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SVIC NOTES

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	Kron
Bungetzianu	Lyapunov
Friedlander	Myklestad
Frobenius	Newmark
Galerkin	Rayleigh
Guyan Reduction	Ritz
Holzer	Stotola
Kantorovich	Van der Pol
Kryloff-Bogoliuboff	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.

J.G.S.

EDITORS RATTLE SPACE

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 evolvement 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.

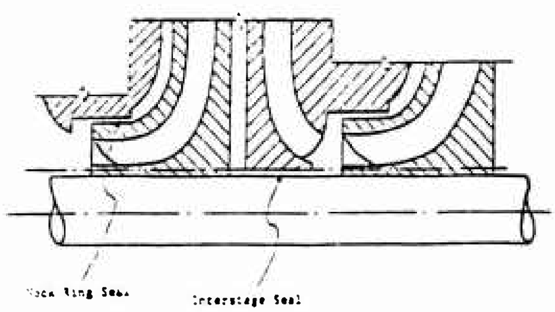

Figure 1. Typical Arrangements of Fine Clearance Annular Seals

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 Ps and that at the seal exit is Pe. 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

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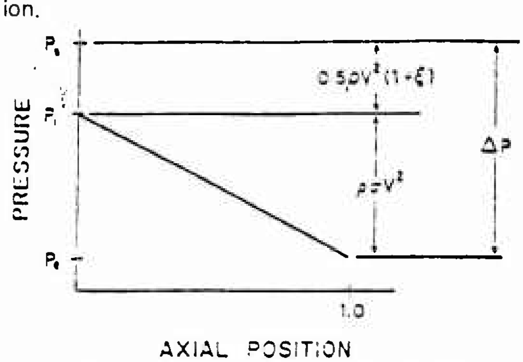
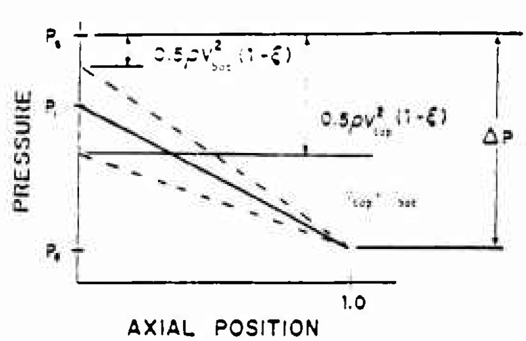
dependent and differ from top to bottom as shown in Figure 2b. At the top, the entrance pressure drop increases; at the bottom the entrance pressure drop decreases. Therefore, a net increase in pressure at the bottom of the seal produces an upward force tending to restore the shaft to its original, centered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



a. Steady Stage Axial Pressure Distribution



b. Pressure Drops at Seal Entrance

Figure 2. Pressure Distributions in a Seal

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

$$\lambda = \frac{n_o}{R_a^{m_o}} \left\{ 1 + a\left(\frac{R_r}{R_a}\right)^2 \right\}^b$$

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 to this point neglected. Thus, the forces are in direct opposition to the motion. The linearized force coefficients are functions of seal 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 nonrotating 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 comparisions 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 occured in 1976 because of instability problems encountered in the space shuttle engine high-pressure hydrogen fuel turbopumps [1, 14, 26]. Rotordynamic 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.

SUMMARY

A good fundamental basis for analyzing the static and dynamic properties of plain turbulent flow annular seals now exists. These analyses utilize a bulk flow model to describe flows. Comparisons to experimental measurements show reasonable correlation of static properties; however, correlation is not good in all cases. Dynamic tests currently underway should provide a comparative basis for dynamic force coefficients.

No complete analytical descriptions now exist for grooved annular seals, a geometric condition often encountered in pumps. Similarly no published information on the effects of flow development in short seals is available.

Most papers dealing with the effects of turbulent flow annular seals on the dynamic response of pumps consider only horizontal pump configurations. Applications to vertical pumps, particularly nuclear reactor main coolant pumps, have not generally been considered. It is apparent, however, from the available literature that these seals can have a strong effect on the dynamic response of pump configurations.

ACKNOWLEDGEMENT

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REFERENCES

1. Allaire, P.E., Gunter E.J., Lee, C.P., and Barrett, L.E., "The Dynamic Analysis of the Space Shuttle Main Engine High-Pressure Fuel Turbopump, Final Report; Part III: Load Capacity and Hybrid Coefficients for Turbulent Interstage Seals," NASA, Marshall Space Flight Center (Sept 1976).

2. Allaire, P.E. and Lin, Y.J., "Linearized Dynamic Analysis of Plain Short Turbulent Seals," J. Lubric. Tech., Trans. ASME, 1979 (submitted for publication).

3. Allaire, P.E., Lee, C.P., and Gunter, E.J., "Dynamics of Short Eccentric Plain Seals with High Axial Reynolds Numbers," J. Spacecraft Rockets, 15 (6), pp 341-347 (Nov-Dec 1978).

4. Batch, B.A., "Effect of Eccentricity on the Rate of Flow through Boiler Feed Pump Gland Seals," CERL Report No. 691 (Jan 1975).

5. Bedger, F.S. and Lomakin, A.A., "Determination of Critical Speed of a Pump Rotor with Reference to Forces Arising in the Seal Gaps," Steam Gas Turbine Engrg., No. 5 (1957).

6. Black, H.F., "Effects of Hydraulic Forces in Annular Pressure Seals on the Vibrations of Centrifugal Pump Rotors," J. Mech. Engrg. Sci., 11 (2), pp 206-213 (Apr 1969).

7. Black, H.F. and Murray, J.L., "The Hydrostatic and Hybrid Bearing Properties of Annular Pressure Seals in Centrifugal Pumps," BHRA Rept. RR1026 (Oct 1969).

8. Black, H.F. and Jenssen, D.N., "Dynamic Hybrid Properties of Annular Pressure Seals," Proc. J. Mech. Engrg., 184, pp 92-100 (1970).

9. Black, H.F., "On Journal Bearings with High Axial Flows in the Turbulent Regime," J. Mech. Engrg. Sci., 12 (4), pp 301-303 (1970).

10. Black, H.F., "Empirical Treatment of Hydrodynamic Journal Performance in the Superlaminar Regime," J. Mech. Engrg. Sci., 12 (2), pp 116-122 (1970).

11. Black, H.F. and Jenssen, D.N., "Effects of High-Pressure Ring Seals on Pump Rotor Vibration," ASME, Paper No. 71-WA/FF-38 (1971).

12. Black, H.F. and Cochrane, E.A., "Leakage and Hybrid Bearing Properties of Serrated Seals in Centrifugal Pumps," Paper G5, 6th Intl. Conf. Fluid Sealing, Munich, German Federal Republic (Feb 27 - Mar 2, 1973).

13. Black, H.F., Allaire, P.E., and Barrett, L.E., "Inlet Flow Swirl in Short Turbulent Seal Dynamics," 9th Intl. Conf. Fluid Sealing, Leeewenhorst, The Netherlands (Apr 1-3, 1981).

14. Childs, D.W., "The Space Shuttle Main Engine High-Pressure Fuel Turbopump Rotordynamic Instability Problem," J. Engrg. Power, Trans. ASME, pp 48-57 (Jan 1978).

15. Childs, D.W., "Dynamic Analysis of Turbulent Annular Seals Based on Hirs Lubrication Equations," ASME, Paper No. 82-Lub-41.

16. Childs, D.W., "Finite-Length Solutions for Rotordynamic Coefficients of Turbulent Annular Seals," ASME, Paper No. 82-Lub-42.

17. Childs, D.W., Dressman, J.B., and Childs, S.B., "Testing of Turbulent Seals for Rotordynamic Coefficients," NASA Conf. Public. 2133, pp 121-138 (1980).

18. Childs, B., Childs, D. and Dressman, J., "Estimation of Seal Stiffness and Damping Parameters from Experimental Data," IMechE, 2nd Intl. Conf. Vib. Rotating Mach., Cambridge, England (Sept 2-4, 1980).

