50 (3), pp 663-668 (Sept 1983) 11 figs, 8 refs
Key Words: Forced vibration, Autoparametric response, Statistical analysis
Chaotic oscillations arising in forced oscillations of a two degree-of-freedom autoparametric system are studied. Statistical analysis of the numerically integrated nonperiodic responses is shown to be a meaningful description of the mean square values and the frequency contents of the responses.

84-367
An Approach to the First Passage Problem in Random Vibration
A.B. Mason, Jr. and W.D. Iwan
Chevron Oil Field Res. Co., P.O. Box 446, LaHabra, CA 90631, J. Appl. Mech., Trans. ASME, 50 (3), pp 641-646 (Sept 1983) 7 figs, 10 refs
Key Words: Random vibration
The first passage problem for the response of a linear oscillator excited by a random excitation is considered. An approximate analytical technique is presented for calculation of the distribution of the time to first excursion across a symmetric double barrier. The approach may be applied to the case of nonstationary response to modulated Gaussian noise with nonwhite spectral density.
Steady-State and Transient Responses of Linear Structures
A.S. Veletsos and A. Kumar
Rice Univ., Houston, TX 77251, ASCE J. Engrg. Mech., 109 (5), pp 1215-1230 (Oct 1983) 8 figs, 2 refs

Key Words: Periodic excitation, Periodic response, Transient response, Undamped structures, Viscous damping

A simple, computationally efficient procedure is presented with which the steady-state response of a discrete linear system to a periodic excitation may be computed from an analysis of its transient response over a single cycle of the excitation. The procedure also is adapted to the solution of the inverse problem; i.e., to evaluate the transient response of the system from knowledge of its steady-state response to a periodic extension of the excitation.

Elastic Response to a Time-Harmonic Torsion-Force Acting on a Bore Surface
R. Parnes
Dept. of Solid Mechanics, Materials and Structures, School of Engrg., Tel-Aviv Univ., 69978 Tel-Aviv, Israel, Intl. J. Solids Struct., 19 (10), pp 925-934 (1983) 6 figs, 8 refs

Key Words: Cavities, Cylindrical cavities, Elastic media, Harmonic excitation

The response of an elastic medium to torsional line loads applied on the surface of a cylindrical cavity, and having a harmonic time-dependence, is studied. Integral representations of the stress and displacement fields are obtained and numerical results along a radial line emanating from the point of load applications and along the bore surface, are presented.

Mechanical Random Vibrations (Mechanische Zufallschwingungen)
W. Schielen
(In German)

Key Words: Random vibration

Random vibration calculation methods and the more important applications are reviewed. Particular emphasis is placed on discrete, nonlinear, time-invariant systems under non-white, nonstationary, forced excitation.

Power System Harmonics: An Overview

Key Words: Harmonic excitation

The assessment of harmonic phenomena and their system effects is characterized by considering long-established harmonic sources and problems, and by detailing new and future sources and their probable effects. There is consider-

A Damping Technology Solution to an Automotive Vibration Problem
M.L. Drake

Key Words: Viscoelastic damping, Motors, Motor vehicle engines

Many options are open to a designer to solve resonant vibration problems (stiffening, damping, isolation, source modification, etc.). This article discusses a design approach using viscoelastic damping as the solution to a vibration problem.
Evaluation of Three Fluid-Film Models for Use in Uncentralized Squeeze-Film Damper Bearing Analysis
S.S. Kossa and R.A. Cookson
Cranfield Inst. of Tech., Cranfield, Bedford, UK, ASLE, Trans., 26 (4), pp 532-537 (Oct 1983) 7 figs, 1 table, 13 refs
Key Words: Dampers, Squeeze-film dampers, Squeeze-film bearings, Rotors, Vibration control

Considerable interest is currently being shown in the development of computational schemes for the prediction of the response of systems which can include a number of squeeze-film dampers. Such computational schemes require adequate modeling of the squeeze-film damper in order that an accurate evaluation of the fluid-film forces acting within the device, and, hence, a correct prediction of the rotor amplitudes, can be made. Three possible fluid-film models are considered, and the rotor amplitudes predicted with the aid of each of these models compared with measured values.

Effect of Soil-Structure Interaction on Damping of Structures
M. Novak and L. El Hifnawy
Key Words: Interaction: soil-structure, Flexible foundations, Structural damping

Damping of structures resting on flexible foundations is affected by soil-structure interaction. These effects are evaluated using two approaches: an energy consideration which is a simple but approximate approach, and the complex eigenvalue analysis which is mathematically accurate but uses damped, nonclassical vibration modes. These two methods are compared and the accuracy of the more convenient energy approach is assessed.