19. Childs, D.W., "Convergent-Tapered Annular Seals: Analysis for Rotordynamic Coefficients," Symp. Vol., Fluid/Structure Interactions Turbomach., ASME Winter Ann. Mtg., pp 35-44 (1981).

20. Childs, D.W., Nelson, C., Noyes, T., and Dressman, J.B., "A High-Reynolds-Number Seal Test Facility: Facility Description and Preliminary Test Data," NASA Conf. Public. 2250, pp 172-186 (1982).

21. Childs, D.W. and Dressman, J.B., "Testing of Turbulent Seals for Rotordynamic Coefficients," NASA Conf. Public. 2250, pp 157-171 (1982).

22. Constantinescu, V.N., "Analysis of Bearings Operating in the Turbulent Regime," J. Basic Engrg., Trans. ASME, 84 (1), pp 139-151 (Mar 1962).

23. Cornish, R.J., "Turbulent Flow through Finite Eccentric Clearances," Phil. Mag., Series 7, 16 (108), p 897 (1933).

24. Domm, U., Dernedde, R., and Handwerker, T., "Influence of the Casing on the Calculation of the Critical Speed of Multi-Stage Pumps," IMechE Proc., 181, Pt. 3A (1966-67).

25. Duncan, A.B., "Vibrations in Boiler Feed Pumps: A Critical Review of Experimental and Service Experience," IMechE, Symp. Vib. Hydraul Pumps and Turbines, Paper No. 8 (Sept 1966).

26. Ek, M.C., "Solution of the Subsynchronous Whirl Problem in the High Pressure Hydrogen Turbomachinery of the Space Shuttle Main Engine, AIAA-SAE 14th Joint Propulsion Conf., Paper 78-1002 (July 1978).

27. Elrod, H.B. and Ng, C.W., "A Theory for Turbulent Fluid Films and Its Application to Bearings," J. Lubric. Tech., Trans. ASME, 89 (3), pp 346-362 (July 1967).

28. Fleming, D.P., "High-Stiffness Seals for Rotor Critical-Speed Control," ASME Paper No. 77-DET-10 (1977).

29. Fleming, D.P., "Effect of Seals on Rotor Systems," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. No. 52, Pt. 1, pp 55-65 (1982).

30. Fritz, R.J. and Kiss, E., "The Vibration Response of a Cantilevered Cylinder Surrounded by an Annular Fluid," KAPL-M-6539, Clearinghouse for Federal and Scientific Information (1966).

31. Fritz, R.J., "The Effects of an Annular Fluid on the Vibrations of a Long Rotor: Part 1: Theory," J. Basic Engrg., Trans. ASME, pp 923-929 (Dec 1970).

32. Fritz, R.J., "The Effects of an Annular Fluid on the Vibrations of a Long Rotor; Part 2: Test," J. Basic Engrg., Trans. ASME, pp 930-937 (Dec 1970).

33. Hirs, G.G., "Fundamentals of a Bulk-Flow Theory for Turbulent Lubrication Films," Ph.D. Dissertation, Delft Tech. Univ., The Netherlands (July 1970).

34. Hirs, G.G., "A Bulk-Flow Theory for Turbulence in Lubricant Films," J. Lubric. Tech., Trans. ASME, pp 137-146 (Apr 1973).

35. Iino, T. and Kaenko, T., "Hydraulic Forces Caused by Annular Pressure Seals in Centrifugal Pumps," NASA Conf. Public. 2133 (1980).

36. Jenssen, D.N., "Dynamics of Rotor Systems Embodying High Pressure Ring Seals," Ph.D. Dissertation, Heriot-Watt University, Edinburgh, Scotland (July 1970).

37. Kaye, J. and Elgar, E.C., "Modes of Adiabatic and Diabatic Fluid Flow in an Annulus with an Inner Rotating Cylinder," Trans. ASME, 80, pp 753-765 (1958).

38. Lomakin, A.A., "Calculation of Critical Speed and Securing of Dynamic Stability of Hydraulic High Pressure Pumps with Reference to Forces Arising in Seal Gaps," Energomashinostroenie, 4 (1), p 1158 (1958).

39. Mallaire, F.R., Nelson, L.H., and Buckman, P.S., "Evaluation of Wear Ring Seals for High-Speed High Pressure Turbopumps," ASME, Paper No. 68-WA Lub 1 (1968).

40. Marcinkowskij, W.A. and Karincev, J.B., "Influence of Seal Gaps on the Critical Speeds of Feed Pump Rotors," Energomashinostroenie, 7 (4), p 33 (1961).

41. Nakagayashi, K., Yamada, Y., and Seo, K., "Rotational and Axial Flow through the Gaps between Eccentric Cylinders of Which the Outer One Rotates," Bull. JSME, 17 (114), pp 1564-1571 (1974).

42. Nixon, R.A. and Cairney, W.D., "Scale Effects in Centrifugal Cooling Water Pumps for Thermal Power Stations," Natl. Engrg. Lab., Rept. No. 505 (Apr 1972).

43. Ng, C.W. and Pan, C.H.T., "A Linearized Turbulent Lubrication Theory," J. Basic Engrg., Trans. ASME, 87 (3), pp 675-688 (Sept 1965).

44. Salamone, D.J. and Gunter, E.J., "Effects of Shaft Warp and Disk Skew on the Synchronous Unbalance Response of a Multimass Rotor in Fluid Film Bearings," ASME, Topics in Fluid Film Bearing and Rotor Bearing Deisgn, and Optimization, pp 79-107 (1978).

45. Stampa, B., "Experimentelle. Untersuchungen an axial durchstromten Ringspalten," Ph.D. Dissertation, Technischen Universitat Carole-Wilhelmina, Braunschweig (1971).

46. Stepanoff, A.J., "Leakage Loss and Axial Thrust in Centrifugal Pumps," Trans. ASME, p 65 (Aug 1932).

47. Tao, L.N. and Donovan, W.F., "Through-Flow in Concentric and Eccentric Annuli of Fine Clearance with and without Relative Motion of the Boundaries," Trans. ASME, 77 (Nov 1955).

48. Taylor, G.I., "Fluid Friction between Rotating Cylinders," Proc. Royal Soc., Ser. A, 157, pp 546-564 (1936).

49. Taylor, G.I., "Stability of a Viscous Liquid Contained between Two Rotating Cylinders," Phil. Trans. Ser. A, 223, pp 289-343 (1923).

50. Ustimenko, B.P. and Zmerkov, V.N., "Hydrodynamics of Flow in an Annular Channel with an Inner Rotating Cylinder," USSR Acad. Sci., High Temperature, 2 (1) (1964).

51. Yamada, Y., "Resistance of Flow through an Annulus with an Inner Rotating Cylinder," Bull. JSME, 5 (1y), pp 302-310 (1962).

52. Yamada, Y., "On Pressure Loss of Flow between Rotating Coaxial Cylinders with Rectangular Grooves," Bull. JSME, 5 (20), pp 642-651 (1962).

53. Yamada, Y., Makagayashi, K., and Suzuki, Y., "Viscous Frictional Moment between Eccentric Rotating Cylinders When Outer Cylinder Rotates," Bull. JSME, 12 (53), pp 1024-1031 (1969).

54. Yamada, Y., Makabayashi, K., and Maeda, K., "Pressure Drop Measurements of the Flow through Eccentric Cylinders with Rotating Inner Cylinders," Bull. JSME, 12 (53), pp 1032-1040 (1969).

55. Younes, M.A., Mobbs, F.R., and Coney, J.E.R., "Power Losses due to Secondary Flow between Rotating Eccentric Cylinders," J. Lubric. Tech., Trans. ASME, 96 (1), pp 141-144 (Jan 1974).