Fatigue Damage Mechanisms and Short Crack Growth
I. LeMay
AD-P001 603
Key Words: Fatigue life, Crack propagation

The growth of short fatigue cracks, where the Paris law does not appear to hold, is discussed. In this regime the mechanisms of fatigue damage are of importance to an understanding of the role of microstructure in affecting growth rate. The paper reviews the operative mechanisms and their effect on short crack growth.

Micro-Crack Initiation, Propagation, and Threshold in Elevated Temperature Inelastic Fatigue
S. Usami, Y. Fukuda, and S. Shida
Hitachi Ltd., Japan, ASME Paper No. 83-PVP-97
Key Words: Fatigue life, Crack propagation

The effects of temperature, strain rate, wave shape, and strain gradient are analyzed and methods for estimating fatigue life and fatigue limits are postulated on the basis of the behavior of the microcracks.

Growth of Short Fatigue Cracks in an Alloy Steel
N.E. Dowling


(Also see No. 312)
A method of analysis that applies the techniques of linear elastic fracture mechanics to piping components under high-cycle fatigue in an environment containing interspersed low-cycle loads is formulated and applied.

Role of a Fatigue Damage Accumulation Plot in Structural Loads Data Analysis

D.M. Holford
AD-A130 112

Fatigue tests of 8-yr. Weathered A588 Steel Weldment

P. Albrecht and Jian-Guo Cheng
Univ. of Maryland, College Park, MD, ASCE J. Struct. Engrg., 109 (9), pp 2048-2065 (Sept 1983) 11 figs, 6 tables, 18 refs

Fatigue tests of 62 specimens determined the effect of 3-year, alternate, and 8-year weathering on the number of cycles to failure of a transverse stiffener detail fabricated from ASTM A588 weathering steel. These three weathering conditions reduced the mean losses in fatigue life by 42%, 42% and 54%, respectively, as compared to the life of the nonweathered control specimens.

Statistical Cumulative Damage Theory for Fatigue Life Prediction

Z. Hashin
Tel-Aviv Univ., Tel-Aviv, Israel, J. Appl. Mech., Trans. ASME, 50 (3), pp 571-579 (Sept 1983) 7 figs, 4 tables, 8 refs

Fatigue Tests of 8-yr. Weathered A588 Steel Weldment

P. Albrecht and Jian-Guo Cheng
Univ. of Maryland, College Park, MD, ASCE J. Struct. Engrg., 109 (9), pp 2048-2065 (Sept 1983) 11 figs, 6 tables, 18 refs

84-381
Statistical Cumulative Damage Theory for Fatigue Life Prediction
Z. Hashin
Tel-Aviv Univ., Tel-Aviv, Israel, J. Appl. Mech., Trans. ASME, 50 (3), pp 571-579 (Sept 1983) 7 figs, 4 tables, 8 refs

Key Words: Fatigue life, Statistical analysis

A statistical cumulative damage theory is developed with the purpose of prediction of mean, standard deviation and probability density of fatigue lifetime of randomly variable specimens subjected to the same deterministic cycle loading program. The theory requires availability of a deterministic cumulative damage theory for ideal nonvariable specimens, called clones.

ELASTICITY AND PLASTICITY
(Also see Nos. 287, 376)

84-382
Nonlinear Fracture Mechanics Approach to the Growth of Small Cracks
J.C. Newman, Jr.
AD-P001 605

Key Words: Crack propagation

Nonlinear fracture mechanics, in particular the J-integral concept, and an empirical length parameter are used to correlate small and large crack-growth rate data.

Key Words: Crack propagation

The kinking of an initially stationary crack in a linear elastic body due to dynamic loading is solved using the linear superposition to construct dual singular integral equations, which are solved numerically. The results for stress wave loading as well as loading on the crack faces only are presented.

84-384
Dynamic Crack-Tip Fields in Rate-Sensitive Solids
K.K. Lo

Key Words: Crack propagation

The asymptotic stress and strain fields near the tip of a crack which propagates dynamically in a rate-sensitive solid are obtained under anti-plane shear and plane strain conditions. The problem is formulated within the context of a small-strain theory for a solid whose mechanical behavior under high strain rates is described by an elastic-viscoplastic constitutive relation.

84-385
Impact Response of a Cracked Orthotropic Medium
M.K. Kassir and K.K. Bandyopadhyay

Key Words: Cracked media, Impact response

A solution is given for the problem of an infinite orthotropic solid containing a central crack deformed by the action of suddenly applied stresses to its surfaces. Laplace and Fourier transforms are employed to reduce the transient problem to the solution of standard integral equations in the Laplace transform plane.

84-386
Prestrained Elastic Laminates: Deformations, Stability and Vibrations

H. Butler and H. Kennerknecht

Key Words: Layered materials, Elastic properties

For a general elastic laminate consisting of different transversely isotropic plane layers an exact method for the calculation of the deformations, stability and eigenvibrations is discussed. The specialization to a laminate composed of alternating stiff reinforcing sheets and soft matrix layers, however, allows a considerable simplification.