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-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

$$P = \tfrac{1}{2}(1 + \xi + 2\sigma)\, v^2$$

where ξ = inlet loss coefficient

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

The correlation between friction factor λ and the axial flow Reynolds number R_a used by Black is

$$\lambda = 24\, R_a^{-1} \text{ (laminar flow)}, \; R_a \leq 3000$$

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

$$\lambda = \frac{0.079}{R_a^{1/4}} \left\{ 1 + \left(\frac{7R_r}{8R_a} \right)^2 \right\}^{3/8}, \; R_a \leq 42000$$

where

$$R_a = \frac{2\rho vc}{\mu}$$

and

$$R_r = \frac{\rho R\omega c}{\mu}$$

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 σ is a nonlinear function of the mean velocity, the equations for P and σ must be solved interactively. Assume initially that the flow velocity is

$$\nu = 25 \text{ m/s}$$

The initial axial Reynolds number is

$$R_a = \frac{(2)(979)(25)(0.00025)}{4.14 \times 10^{-4}} = 25559$$

and

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

Solving for σ gives

$$\sigma = \frac{0.079}{25559^{1/4}} \left\{ 1 + \left[\left(\frac{7}{8}\right) \left(\frac{5572}{25579}\right) \right]^2 \right\}^{3/8} \left(\frac{0.05}{0.00025}\right) = 1.266$$

Rewrite the equation for P as

$$V = \left\{ \frac{2P}{(1 + \xi + 2\sigma)} \right\}^{1/2}$$

and solve for a new value of v.

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

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

$$\begin{Bmatrix} F_x \\ F_y \end{Bmatrix} = - \begin{bmatrix} k & k_c \\ -k_c & k \end{bmatrix} \begin{Bmatrix} x \\ y \end{Bmatrix} - \begin{bmatrix} c & c_c \\ -c_c & c \end{bmatrix} \begin{Bmatrix} \dot{x} \\ \dot{y} \end{Bmatrix} - \begin{bmatrix} m_a & 0 \\ 0 & m_a \end{bmatrix} \begin{Bmatrix} \ddot{x} \\ \ddot{y} \end{Bmatrix}$$

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

The stiffness coefficients are

$$k = \frac{\pi RP}{\lambda} (\mu_0 - \mu_2^2 T^2/4)$$

$$k_c = \frac{\pi RP}{\lambda} (\mu_1 \omega T/2)$$

The damping coefficients are

$$c = \frac{\pi RP}{\lambda} (\mu_1 T)$$

$$c_c = \frac{\pi RP}{\lambda} (\mu_2 \omega T^2)$$

and the inertia coefficient is

$$m_a = \frac{\pi RP}{\lambda} \mu_2 T^2$$

The coefficients μ are given by

$$\mu_0 = \frac{(1 + \xi)\sigma^2}{(1 + \xi + 2\sigma)^2}$$

$$\mu_1 = \frac{(1 + \xi)^2 + (1 + \xi)(2.33 + 2\xi)\sigma^2 + 3.33(1 + \xi)\sigma^3 + 1.33\sigma^4}{(1 + \xi + 2\sigma)^3}$$

$$\mu_2 = \frac{0.33(1 + \xi)^2(2\xi - 1)\sigma + (1 + \xi)(1 + 2\xi)\sigma^2 + 2(1 + \xi)\sigma^3 + 1.33\sigma^4}{(1 + \xi + 2\sigma)^4}$$

The mean passage time given is

$$T = L/V$$

Substituting $\xi = 0.1$ and $\sigma = 1.266$ into the equations for μ_0, μ_1, and μ_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

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

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

$$= 7.080 \times 10^{6} \text{ N/m}$$

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

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

$$= 1.813 \times 10^{6} \text{ N/m}$$

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 propulson 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 torsinally 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 [5] 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.

Kempner 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 crankshafting have been discussed [64, 65]. Detuning of a fan motor by symmetrication 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 Hookes 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]. A crankshaft has been experimentally established as a source of noise in refrigerant compressors [41].

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 torsinal 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]. Tests [41] have indicated that a torsional system is a major source of compressor frame vibrations. 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 stueied [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

1. Measurement of Torsional Vibrations by a Non-contacting Laser Probe System," Noise Control Vib. Isol., 10 (1), p 23 (1979).

2. Alden, R.T.H., Nolan, P.J., and Bayne, J.P., "Shaft Dynamics in Closely Coupled Identical Generators," IEEE Trans. Power Appar., PAS-96 (3), pp 721-728 (1977).

3. Auslander, D.M., Tsai, N.T., and Farazian, F., "Bond Graph Models for Torsional Energy Transmissions," J. Dynam. Syst. Measurement Control, pp 53-59 (1975).

4. Bagci, C., "A Computer Method for Computing Torsional Natural Frequencies of Nonuniform Shafts, Geared Systems, and Curved Assemblies," Proc. 3rd OSU Appl. Mech. Conf., Oklahoma, pp 40.1 - 40.15 (1973).

5. Bagci, C. and Falconer, D.R., "Critical Speeds of Multi-Throw Crankshafts Using Spatial Line Element Method," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 51, Pt 3, pp 25-41 (1981).

6. Ball, J.H., "Vibration Analysis of a High HP Driveline," Proc. Natl. Conf. Power Trans., Cleveland, OH, pp 93-101 (1980).

7. Bamer, F., "Occurrence of Speed Variations in the Otto Engine," VDI Z., 6 (63) (1979) (in German).

8. Barsch, H. and Hermans, E., "Torsional Vibration Measurement of Crankshafts Using a Desk Calculator," VDI Berichte, 320, pp 95-101 (1978) (in German).

9. Bishop, R.E.D., Price, W.G., and Tam, P.K.Y., "On Damping of Torsional Vibrations in a Propulsion System Having a Fluid Drive," Inst. Mar. Engr., Trans., pp 109-123 (1979).

10. Bochman, J., Przystupa, F., and Wlodarski, W., "Analysis of Torsional Vibrations of Drive Systems," Przegl. Mech., 34 (13-14), pp 445-447 (1975).

11. Bohm, R. and Muller, K.G., "Torsional Vibration of Machine Tool Drives Using Speed Change Gears," Proc. 17th Mach. Tool Des. Res. Conf., 2, pp 233-240 (1976).

12. Bohm, R., "Torsional Vibration Calculation of Machine Tool Drives," Konstruktion, 29 (7), pp 259-264 (1977) (in German).

13. Bremer, R.C., "Practical Treatise on Engine Crankshaft Torsional Vibration Control," SAE Special Publ., SP-445 (1979).

14. Buckens, F., "On Damped Coupled Torsional and Flexural Vibrations of Gear-connected Parallel Shafts," ASME Paper 80-C2/DET-6 (1980).

15. Carlton, J.S. and Bantham, I., "Full Scale Experience Relating to the Propeller and Its Environment," Symp. Propellers 1978, SNAME, pp 1-10 (1979).

16. Catchpole, A.P., Healy, S.P., and Hodgetts, D., "Torsional Vibrations of a Vehicle Drive Line," ASME Paper No. 77-DET-24 (1977).

17. Crolla, D A., "Torsional Vibrations in Tractor Power-Take-Off Drive Lines," Noise Vib. Engines Transmissions, IMechE Conf. Publ. 179-10, pp 91-97 (1977).

18. Chistyakov, U.K., "Design Diagrams of Internal Combustion Engines and General Equations of Interconnected Vibrations," Izv. Vyssh. Uchebn. Zaved Mashinostr., 8, pp 89-93 (1980) (in Russian).

19. Daly, K.J. and Smith, J.D., "Estimation of Excitation and Transmissibility from Output Measurements with Application to Gear Drives," J. Sound Vib., 75 (1), pp 37-50 (1981).

20. Dawson, B. and Davies, M., "An Accelerated Automatic Root Search Algorithm for Iterative Methods in Vibration Analysis," Intl. J. Numer. Methods Engrg., 12 (5), pp 809-820 (1978).

21. Dawson, B. and Davies, M., "An Improvement in Shaikh's Method for Torsional Vibration Analysis of Branched Systems," Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 51, Pt 3, pp 1-10 (1981).

22. Dawson, M.J. and Denkhaus, H.G., "Program HOLZER: Computer Program to Determine the Natural Frequencies of a Multimass Torsional Vibration System," NMERI Pretoria, Rept. No. CSIR-ME-1559 (1978).

23. Dittrich, G. and Krumm, H., "Parametrically Excited Torsional Vibrations in Systems of Engines and Driven Machines with Periodically Varying Moments of Inertia," Ing.-Wesen, 46 (6), pp 181-195 (1980).