WAVE PROPAGATION
(Also see Nos. 354, 415)

84-387
Forced Oscillations in a Two-Layer Fluid of Finite Depth
R.K. Manna

Key Words: Fluids, Forced vibration

An initial value investigation is made of the development of surface and internal wave motions generated by an oscillatory pressure distribution on the surface of a fluid that is composed of two layers of limited depths and of different densities. The displacement functions both on the free surface and on the interface are obtained with the help of generalized Fourier transformation. The method for the asymptotic evolution of the wave integrals is based on Bleistein's method.

84-388
Space-Time Integral Equation Solution for Hard or Soft Targets in the Presence of a Hard or Soft Half Space
C.L. Bennett and H. Mieras

Key Words: Wave scattering, Integral equations, Time domain method
The responses of a hard or soft target in the presence of a hard or soft half space are computed using space-time integral equations formulated in the time domain. The technique is applicable to targets of arbitrary contour and is demonstrated for a sphere and right-circular cylinder at various locations relative to the half space.

84-391
Present Thinking on the Use of the Singularity Expansion in Electromagnetic Scattering Computation
L.W. Pearson
Dept. of Electrical Engrg., Univ. of Mississippi, MS 38677, Wave Motion, 5 (4), pp 355-368 (Aug 1983) 4 figs, 33 refs

Key Words: Wave scattering, Electromagnetic waves, Singularity expansion method

This paper surveys the present understanding of the singularity expansion of electromagnetic scattering responses from the pragmatist's point-of-view. Attention is given to recent work which clarifies points which have been debated in the past. The interpretation of the expansion in the presence of a time-limited excitation function is discussed. Various means for determining the expansion parameters for a given object are surveyed.

84-392
Electromagnetic and Acoustic Resonance Scattering Theory
Dept. of Physics, Catholic Univ., Washington, DC 20064, Wave Motion, 5 (4), pp 307-329 (Aug 1983) 16 figs, 46 refs

Key Words: Wave scattering, Acoustic waves, Electromagnetic waves

The excitation of the eigenfrequencies of finite radar or sonar targets, of inhomogeneities in elastic materials, of geological strata or of the entire earth by the impact of propagating waves manifests itself in the appearance of poles in the resulting wave amplitudes, as described by the resonance scattering theory. In the complex frequency plane, these poles relate to the ringing of the scattering resonances. In the complex mode number plane, corresponding poles are connected with circumferential or creeping waves. An analytic relation between these two descriptions is indicated here, and a number of examples from the above-mentioned fields is discussed.

84-393
Scattering of Elastic Waves from Simple Defects in Solids, A Review
B.R. Tittmann

Key Words: Wave scattering, Elastic waves, Time domain method, Nondestructive tests

This paper presents a review of recent work on the scattering of elastic waves from simple defects in solids. The emphasis in the report is on the representation in the time-domain as contrasted to that in the frequency-domain, although both aspects are discussed. The defects are principally small voids ranging in shape from spherical voids to simulated flat cracks with combinations of these.

84-394
On Wave Propagation in Random Particulate Composites
A.I. Beltzer, C.W. Bert, and A.G. Striz

Key Words: Composite materials, Viscoelastic properties, Wave propagation

A new method is presented for analysis of wave propagation in random particulate viscoelastic composites. The method incorporates both the scattering effect and viscoelastic losses as well as the Kramers-Kronig relationships valid for any casual linear system. Explicit expressions for the attenuation and dispersion are given and compared with available experimental data.

84-395
On Three Modal Synthesis Variants
A. Curnier
Laboratoire de Mecanique Appliquee, Ecole Polytechnique Federale de Lausanne, CH-1015, Lausanne, Switzerland, J. Sound Vib., 90 (4), pp 527-540 (Oct 22, 1983) 3 figs, 1 table, 8 refs

Key Words: Modal synthesis

A unified formulation of fixed, free and loaded interface variants of modal synthesis is presented. A formal proof of the exactness of all three variants in the absence of modal truncation is established. The sensitivity of the truncation error to the different interface conditions is studied.

84-396
On the Application of the Mode-Acceleration Method to Structural Engineering Problems
R.E. Cornwell, R.R. Craig, Jr., and C.P. Johnson

Key Words: Mode acceleration method, Mode displacement method, Mode superposition method

The results of a systematic study comparing the accuracy of the mode-displacement and mode-acceleration methods when applied to structures with various levels of damping or various excitation frequencies are summarized. Several details concerning the implementation of the mode-acceleration method are also discussed.