24. Doppler, S., "Absorption of Driving Shaft Vibrations via Friction Mass," Elektrotech. Maschinenbau, 97 (2), pp 48-55 (1980) (in German).

25. Doughty, S., "Eigenvalue Derivatives for Damped Torsional Vibrations," J. Mech. Des., Trans. ASME, 104 (2), pp 463-465 (1982).

26. Eidnov, M.S., Nyrko, V.A., Makhaev, S.N., and Galchum, B.R., "Analytical Investigation of Resonance Conditions in Systems with a Propeller Shaft and Universal Joints," Izv. Vyssh. Uchebn. Zaved. Mashinostr., 5, pp 48-52 (1975) (in Russian).

27. Eshleman, R.L., "Torsional Vibrations of Machine Systems," Proc. Sixth Turbomachinery Symp., pp 13-22 (1977).

28. Eshleman, R.L., "Vibration Standards for Power Transmission Equipment," Power Trans. Des., 22 (4), pp 26-29 (1980).

29. Eshleman, R.L., "Measurement and Analysis of Torsional Vibrations," Proc. Mach. Vib. Sem., Vibration Institute, Cherry Hill, NJ (1980).

30. Federn, K., "Designing of Viscous Torsional Vibration Dampers for Reciprocating Engines," MTZ Motortech. Zeit., 43 (11), pp 515-518 (1982).

31. Ferrari, G., Ferrari, T., and Taverna, F., "Experimental Investigation of Some Irregularities

in the Operation of a Reciprocating Helicopter Engines," Termotecnica, 30 (6), pp 296-302 (1976).

32. Fitzgerald, D. and Williams, F.W., "Compact Distributed Inertia Solution for Free Torsional Vibration of Shaft and Rotor System," J. Sound Vib., 46 (3), pp 311-322 (1976).

33. Fujisawa, F., Sagawa, Y., and Shiga, M., "Prevention of Torsional Vibration in Fan Motor Shaft Systems with Multiblade Fans; Pt. 2: Effect of Making the Shaft System Symmetrical on Vibration Reduction," Bull. JSME, 22 (171), pp 1299-1306 (1979).

34. Groza, Y.F. and Yanushevskaya, V.F., "Complex Oscillations of the Crankshaft of a Tractor Engine," Izv. Vyash. Uchebn. Zaved Mashinostr., 2, pp 76-79 (1980) (in Russian).

35. Goodman, E.D. and Barton, T.H., "Startup Torques in Synchronous Motor Drives," IEEE Trans. Indus. Applic., IA-14 (3), pp 193-198 (1978).

36. Hafner, K.E., "Influence of the Reciprocating Masses of Crank Mechanisms on Torsional Vibrations of Crankshafts," Proc. 11th Intl. Congr. Combust. Engrg., 1, pp 69-90 (1975).

37. Herman, A.S., "Torsionally Resilient Couplings in Diesel Engine Drives," Proc. 4th Natl. Conf. Power Transm., pp 275-279 (1979).

38. Hershkowitz., H. "An Effective Discriminant for Evaluating the Quality of Viscous Dampers Applied to EMD 20-645E3 Locomotives," Proc. Mach. Vib. Monitoring Anal. Sem., Vibration Institute, pp 147-153 (1972).

39. Hershkowitz., H., "Viscous Damper Qualifications on Diesel Locomotive Engines -- A Case History," Proc. Mach. Vib. Monitoring Anal. Sem., Houston, Vibration Institute (1978).

40. Iida, H., Tamura, A., Kikuchi, K., and Agata, H., "Coupled Torsional Flexural Vibration of a Shaft in a Geared System of Rotors," Bull. JSME, 23 (186), pp 2111-2117 (1980).

41. Imachi, K., Ishii, N., and Imasu, K., "Vibration Source in Refrigerant Compressor," ASME Paper No. 81-DET-72 (1981).

42. Jayner, R.G., "The Driveline as a Source of Vibration," SAE Paper No. 780778 (1978).

43. Jeon, H. and Tsuda, K., "Theoretical Analysis of the Coupled Torsional Axial Forced Vibration of the Marine Diesel Engine Shafting," J. Fac. Engrg. Univ. Tokyo, 32B (3), pp 535-561 (1974).

44. Kempner, M.L. and Nesterova, S.V., "Determination of the Frequencies and Modes of Coupled Torsional-Axial Vibrations of Crankshafts by the Initial Parameter Method," Izv. Vyssh. Uchebn. Zaved, Mashinostr., 9, pp 22-25 (1974) (in Russian).

45. Kishor, B., "Effects of System Parameters and Gear Errors on Drive-Train Vibrations of Machine Tools," Proc. 27th Intl. Conf. Prod. Engrs., New Delhi, 1 (1977).

46. Klement, H.D., "A Program for the Calculation of Torsional Vibrations," Konstruktion, 31 (2), pp 79-83 (1979) (in German).

47. Klier, H., "Influence of the Periodic Variations of the Mass Inertia on the Torsional Vibrations of a Four-Cylinder Engine," MTZ Motor Techn. Zeit., 39 (7/8), pp 341-345 (1978) (in German).

48. Kohli, D., Sander, G.N., and Sanjay, G., "Vibration Analysis of Automotive Drive Shaft," Proc. 4th Appl. Mech. Conf., Chicago (1976).

49. Kolenda, J., "More Accurate Description of the Forced Vibration of Shafting with Allowance for Assymmetry of the Flexural Rigidity and Compliance of Foundations," Mech. Teor. Stosow., 17 (1), pp 105-136 (1979) (in Polish).

50. Kramer, E.O., "Calculation of Crank Drive Vibrations," VDI Brichte, 320 (1978) (in German).

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

gines," Konstruktion, 31 (9), pp 357-362 (1981) (in German).

52. Krumm, H., "Forced and Parametric Excitation of Torsional Crankshaft Vibrations," VDI Berichte, 320, pp 87-93 (1978) (in German).

53. Kurowski, W. and Dekert, J., "Research on the Vibration Correlation between the Gear Shaft System and the Dynamic Loads on the Gear Teeth," Arch. Budowy Maszy., 21 (3), pp 331-340 (1974) (in German).

54. Larsen, O.C., "Some Consideration of the Marine Shafting Design," Indus. Lubric. Tech., 33 (6), pp 204-209 (1981).

55. Lazurko, V.P., Solomonik, V.A., and Komoskii, V.R., "Frequency Spectrum of the Indicator Process of Internal Combustion Engines as an Object of Measurement," Energomashinostr., 3, pp 26-27 (1978) (in Russian).

56. Martinek, F., "Behaviour of Torsional Vibration Damper with Flexible Coupling during Misfiring of a Cylinder," MTZ Motortech. Zeit., 42 (5), pp 173-176 (in German).

57. Martinek, F., "Acceleration of Torsional Crankshaft Vibrations in a Diesel Engine with a Tuned Vibration Damper," MTZ Motortech. Zeit., 43 (6), pp 269-270 (1982) (in German).

58. Nagamatsu, A. and Nagarika, M., "Vibration Analysis of a Movable Part of Internal Combustion Engine; Part 1: Crankshaft," Bull. JSME, 24 (198), pp 2141-2146 (1981).

59. Nakamura, T., Hirayama, T., Omura, V., Kagawa, K., Fujita, K., and Onou, M., "Results of Vibration Test of Stern Part Structure of Twin Screw Container Ship," Tech. Rev. Mitusubishi Heavy Indus., 14 (3), pp 505-512 (1977).

60. Nazrov, P.N., "Analysis of Disturbing Forces in Internal Combustion Engines," Izv. Vyssh. Uchebon. Zaved Mashinostr., 11, pp 91-94 (1974) (in Russian).

61. Nazrov, P.N., "Algebraic Methods of Calculation of Torsional Vibrations," Izv. Vyssh. Uchebn Zaved. Mashinostr., 12, pp 37-41 (1976) (in Russian).

62. Nazrov, P.N., "Algebraic Methods of Calculation of Coupled Vibrations of Crankshafts," Izv. Vyssh. Uchebn Zaved. Mashinostr., 13, pp 123-127 (1977) (in Russian).

63. Neidherdt, R., "Results of Separating Calculations for Representing Gears as Torsional Oscillating Systems," Maschinenbautechnik, 30 (12), pp 553-559 (1981) (in German).

64. Nishikawa, T. and Ono, T., "Synthesis of a Torsional Vibration System of a Diesel Engine," ASME Paper No. 80-DGP-12 (1980).

65. Nishikawa, T. and Ono, T., "Method of Synthesis of Torsional Vibration System of Diesel Engines," 13th CIMAC, p D52 (1979).

66. Ochiai, K. and Nakano, M., "Relation between Crankshaft Torsional Vibration and Engine Noise," Diesel Engine Noise Conf., pp 185-192 (1979).

67. O'Rourke, M. and Zebrowski, T.F., "Lower Bounds for Fundamental Torsional Frequencies," J. Appl. Mech., Trans. ASME, 43 (3), pp 510-511 (1976).

68. Pandey, R.C. and Midha, A., "On Flexible Input Shaft and Flywheel Interaction in High Speed Machines," Mech. Mach. Theory, 16 (4), pp 321-327 (1979).

69. Panteliou, S. and Dimarogonas, A., "Heat Propagation due to Torsional Vibration of Shafts," J. Sound Vib., 73 (2), pp 239-249 (1980).

70. Pasricha, M.S. and Carnegie, W., "Diesel Crankshaft Failure in Marine Industry -- a Variable Inertia Effect," J. Sound Vib., 78 (3), pp 347-354 (1981).

71. Panagin, R., "Analysis of Torsional Oscillations Acting on Transmissions of Diesel-Mechanical and Diesel-Hydraulic Rail Cars," Ing. Ferrov, 32 (2), pp 84-93 (1977) (in Italian).

72. Pavlenko, A.P., "Elastic Characteristics of Traction Drives of Transport Vehicles," Russian Engrg. J., 54 (12), pp 8-12 (1974).

73. Pinnekemp, W., "Vibration Problems with Large Reduction Gears in Marine Engines," MTZ Motortech. Zeit, 41 (9), pp 355-361 (1980).

74. Pilkey, W.D. and Jay, A., "Structural Members and Mechanical Elements," in Structural Mechanics Computer Programs. Ed. by W. Pilkey et al, Univ. Press Virginia, pp 541-590 (1974).

75. Pollard, E.I., "Torsional Response of Systems," J. Engrg. Power, Trans. ASME, pp 316-324 (1967).

76. Pollard, R.I., "Transient Torsional Vibration due to Suddenly Applied Torque," J. Engrg. Indus., Trans ASME, pp 595-602 (1972).

77. Pixton, T.A.H. and Ali, R., "Analysis of Torsional Vibration of an Automotive Gear Box," Auto. Engr. (SAE), 3 (4), pp 64-66 (1978).

78. Rao, D.K., "Program TORVAR -- Computer Program for Torsional Vibration Analysis of Reciprocating Machinery Shafting. User Manual," Project Report, Dept. Mech. Engrg., I.I.T., Kharagpur.

79. Rao, D.K. and Sanyal, A., "Torsional Vibration of Ship Engine Shafts," Shock Vib. Dig., 12 (12), pp 3-8 (1980).

80. Rawtani, S., "Vibration Analysis of Branched System by Holzer Method -- a Caution," J. Inst. Engr. (India), 63 (ME2). pp 64-65 (1982).

81. Rieger, N.F., "Rotor-Bearing Systems," in Structural Mechanics Computer Programs, ed. by W. Pilkey et al., Univ. Press Virginia, pp 473-498 (1974).

82. Ripianu, A., "Contribution to the Study of Type Holset Friction Absorbers Designed to Eliminate Torsional Vibration of Crankshafts," Rev. Rom. Sci. Tech Ser. Mech. Applic., 23 (2), pp 273-286 (1978).

83. Robert, M., "Study of Some Error Sources for the Evaluation of the Top Dead Center in Piston Engines," J. Mech. Appl., 3 (1), pp 7-20 (1979) (in French).

84. Rubinstein, N., Sigillito, V.G., and Stadter, J.T., "Bounds to Frequencies of Shafts in Torsional Vibration with Restraints and Attached Masses," J. Sound Vib., 61 (1), pp 31-44.

85. Sagawa, Y., Fujisawa, F., Shiohatta, K., and Shiga, M., "Prevention of Torsional Vibration in Fan Motor Shaft Systems with Multiblade Fans; Pt 3: Method of Frequency Control Using Correction Weights," Bull. JSME, 22 (171), pp 1307-1313 (1979).

86. Sankar, S., "On the Torsional Vibration of Branched Systems Using Extended Transfer Matrix Method," J. Mech. Design, Trans. ASME, 101 (4), pp 546-553 (1979).

87. Schneider, B. and Rack, M., "System Identification of Crankshaft Torsional Vibration," VDI Berichte, 320, pp 103-1-8 (1978) (in German).

88. Schwerdlin, H. and Eshleman, R.L., "Improve Coupling Selection through Torsional Vibration Modeling," Power Transm. Des., 23 (2), pp 56-59 (1981).

89. Shapiro, W., Horner, G.C., and Pilkey, W.D., "Rotating Machinery," in Shock and Vibration Computer Programs, ed. by W. Pilkey and B. Pilkey, Shock Vib. Info. Ctr., pp 453-496 (1975).

90. Shryaev, M.P., Misllev, M.A., and Kudozhilov, V.A., "Forced Vibration in the Automotive Speed Control Systems of a Diesel Installation with an Elastic Shaft Line," Energimashinostr., 2, pp 34-35 (1977) (in Russian).

92. Tsai, N.T. and Wang, S.M., "Delay Bond Graph Models for Geared Torsional Systems," J. Appl. Mech., Trans. ASME, pp 366-370 (1974).

93. Tsai, N.T., "Torsional Systems," in Shock and Vibration Computer Programs, ed. by W. Pilkey and B. Pilkey, Shock Vib. Info. Ctr., pp 63-73 (1975).

94. Tonndorf, J., "Torsional Excitation of Drive Units during Intermittent Service of a Combustion Engine," VDI Berichte, 381, pp 11-21 (1980).

95. Troeder, Ch., Peeken, H., and Diekhaus, "Calculation of the Stationary Behaviour of a Drive System with Reciprocating Engines," VDI Berichte, 381, pp 23-35 (1980) (in German).

96. Uru ov, I.D. and Kamasha, M.M., "Problem of Strength in the Presence of Torsional Vibrations in Turbogenerator Shaft Trains," Power Engrg., 18 (1), pp 321-29 (1980).

97. Wakabayashi, K., Nikura, T., and Yamamoto, A., "A Simulation Method for the Vibration Waveform of a Crankshaft with a Rubber Damper," Noise Vib. Engines Transm., Conf. Proc., IMechE, pp 21-31 (1979).

98. Wang, C., "Calculating the Natural Frequencies with Extended Tuplin's Method," J. Mech. Des., Trans. ASME, 103 (2), pp 379-386 (1981).

99. Wang, S.M. and Morse, I.E., Jr., "Torsional Response of a Gear Train Systems," J. Engrg. Indus., Trans. ASME, 94, pp 583-594 (1972).

100. Williams, L.E., "Engine Crankshaft Torsional Vibration Control," Natl. Conf. Power Trans., Proc., Sixth Ann. Mtg., pp 143-151 (1979).

101. Wright, M.D., "Torsionally Soft Flexible Couplings," Natl. Conf. Power Trans. Proc., Sixth Annl. Mtg., pp 275-279 (1979).

102. Wu, J.S. and Chen, W.H., "Computer Method for Forced Torsional Vibration of Propulsive Shafting System of Marine Engines with or without Damping," J. Ship Res., 26 (3), pp 176-189 (1982).

103. Zubritsky, P.D., "The Effects of Torsional Vibration," Diesel Prog., 47 (7), pp 31-34 (1981).

BOOK REVIEWS

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 electroacoustics 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 mathematical background who wants to gain insight into electromechanical analogies and access to the advanced 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 acoustical). 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 theorems of the analytical mechanics used in the variational treatment of nonlinear electric circuits. Lagrange'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 suggested 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 (topological) description of their time evolution are treated in detail.