84-397
A. Nagamatsu, A. Nakao, T. Iwamoto and M. Nagaike
Tokyo Inst. of Tech., 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, 152, Japan, Bull. JSME, 26 (219), pp 1635-1640 (Sept 1983) 15 figs, 8 refs

Key Words: Substructuring methods, Vibration analysis, Modal analysis, Curve fitting

A new, convenient and accurate method is introduced for curve fitting of a frequency spectrum of a transfer function with light damping. Using this method, both the building block approach and the extracting block approach are tested to analyze the vibration of a simple model structure.
84-398
Combination of Multiple Dynamic Responses
R.P. Kennedy
Structural Mechanics Associates, Inc., Newport
Beach, CA, ASME Paper No. 83-PVP-12

Key Words: Root mean squares

The rationale behind the square-root-sum-of-squares method
of response combination is presented along with criteria
for judging the acceptability of this method. The results
of studies to validate these acceptance criteria are sum-
marized. Special problems associated with the problems
of correlated peak responses and nonlinear analyses are also
discussed.

84-399
Design of Model Reference Adaptive Systems Using
Frequency Response Methods
P.T. Kidd and N. Munro
Control Systems Ctr., Univ. of Manchester Inst. of
Science and Tech., UK, Rept. No. CONTROL SYS-
TEMS CENTRE-557, 33 pp (1982)
PBB3-232488

Key Words: Frequency domain method

A multivariable frequency-domain adaptive performance
criterion is developed. The similarities between passive
adaptive and signal synthesis adaptive model following con-
trol systems are discussed. A multivariable frequency-re-
sponse design method for passive adaptive model following
control systems is proposed and applied to a 2-input, 2-out-
put multivariable model with variable gains, and to a scalar
second-order system with variable damping and natural
frequency.

84-400
System Analysis and Time Delay Spectrometry
(Part II)
H. Biering and O.Z. Pedersen
Bruel & Kjaer Instruments, Inc., 185 Forest Street,
Marlborough, MA 01752, Technical Review, (2),
pp 3-45 (1983) 7 figs, 2 refs

Key Words: Signal processing techniques, Time delay spec-
trometry

Time delay spectrometry (TDS) is a relatively new method
for measurement of system response. Based on a linear sine
sweep it optimizes measurement performance eliminating
some earlier drawbacks of swept measurements. This paper
deals specifically with the TDS technique and its practical
implementation in a time delay spectrometry system.

84-401
Measurement of Crossflow Forces on Tubes
T.M. Mulcahy
Argonne Natl. Lab., Argonne, IL, ASME Paper No.
83-PVP-77

Key Words: Transducers, Force measurement, Tubes, Fluid-
induced excitation

A force transducer for measuring lift and drag coefficients
for a circular cylinder in turbulent water flow is presented.
In addition to describing the actual design, requirements for
obtaining valid fluid force test data are discussed, and pertinent
flow test experience is related.

DYNAMIC TESTS
(Also see No. 393)

84-402
An Investigation of the Excitation Frequency Depen-
dent Behavior of Fiber Reinforced Epoxy Composites
During Vibrothermographic Inspection
S.S. Russell
Ph.D. Thesis, Virginia Polytechnic Inst. and State
Univ., 195 pp (1982)
DA8316894

Key Words: Nondestructive tests, Vibrothermographic tech-
niques, Fiber composites

This investigation concerns the frequency related behavior of
delaminations in fiber reinforced composites during vibro-
thermography, the use of active thermography with a me-
chanical excitation for the nondestructive evaluation of a
structure or part. Two models, one where the size and
geometry of the flaw control a local resonance and the
other where the part or panel is undergoing structural reso-
nance with the flaws dissipating the mechanical energy, are
proposed for this frequency related behavior and tested
on simulated and service produced delaminations in coupons,
panels, and a machine part of complex geometry.
84403
Model Mount System for Testing Flutter
M.G. Farmer
Appl. No. 6481 106, 15 pp (Mar 31, 1983)

Key Words: Mountings, Wind tunnel testing, Aircraft, Flutter

A wind tunnel model mount system is described for effectively and accurately determining the effects of angle of attack and airstream velocity on a model aircraft or aircraft.

DIAGNOSTICS

84404
The Matrix of Power Spectra Levels of Turned Surfaces Roughness
A.L. Konczakowski

Key Words: Diagnostic techniques, Monitoring techniques, Machine tools, Power spectra

This paper deals with the application of a scheduling algorithm for computed surface roughness power spectra obtained for combinations of cutting conditions in a turning process. The matrix of power spectra levels as the complex discriminant is presented.

84405
Prevention of Vibration Damage by Maintenance (Instandhaltung Schwingchäden vermeiden)
H.P. Fuchs
Industrie Anzeiger, 106 (79), pp 30-32 (Oct 5, 1983) 3 figs, 1 table
(In German)

Key Words: Diagnostic techniques, Vibration measurement, Measuring instruments

The author describes two types of vibration measurement carried out in machine diagnostics: the absolute and the relative vibration measurement. The application of each method is discussed which is determined by the type of bearings, rotor to stator mass ratio, and machine foundations.