Chapter 4 includes a Lagrangean description of electrical networks with special reference to nonlinear time-invariant circuits. Energy functions of electrical networks are presented, stationarity theorems are proved for resistive networks, and the duality of the variational description of RLC networks is demonstrated. An important result states that, in a variational description using nonhomogeneous bases (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 equations are obtained in an original way. A general form of these equations is obtained that applies to networks 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 networks for mechanical and mechano-acoustical systems are presented.

Chapter 7 considers electromechanical transducers. A general treatment is given to linear n-port transducers, 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 quadrilaterla, and six node triangular elements. Applications to plates, beams, shells, and other structural systems are demonstrated. This chapter does not include any computer algorithms for numerical solutions.

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.

The book is purely theoretical and can be recommended for researchers in the area of theoretical mechanics.

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RECENT ADVANCES IN PIPE SUPPORT DESIGN

E. Van Stijgeren, editor
ASME Publ. PVP-68, New York, NY
1982, 115 pages

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 DYNAPO-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 currenly 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 axi-symmetric 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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Deparment of Mechanical Engineering
Texas Tech University
Lubbock, Texas 79409

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 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.

MAY

ELECTROEXPLOSIVES DEVICES

Dates: May 15-17, 1984
October 16-19, 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.

Contact: E&P Affairs, The Franklin Research Center, 20th and Race Streets, Philadelphia, PA 19103 - (215) 448-1000.

MACHINERY VIBRATION ANALYSIS

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 illustratre 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, Jessee Philips Center 36, 300 College Park Avenue, Dayton, OH 45469 - (513) 229-2644.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

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

ABSTRACT CONTENTS

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 coefficients

Pump seals, unshrouded turbines, shrouded turbines with tip seals, gas labyrinth seals, gas seals with constant-clearance and convergent-tapes 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 Arbitarily 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

Dept. of Mech. Engrg., Stevens Inst. of Tech., Hoboken, NJ 07030, J. Sound Vib., 90 (4), pp 479-490 (Oct 22, 1983) 14 figs, 25 refs

Key Words: Mufflers, Exhaust systems, Internal combustion engines, Noise measurement, Transfer functions

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. Tlusty and F. Ismail

McMaster Univ., Hamilton, OH, J. Vib. Acoust. Stress Rel. Des., Trans. ASME, 105 (1), pp 24-32 (Jan 1983) 16 figs, 7 refs

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-workpice 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

BRIDGES

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

Bull Ferranti and Collier, Consulting Engineers, Sydney, Australia, Earthquake Engrg. Struc. Dynam., 11 (5), pp 649-665 (Sept/Oct 1983) 12 figs, 20 refs

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

Polytechnic Inst. of New York, Brooklyn, NY 11201, Engrg. Struc., 5 (4), pp 282-288 (Oct 1983) 10 figs, 12 refs

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

Ctr. for Building Tech., Natl. Engrg. Lab., Natl. Bureau of Standards, Washington, DC 20234, Engrg. Struc., 5 (4), pp 273-281 (Oct 1983) 9 figs, 3 tables, 189 refs

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

Louisiana Tech. Univ., Ruston, LA, ASCE J. Engrg. Mech., 109 (5), pp 1189-1202 (Oct 1983) 9 figs, 14 refs

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

J.G. Bouwkamp, Inc., Berkeley, CA, Earthquake Engrg. Struc. Dynam., 11 (5), pp 623-647 (Sept/Oct 1983) 7 figs, 9 tables, 15 refs

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 modal 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. Struc. 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

Bldg. Res. Establishment, Garston, Watford WD2 7JR, UK, Engrg. Struc., 5 (4), pp 289-298 (Oct 1983) 19 figs, 2 tables, 2 refs

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 Analyses

A. Hejazi

Ph.D. Thesis, Louisiana Tech. Univ., 250 pp (1983) DA8312261

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.

HARBORS AND DAMS

84-265

Decoupling Approximation to the Evaluation of Earthquake-Induced Plastic Slip in Earth Dams

Jeen-Shang Lin and R.V. Whitman

Dept. of Construction Engrg. and Tech., Taiwan Inst. Tech., Taipei, Taiwan, Rep. of China, Earthquake Engrg. Struc. Dynam., 11 (5), pp 667-678 (Sept/Oct 1983) 16 figs, 13 refs

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

Structural Dynamics Lab., Fullerton, CA, ASME Paper No. 83-PVP-73

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

A case study is presented where the combined modal 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 past 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

Simon Engrg. Labs., Univ. of Manchester, Manchester, UK, Intl. J. Mech. Sci., 25 (9/10), pp 615-621 (1983) 11 figs, 9 refs

Key Words: Off-shore structures, Energy absorption, Ships, Collision research (ships), Impact shock

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

London Centre for Marine Technology, Dept. of Mech. Engrg., University College London, London WC1E 7JE, UK, Engrg. Struc., 5 (4), pp 299-308 (Oct 1983) 9 figs, 1 table, 11 refs

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

Res. and Development Div., McDermott, Inc., New Orleans, LA 70160, J. Energy Resources Tech., Trans. ASME, 105 (3), pp 296-299 (Sept 1983) 9 figs, 7 refs

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.

VEHICLE SYSTEMS

GROUND VEHICLES
(Also see Nos. 299, 300, 301)

84-274
Protection of Car Occupants in Frontal Impacts with Heavy Lorries: Frontal Structures
W. Johnson and A.C. Walton
Cambridge Univ. Engrg. Dept., Trumpington St., Cambridge CB2 1PZ, UK,
Intl. J. Impact Engrg., 1 (2), pp 111-123 (1983) 3 figs, 1 table, 20 refs

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 greater 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.

SHIPS
(Also see Nos. 268, 296)

84-275
Mechanics of Minor Ship Collisions
K.A. Reckling
Technical University of Berlin, Fachbereich 9, Physikalische Ingenieurwissenschaft, Institute f. Mechanik, 1000 Berlin 12, W. Germany,
Intl. J. Impact Engrg., 1 (3), pp 281-299 (1983) 12 figs, 28 refs

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.

84-276
A Proposed Method of Predicting Ship Collision Damage
K. Hagiwara, H. Takanabe, and H. Kawano
Nagasaki Technical Inst., Mitsubishi Heavy Industries, Ltd., Nagasaki, Japan,
Intl. J. Impact Engrg., 1 (3), pp 257-279 (1983) 20 figs, 3 tables, 24 refs

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.

AIRCRAFT
(Also see No. 295)

84-277
On the Energy Characteristics of the Aerodynamic Matrix and the Relationship to Possible Flutter

J.G. Jones
Royal Aircraft Establishment, Farnborough, Hampshire, UK, Aeronaut. Quart., 34 (3), pp 212-225 (Aug 1983) 19 refs

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

Aeroelastic Response of an Aircraft Wing to Random Loads (Response Aeroelastique d'une Alle D'Aeronef a des Charges Aleatoires)

B.H.K. Lee
High Speed Aerodynamics Lab., National Aeronautical Establishment, Ottawa, Ontario, Canada, Rept. No. NAE-LR-613, NRC-21230 (Apr 1983)
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. Doggestt, Jr.
NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 20 (10), pp 835-840 (Oct 1983) 12 figs, 1 table, 8 refs

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
NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 20 (10), pp 841-847 (Oct 1983) 7 figs, 19 refs

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

Auburn Univ., Auburn, AL, J. Aircraft, 20 (9), pp 753-761 (Sept 1983) 9 figs, 1 table, 27 refs

Key Words: Aircraft, Flutter, Vibration analysis, Time domain method

The objective of this investigation was to develop and evaluate a nonlinear technique for the stability assessment of high-performance aircraft in the time domain. The technique employed is compatible with popular digital flutter and/or vibration mathematical models and is adaptable to various aircraft control systems and/or modal information.

84-283

Correction of Fan Noise for Effects of Forward Flight

R.K. Amiet

United Technologies Res. Ctr., East Hartford, CT 06108, J. Sound Vib., 89 (2), pp 243-259 (July 22, 1983) 9 figs, 18 refs

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. Revell

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

FluiDyne Engrg. Corp., Minneapolis, MN, J. Aircraft, 20 (10), pp 866-871 (Oct 1983) 16 figs, 3 refs

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

Royal Aircraft Establishment, Farnborough, England, 20 pp (Apr 1983). From 'Behaviour of Short Cracks in Airframe Components, Conf. Proc. of the Mtg. of the AGARD Structures and Materials Panel (55th), held at Toronto, Canada on Sept 19-24, 1982,' AD-A131 159, pp 3-1 - 4-13

Key Words: Aircraft, Crack propagation

The application of small crack propagation data to the design of aircraft structures is examined.

84-288

Safety Report: General Aviation Crashworthiness Project. Phase 1

Bureau of Technology, Natl. Transportation Safety Board, Washington, DC, Rept. No. NTSB/SR-83/01, 94 po (June 27, 1983)
Paper copy also available on subscription, North American Continent price $90.00/per year; all others write for quote
PB83-917004

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

NASA Ames Res. Ctr., Moffett Field, CA, U.S. Patent Appl. No. 6-489 675, 21 pp (Apr 28, 1983)

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

GEC Mech. Engrg. Lab., Whetstone, Leicester, UK, Aeronaut. Quart., 34 (3), pp 226-242 (Aug 1983) 6 figs, 36 refs

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 axi-symmetry. 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

Univ. of California, Los Angeles, CA 90024, J. Appl. Mech., Trans. ASME, 50 (3), pp 669-673 (Sept 1983) 3 figs, 1 table, 11 refs

Key Words: Antennas, Spacecraft antennas, Vibration damping

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.

BIOLOGICAL SYSTEMS

HUMAN

(Also see No. 426)

84-293

Truck Cab Vibrations and Highway Safety

T.D. Gillespie, L. Segel, R.D. Ervin, L.W. Schneider, and K.L. Campbell

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-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.

84-294

Truck Cab Vibrations and Highway Safety

T.D. Gillespie, L. Segel, R.D. Ervin, L.W. Schneider, and K.L. Campbell

Highway Safety Res. Inst., Michigan Univ., Ann Arbor, MI, Rept. No. UM-HSRI-82-9/2, FHWA/RD-82/082, 40 pp (Mar 1982)
PB83-229518

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.

84-295

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.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

(Also see Nos. 268, 275, 410)

84-296

Strip Model Simulation for Low Energy Impacts on Flat-Plated Structures

E. Samuelides and P.A. Frieze

Univ. of Glasgow, Glasgow G12 8QQ, Scotland, Intl. J. Mech. Sci., 25 (9/10), pp 669-685 (1983) 13 figs, 1 table, 21 refs

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

A dynamic analysis method for predicting the elasto-plastic large-deflection small strain response of a plate-strip subjected 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)
DE83[illegible]5

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. Kaneda and K. Seto
Daido Inst. of Tech., Daido-chyo 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
Ford Motor Co., Dearborn, MI 48121,
Intl. J. Impact Engrg., 1 (3), pp 199-225 (1983) 29 figs, 11 refs

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
Toyota Central Res. and Dev. Labs., Inc., Nagakute-cho, Aichi-ken, Japan,
Intl. J. Impact Engrg., 1 (3), pp 227-247 (1983) 16 figs, 10 refs

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
Dept. of Engrg., Univ. of Cambridge, Trumpington St., Cambridge CB2 1PZ, UK,
Intl. J. Impact Engrg., 1 (3), pp 301-308 (1983) 4 figs, 2 tables, 7 refs

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
Polish Academy of Sciences, Inst. for Fundamental Technological Res., Swietokrzyska 21, 00-049, Warsaw, Poland, Intl. J. Impact Engrg., 1 (3), pp 309-317 (1983) 7 figs, 13 refs

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
Univ. of Manchester, Inst. of Science and Tech., Manchester, UK, Intl. J. Mech. Sci., 25 (9/10), pp 747-773 (1983) 27 figs, 1 table, 18 refs

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
Dept. of Engrg., Univ. of Cambridge, Trumpington St., Cambridge CB2 1PZ, UK, Intl. J. Mech. Sci., 25 (9/10), pp 637-647 (1983) 7 figs, 2 tables, 9 refs

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
Univ. of Aberdeen, Marischal College, Aberdeen, AB9 1AS, Scotland, Intl. J. Mech. Sci., 25 (9/10), pp 649-667 (1983) 14 figs, 1 table, 16 refs

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
K.R.F. Andrews, G.L. England, and E. Ghani
King's College London, Strand, London WC2R 2LS, UK, Intl. J. Mech. Sci., 25 (9/10), pp 687-696 (1983) 6 figs, 1 table, 5 refs

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
Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Intl. J. Impact Engrg., 1 (2), pp 157-174 (1983) 16 figs, 10 refs

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.

84-308

Examination of Mechanical Snubbers from TMI-2. Final Report

F.L. Wadsworth, R.S. Walker, and E.P. Kurdziel
International Energy Associates Ltd., Washington, DC, Rept. No. EPRI-NP-2966, 116 pp (Mar 1983)
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 Meglkone 786027S5 Mounting

B. Vandergraaf
Technisch Physische Dienst TNO-TH, Delft, The Netherlands, Rept. No. TDCK-77327, 21 pp (Sept 2, 1982)
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: 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.

84-311

Influence of Base Isolation on the Seismic Response of Light Secondary Equipment. Final Report (PWR; BWR)

J.M. Kelly
Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Rept. No. EPRI-NP-2919, 64 pp (Mar 1983)
DE83902272

Key Words: Base isolation, Seismic response, Pumps, Valves, Control systems, Piping systems, Power plants (facilities)

The seismic response of light secondary systems such as pumps, valves, control devices, and piping systems in a power plant is produced by the response of the primary structural system to the seismic ground motion with the result that very high accelerations can be induced in such secondary systems. This response can be reduced through the use of base isolation. In a series of experiments designed to evaluate the effect on equipment response of three forms of base isolation system, a large-scale structural model was subjected to dynamic testing on a shaking table.

84-312

Fatigue Problems in Structural Control

Wang Dian-Fu and J.T.P. Yao
Purdue Univ., Lafayette, IN, Rept. No. CE-STR-83-1, NSF/CEE-83021, 28 pp (1983)
PB83-211763

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
Applied Res. Lab., Pennsylvania State Univ., State College, PA, Ph.D. Thesis, Rept. No. ARL/PSU/TM-83-27, 107 pp (Jan 25, 1983)
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
Mission Drilling Products Div., TRW, Inc., Houston, TX 77040, J. Energy Resources Tech., Trans. ASME, 105 (3), pp 394-395 (Sept 1983) 5 figs, 5 refs

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

George C. Marshall Space Flight Ctr., NASA, Huntsville, AL, U.S. Patent Appl. No. 6-489 902, 11 pp (Apr 28, 1983)

Key Words: Seals, Turbomachinery, Dampers

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

Dept. of Theoretical and Applied Mechanics, Natl. Tech. Univ. of Athens, 5 Heroes of Polytechnion Ave., Zographou, Athens 624, Greece, J. Sound Vib., 89 (2), pp 195-211 (July 22, 1983) 14 refs

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

Dept. of Electrical Engrg., Univ. of Wyoming, Laramie, WY 82071, J. Sound Vib., 90 (4), pp 471-478 (Oct 22, 1983) 5 figs, 11 refs

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

Brown, Boveri & Co., Ltd., Res. Ctr., CH-5405 Baden-Dattwil, Switzerland, J. Mech. Phys. Solids, 31 (4), pp 329-345 (1983) 13 figs, 19 refs

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
Natl. Tech. Univ., Athens, Greece, Acta Mech., 48 (1-2), pp 209-217 (1983) 6 figs, 17 refs

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
NASA Langley Res. Ctr., Hampton, VA, Rept. No. L-15580, NASA-TP-2160, 30 pp (June 1983) N83-28491

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 lenghthening 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.