ANALYSIS AND DESIGN

84406
A Conservation Theorem for Simple Nonholonomic Systems
T.R. Kane and A.K. Banerjee

Key Words: Nonholonomic systems

When the Hamiltonian of a holonomic system is free of explicit time dependence it remains constant throughout all motions of the system. In this paper, it is shown how, given a homogeneous simple nonholonomic system \( S \), one can form a function \( E \) that remains constant throughout all motions of \( S \), providing the forces acting on \( S \) fulfill certain requirements. An illustrative example is examined in detail.

84407
Complementary Variational Principles and Their Application to Rheo-Linear and Rheo-Non-Linear Vibrations
J.G. Papastavridis
Key Words: Variational methods, Stability, Vibration analysis

A complementary (to Hamilton's) variational principle, and its subsequent energetic specialization to periodic systems are developed, and, subsequently, applied to the approximate determination of the stability/instability boundaries, first of the linear Mathieu equation, and then of two common types of nonlinear Mathieu-like equations. Extensions of the methodology are also indicated.

84-408

Analysis of Critical and Post-Critical Behaviour of Nonlinear Dynamical Systems by the Normal Form Method, Part I: Normalization Formulae
L. Hsu

Key Words: Nonlinear systems, Bifurcation theory, Dynamic response, Perturbation theory, Normal form method

A method, based on normal form theory, is presented to study the dynamical behavior of a system in the neighborhood of a nearly critical equilibrium state associated with a bifurcation condition. Explicit formulae for the normalization procedure are derived.

84-409

Analysis of Critical and Post-Critical Behaviour of Non-Linear Dynamical Systems by the Normal Form Method, Part II: Divergence and Flutter
L. Hsu

Key Words: Nonlinear systems, Bifurcation theory, Dynamic response, Perturbation theory, Normal form method, Flutter

The normal form method presented in Part I is applied to the analysis of systems near two basic bifurcation conditions: divergence and flutter. The reduced system and the normalizing transformation are utilized to determine the stability of the bifurcating singular point, the local equilibrium paths associated with divergence bifurcation, and the amplitude and frequency of post-flutter oscillations.

84-410

Self-Tuning Regulators: Non-Parametric Algorithms
P.E. Wellstead and M.B. Zarrop
Control Systems Ctr., Univ. of Manchester Inst. of Science and Tech., UK, Rept. No. CONTROL SYSTEMS CENTRE-651, 37 pp (May 1982)
P883-232793

Key Words: Tuning, Vibration tuning, Seismic analysis, Simulation

Self-tuning control system algorithms share the common feature that the system to be controlled is finite order, linear and parametric. This report reviews previous work on this topic, outlines the problem of self-tuning vibration control, and describes in detail experiments with non-parametric self-tuning. Recursive algorithms are discussed and ways are illustrated for improving their convergence behavior.

84-411

Mixed Variational Principles in Vibrational Mechanics
P. Gibert
N83-26115
(In French)

Key Words: Variational methods, Complex structures, Harmonic response

Harmonic vibrations of mechanical systems with nonholonomic constraints are analyzed using a mixed variational formulation for the spectral problem. A connection with methods of the intermediate problem type is established.

MODELING TECHNIQUES

84-412

ARMA Algorithms for Ocean Wave Modeling
P-T.D. Spanos
Univ. of Texas, Austin, TX 78712, J. Energy Resources Tech., Trans. ASME, 106 (3), pp 300-309 (Sept 1983) 17 figs, 22 refs
Key Words: ARMA (autoregressive moving average) models, Floating structures, Submerged structures, Wave forces, Simulation

Three different algorithms are presented for simulating a time series which is compatible with a given power spectrum of ocean waves. These algorithms are applied to the Pierson-Moskowitz spectrum, exclusively. The advantages and disadvantages of each of the three algorithms are discussed in context with their applicability to offshore engineering problems.

84-413 Constituteive Model for Concrete under Dynamic Loading
N. Bicanic and O.C. Zienkiewicz
Univ. of Zagreb, Zagreb, Yugoslavia, Earthquake Engrg. Struc. Dynam., 11 (5), pp 689-710 (Sept/Oct 1983) 15 figs, 1 table, 37 refs

Key Words: Concretes, Seismic excitation, Constitutive equations, Mathematical models

A rate and history dependent numerical model for plain concrete under seismic loading conditions is proposed. The model follows the modified Perzyna’s theory of elastoviscoplasticity employing the stress rate sensitive fluidity parameter and two surfaces in the principal stress space — the discontinuity surface defining the departure from elasticity, and the strength limit surface, to serve as a damage monitoring device and to initiate the degradation of the discontinuity surface once the stress point reaches the limiting strength level.

STATISTICAL METHODS

84-414 Statistical Analysis of Slow-Drift Responses
C.T. Stansberg

Key Words: Statistical analysis, Wave forces

The statistical properties of second-order wave-induced response processes are investigated theoretically. Emphasis is placed on the slow-drift components. The assumed forcing waves are irregular with continuous frequency spectra. A spectral analysis of the response of a general system is made.

PARAMETER IDENTIFICATION

84-415 Parametric Identification of Transient Electromagnetic Systems
D.G. Dudley
Dept. of Electrical Engr., Univ. of Arizona, Tucson, AZ 85721, Wave Motion, 5 (4), pp 369-384 (Aug 1983) 14 figs, 1 table, 23 refs

Key Words: Parameter identification technique, Wave scattering, Electromagnetic waves

Data into and out of a transient electromagnetic system are considered in the framework of modern system identification. System solutions that take the form of a complex exponential series are discussed.

84-416 On the Identification of Structural Systems in the Frequency Domain (Zur Identifikation mechanischer Systeme im Frequenzbereich)
H.G. Natke
Curt-Risch-Institut f. Dynamik, Schall- und Mess- technik, Universität Hannover, Callinstr. 32, 3000 Hannover 1, Techn. Messen-TM, 50 (9), pp 315-322 (Sept 1983) 5 figs, 1 table, 10 refs
(In German)

Key Words: Parameter identification technique, System identification techniques, Frequency domain method

The prediction of the dynamic behavior of elastomechanical systems able to vibrate is generally performed using linear discrete computational models (results of system analysis). The dynamic properties of the system are determined through experimental investigations.

84-417 Dynamic Identification Method of Complex Structures
L. Barthe-batsalle
N83-26116
Key Words: System identification techniques, Complex structures, Harmonic response

A global identification method for complex structures, which improves the finite element computation model for the study of harmonic vibratory, based on measured natural modes is outlined. Modes are introduced as displacements imposed on a part of the structure in a static problem involving rigidity and mass operators. The method seeks the unknown parameters which minimize the euclidian norm of the reaction forces corresponding to the prescribed measured displacements.

The parameter identification algorithms developed in Part I are applied to a number of distributed systems. Sensitivity analyses are performed to determine how sensitive this identification method is to changes in the variables of the method, such as finite element length, derivative filter cut-off frequency and gain constants. The effect of the measurement noise is also investigated via computer simulation.

COMPUTER PROGRAMS
(Also see No. 299)

84-418
Real-time Parameter Identification in a Class of Distributed Systems Using Lyapunov Design Method Part I. Theory
H. Sehitoglu
2 figs, 12 refs

Key Words: Parameter identification technique, Real time techniques, Continuous parameter method, Lyapunov's method

A method is presented for the real-time identification of parameters in distributed parameter systems governed by parabolic partial differential equations. The method uses a finite element technique to reduce the system's governing equation into a set of ordinary differential equations. A suitable performance index is then formed as a function of identification error. The Lyapunov design technique is used to develop proportional and integral type identification algorithms. The method can be used either on-line or off-line for identification purposes.

84-420
Computer Program SPILAD for the Calculation of Static and Undamped Dynamic Response of Spindle-Bearing Systems (Programm SPILAD zur Berechnung des statischen und ungedämpften dynamischen Verhaltens von Spindel-Lager-Systemen)
Konstruktion, 35 (8), p 328 (Aug 1983) 1 fig
(In German)

Key Words: Computer programs, Spindles, Bearings

A desk top computer program SPILAD is summarized which, in addition to the determination of static deformations, calculates three lowest natural frequencies and the associated mode shapes of spindle-bearing systems. The program is written in BASIC. It is available from the editorial staff of Konstruktion, Springer-Verlag, Ott-Suhr-Allee 26-28, 1000 Berlin 10, W. Germany.

84-419
Real-time Parameter Identification in a Class of Distributed Systems Using Lyapunov Design Method Part II. Applications
H. Sehitoglu
10 figs, 3 refs

Key Words: Parameter identification technique, Real time techniques, Continuous parameter method, Lyapunov's method

84-421
A Computer Code for Seismic Qualification of Nuclear Service Valves
W. Djordjevic
Stevenson & Assoc., Boston, MA, ASME Paper No. 83-PVP-81

Key Words: Computer programs, Seismic analysis, Nuclear reactor components, Valves

The computer code, Certivalve, has been developed for detailed frequency, seismic stress, and deformation analysis of nuclear service valves. It is an expedient means of analyzing, designing, and qualifying nuclear service valves for dynamic loads and can evaluate valves of nearly all major manufacturers, both foreign and domestic.
A computer program for simulating the steady state and transient performance of a four cylinder Stirling engine is presented. The thermodynamic model includes both continuity and energy equations and linear momentum terms (flow resistance). Each working space between the pistons is broken into seven control volumes. Drive dynamics and vehicle load effects are included.

Key Words: Computer programs, Simulation, Engines, Stirling engines

This new standard contains guidelines for the preparation of procedures (standards, test codes, recommended practices, etc.) for determination of noise emission from sources. Included are general questions to be considered during development of a measurement procedure. Guidelines on the following subjects are included: prefatory material, measurement conditions, measurement operations, data reduction, preparation of a test report, and guidelines for the selection of a descriptor for noise emission.

Key Words: Standards and codes, Acoustic emission, Measurement techniques

This issue of ZAMM is devoted to papers presented at the Annual Meeting of GAMM held Apr 13-16, 1982, Budapest, Hungary. The issue contains two main papers and 350 brief communications. An abstract of one of the main papers on random vibrations can be found in the vibration excitation section.

This standard provides consensus quantitative definitions of explosion characteristics for a single point explosion in air along with methodologies for scaling these characteristics for a wide range of yield and ambient air conditions. Factors for use with common solid explosives are also included. Methods are provided for predictions of long-range propagation under atmospheric refractive influences. Target damage estimation procedures are provided for use in explosion operation planning and evaluation.

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Reactions of humans to vibrations of 1 to 80 Hz inside buildings were assessed in this standard by use of degrees of perception and associated vibration levels and durations. Accelerations or velocities inside buildings may be measured to assess perceptibility and possible adverse reactions from those inside. A variety of building types and situations are covered by the use of multiplying factors applied to the basic curves.

USEFUL APPLICATIONS

84-427

Effect of Vibration on the Natural Convection Heat Transfer of a Horizontal Cylinder
H. Kimoto, A. Kadotsuji, and T. Hirose
Osaka Univ., Machikaneyama 1-1, Toyonaka, Osaka 560, Japan, Bull. JSME, 26 (217), pp 1154-1161 (July 1983) 16 figs, 8 refs

Key Words: Cylinders, Vibrating structures, Heat transfer

The local heat transfer rate around a heated, horizontally vibrating cylinder is measured, and the thermal profile, close to the cylinder surface, is obtained by a Mach-Zender interferometer. The velocity and thermal profiles of the upward stream of natural convection are measured by a hot-wire anemometer and a unit of temperature-measurement, and the change in the flow pattern of natural convection is examined by a flow visualization method.

84-428

Large Screens with Double Vibration Mechanisms
B. Doublier and J.P. Moutot
SKF Clamart, Ball Bearing J., 215, pp 26-28 (July 1983) 5 figs

Key Words: Screening, Vibratory techniques

To meet market demands for larger vibratory screens and higher productivity, a special solution has been developed. The conventional approach using a single vibration mechanism has been replaced by two separate but synchronized mechanisms. These are fitted with a total of four SKF bearings. The original screens have been in operation for over 10,000 hours.

84-429

A Unique Use for Quasi-Random Vibration for Wire Panel Production Screening
F.G. Adams

Key Words: Screening, Vibratory techniques

A cost effective method of vibrating wire panel assemblies over a large size and weight range has been developed. The approach involves the use of pneumatic vibration in a special application. The special vibration fixtures involve two types: a vibration table for small to intermediate panels and an "I-Beam" clamp-on fixture for large panels.
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S.K. Hati and S.S. Rao
Cooperative Solution in the Synthesis of Multidegree-of-Freedom Shock Isolation Systems

G. L. McAninch
A Note on Propagation through a Realistic Boundary Layer
J. Sound Vib., 88 (.), pp 271-274 (May 22, 1983) 1 fig, 6 refs

N.W.M. Ko and K.M. Lam
Interaction between the Plenum Chamber and the Flow of an Annular Jet
J. Sound Vib., 88 (2), pp 282-286 (May 22, 1983) 5 figs, 6 refs

C.V. Massalas and V.K. Kalpakidis
Coupled Thermoelastic Vibrations of a Simply Supported Beam
J. Sound Vib., 88 (3), pp 425-429 (June 8, 1983) 2 figs, 6 refs

M. Corti, F. Parmigiani, and A. DeAgostini
Measurements on the Dynamical Behaviour of a Naturally Excited Chimney by a Laser Technique
J. Sound Vib., 88 (3), pp 421-424 (June 8, 1983) 3 figs, 1 table, 8 refs

K.S. Peat
A Note on One-Dimensional Acoustic Elements
J. Sound Vib., 88 (4), pp 572-575 (June 22, 1983) 2 figs, 4 refs

N.W.M. Ko
Excited Annular Jets of Large Inner Diameter
J. Sound Vib., 88 (4), pp 576-578 (June 22, 1983) 2 figs, 4 refs

M. Ohta, K. Hatakeyama, and S. Hiromitsu
A New Trial of Parameter Estimation for Road Traffic Noise from a System-Theoretical Viewpoint
Acustica, 53 (2), pp 86-91 (June 1983) 5 figs, 1 table, 8 refs

M. Stamac and I. Stamac
A Method of Computer-Aided Optimization of the Absorption in an Enclosure
Acustica, 52 (2), pp 91-95 (June 1983) 5 figs, 5 refs

H. Takeishi and Y. Yasumoto
Generation of Stress Pulse Due to Electro-Magnetic Induction and Its Observation Using the Method of Dynamic Photo-Elasticity
Acustica, 52 (2), pp 95-99 (June 1983) 16 figs, 6 refs

L.S. Czarnecki
Measurement of the Individual Harmonics Reactive Power in Nonsinusoidal Systems

I.M. Smith and E. E. Heshmati
Use of a Lanczos Algorithm in Dynamic Analysis of Structures

J.R. Sladek and R.E. Klingner
Effect of Tuned-Mass Dampers on Seismic Response

I.G. Bromilow and R.R. Clements
A Discrete Vortex Simulation of Kelvin-Helmholtz Instability
AIAA J., 21 (9), pp 1345-1347 (Sept 1983) 4 figs, 10 refs

B.V. DeGreco and P.A.A. Laura
Antisymmetric Vibrations of Circular Plates with Thickness Varying in a Bilinear Fashion
Appl. Acoust., 16 (5), pp 393-397 (1983) 1 fig, 2 tables, 4 refs
# CALENDAR

## MARCH 1984

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<tr>
<td>20-23</td>
<td>Balancing of Rotating Machinery Symposium [Vibration Institute]</td>
<td>Philadelphia, PA (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)</td>
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## APRIL 1984

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<td>9-12</td>
<td>Design Engineering Conference and Show [ASME]</td>
<td>Chicago, IL (ASME Hqs.)</td>
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<tr>
<td>9-13</td>
<td>2nd International Conference on Recent Advances in Structural Dynamics [Institute of Sound and Vibration Research]</td>
<td>Southampton, England (Dr. Maurice Petyt, Institute of Sound and Vibration Research, The University of Southampton, SO9 5NH, England - (0703) 559122, Ext. 2297)</td>
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<tr>
<td>30-May</td>
<td>Institute of Environmental Sciences' 30th Annual Technical Meeting [IES]</td>
<td>Orlando, FL (IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)</td>
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## MAY 1984

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<tr>
<td>7-10</td>
<td>30th International Instrumentation Symposium [Instrument Society of America]</td>
<td>Denver, CO (Robert Jarvis, Grumman Aerospace Corp., Mail Stop 701-05, Bethpage, NY 11714)</td>
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<td>7-11</td>
<td>Acoustical Society of America, Spring Meeting [ASA]</td>
<td>Norfolk, VA (ASA Hqs.)</td>
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<td>10-11</td>
<td>12th Southeastern Conference on Theoretical and Applied Mechanics [Auburn University]</td>
<td>Pine Mountain, GA (J. Fred O'Brien, Director, Engineering Extension Service, Auburn University, AL 36849 - (205) 826-4370)</td>
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## JUNE 1984

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<td>3-7</td>
<td>29th International Gas Turbine Conference and Exhibit [ASME]</td>
<td>Amsterdam, The Netherlands (ASME Hqs.)</td>
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<td>26-28</td>
<td>Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute]</td>
<td>New Orleans, LA (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)</td>
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<td>21-28</td>
<td>8th World Conference on Earthquake Engineering [Earthquake Engineering Research Institute]</td>
<td>San Francisco, CA (EERI-SWCEE, 2200 Telegraph Avenue, Berkeley, CA 94704)</td>
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<td>6-9</td>
<td>West Coast International Meeting [SAE]</td>
<td>San Diego, CA (SAE Hqs.)</td>
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<td>19-25</td>
<td>XV11th International Congress on Theoretical and Applied Mechanics [International Union of Theoretical and Applied Mechanics]</td>
<td>Lyngby, Denmark (Prof. Frithiof Niordson, President, or Dr. Niels Olof, Executive Secretary, ICTAM, Technical University of Denmark, Bldg. 404, Dk-2800 Lyngby, Denmark)</td>
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<td>Petroleum Workshop and Conference [ASME]</td>
<td>San Antonio, TX (ASME Hqs.)</td>
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<td>11-13</td>
<td>Third International Conference on Vibrations in Rotating Machinery [Institution of Mechanical Engineers]</td>
<td>University of York, UK (IMEchE Hqs.)</td>
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<td>Acoustical Society of America, Fall Meeting [ASA]</td>
<td>Minneapolis, MN (ASA Hqs.)</td>
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<td>9-11</td>
<td>13th Space Simulation Conference [IES, ALPA, ASTM, and NASA]</td>
<td>Orlando, FL (Institute of Environmental Sciences, 940 E. Northwest Hwy, Mt. Prospect, IL 60056 - (312) 255-1561)</td>
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Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

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February 1984

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