CYLINDERS

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
Dept. of Mathematics and Statistics, Univ. of Calgary, Alberta, Canada, Intl. J. Engrg. Sci., 21 (11), pp 1397-1408 (1983) 8 figs, 10 refs

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
Dept. of Mech. Engrg., University of Lulea, S-951 87 Lulea, Sweden, J. Sound Vib., 89 (2), pp 261-272 (July 22, 1983) 7 figs, 13 refs

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
Univ. of Rochester, Rochester, NY 14627, J. Appl. Mech., Trans. ASME, 50 (3), pp 525-530 (Sept 1983) 6 figs, 8 refs

Key Words: Disks, Rotating structures, Periodic response

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.

PANELS

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.

PLATES

(Also see No. 276)

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, Torsional 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. Umezawa, 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 mode 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

Structures Dept., The Aeronautical Res. Inst. of Sweden, S-161 11, Bromma, Sweden, J. Sound Vib., 90 (4), pp 559-584 (Oct 22, 1983) 10 figs, 1 table, 18 refs

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

Dept. of Mech. Engrg., Queen Mary College, London E1 4NS, UK, J. Sound Vib., 90 (3), pp 299-308 (Oct 8, 1983) 6 figs, 17 refs

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

Hokkaido Univ., Kita-13, Nishi-8, Kita-ku, Sapporo, 060 Japan, J. Appl. Mech., Trans. ASME, 50 (3), pp 544-548 (Sept 1983) 5 figs, 21 refs

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

Dept. of Mechanics, Peking Univ., Beijing, China, Intl. J. Impact Engrg., 1 (3), pp 249-256 (1983) 4 figs, 5 refs

Key Words: Shells, Cylindrical shells, Dynamic buckling

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

84-338

Nonlinear Shell Dynamics - Intrinsic and Semi-Intrinsic Approaches

A. Libai

Dept. of Aeronautical Engrg., Technion - Israel Inst. of Tech., Haifa 32000, Israel, J. Appl. Mech., Trans. ASME, 50 (3), pp 531-535 (Sept 1983) 15 refs

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

Florida Atlantic Univ., Boca Raton, FL 33431, J. Appl. Mech., Trans. ASME, 50 (3), pp 517-524 (Sept 1983) 8 figs, 2 tables, 4 refs

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.

PIPES AND TUBES

(Also see Nos. 269, 297, 378, 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

Div. of Structural Mechanics, The Norwegian Inst. of Tech., 7034 Trondheim - NTH, Norway, J. Energy Resources Tech., Trans. ASME, 104 (4), pp 325-329 (Dec 1982) 8 figs, 11 refs

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 movements 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.

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
EG&G Idaho, Inc., Idaho Falls, ID, ASME Paper No. 83-PVP-67

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
Brookhaven Natl. Lab., Upton, NY, Rept. No. BNL-NUREG-32862, CONF-830607-11, 11 pp (1983) (ASME Pressure Vessel and Piping Conf., Portland, OR, June 19, 1983)
DE83012215

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.

DUCTS
(Also see No. 353)

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.

ELECTRIC COMPONENTS

MOTORS

84-347
Modeling and Analysis of Induction Machines Containing Space Harmonics. Part I: Modeling and Transformation
H.R. Fudeh and 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

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 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.

84-348

Modeling and Analysis of Induction Machines Containing Space Harmonics. Part II: Analysis of Asynchronous and Synchronous Actions

H.R. Fudeh and 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. Fudeh and 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.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

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

84-350

Sound Radiation from Periodically Connected Double-Plate Structures

D. Takahashi
Dept. of Architectural Engrg., Kyoto Univ., Yoshida Honmachi Sakyo-ku, Kyoto, 606 Japan, J. Sound Vib., 90 (4), pp 541-557 (Oct 22, 1983) 9 figs, 8 refs

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
Dept. of Mech. Engrg., Stevens Inst. of Tech., Hoboken, NJ 07030, J. Sound Vib., 90 (4), pp 491-508 (Oct 22, 1983) 21 figs, 34 refs

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 level, 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
Cambridge Univ. Engrg. Dept., Cambridge CB2 1PZ, UK, J. Sound Vib., 90 (3), pp 309-324 (Oct 8, 1983) 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.

SHOCK EXCITATION

(Also see Nos. 346, 413, 425)

84-355

Dynamic Pulse Buckling - Theory and Experiment

H.E. Lindberg and A.L. Florence
SRI International, Menlo Park, CA, Rept. No. DNA-6503H, 400 pp (Feb 1983)
AD-A130 910

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
Univ. of Alberta, Edmonton, Alberta, Canada, J. Appl. Mech., Trans. ASME, 50 (3), pp 637-640 (Sept 1983) 3 figs, 3 refs

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

Univ. of Cape Town, Faculty of Engrg., Rondebosch 7700, Rep. of South Africa, Intl. J. Impact Engrg., 1 (2), pp 125-141 (1983) 9 figs, 11 refs

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

Univ. of Cape Town, Faculty of Engrg., Rondebosch 7700, Rep. of South Africa, Intl. J. Impact Engrg., 1 (2), pp 143-156 (1983) 6 figs, 6 refs

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

Dept. of Engrg., Univ. of Aberdeen, Aberdeen AB9 1AS, UK, Intl. J. Impact Engrg., 1 (2), pp 175-191 (1983) 9 figs, 1 table, 8 refs

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

Scientific Service, Inc., Redwood City, CA, Rept. No. SSI-8144-12, 276 pp (May 1983)
AD-A129 880

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

Ballistic Res. Lab., Army Armament Res. and Dev. Command, Aberdeen Proving Ground, MD, Rept. No. ARBRL-MR-03279, SBI-AD-F300 268, 70 pp (June 1983)
AD-A130 028

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

Dept. of Civil Engrg., Univ. of Cape Town, Cape Town, Rep. of South Africa, Engrg. Struc., 5 (4), pp 247-254 (Oct 1983) 10 figs, 6 refs

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

Westinghouse Electric Co., Pittsburgh, PA, ASME Paper No. 83-PVP-69

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

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 90 (4), pp 457-470 (Oct 22, 1983) 12 figs, 7 refs

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.

84-368
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.

84-369
Mechanical Random Vibrations (Mechanische Zufallschwingungen)
W. Schielen
Institut B für Mechanik, Univ. Stuttgart, Pfaffenwaldring 9, D-7000 Stuttgart 80, W. Germany, Z. angew. Math. u. Mech., 63 (4), pp T14-T20 (1983) 1 fig, 46 refs
(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 nonwhite, nonstationary, forced excitation.

84-370
Power System Harmonics: An Overview
IEEE Working Group on Power System Harmonics, Power Apparatus Syst., IEEE Trans., PAS-102 (8), pp 2455-2460 (Aug 1983) 7 figs, 16 refs

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 considerable activity to identify harmonic effects, define acceptable measurement procedures, and set a proper basis for control procedures and standards. This paper is a treatment of the concerns being addressed, especially as they relate to new technologies of energy control, energy conservation, and modern power conversion.

84-371
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 Struc., 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 PROPERTIES

DAMPING

(Also see Nos. 292, 317)

84-372
A Damping Technology Solution to an Automotive Vibration Problem
M.L. Drake
Univ. of Dayton Res. Inst., Dayton, OH, S/V, Sound Vib., 19 (9), pp 20-24 (Sept 1983) 11 figs, 13 refs

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.

84-373

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.

84-374

Effect of Soil-Structure Interaction on Damping of Structures

M. Novak and L. El Hifnawy

Univ. of Western Ontario, London, Ontario, Canada, Earthquake Engrg. Struc. Dynam., 11 (5), pp 595-621 (Sept/Oct 1983) 22 figs, 37 refs

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

(Also see No. 312)

84-375

Growth of Short Fatigue Cracks in an Alloy Steel

N.E. Dowling

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, ASME Paper No. 83-PVP-94

Key Words: Fatigue (materials), Crack propagation, Steel

Fatigue crack growth rate data are presented for an AISI 4340 steel under both completely reversed and zero to maximum loading. Growth rates are compared for short surface cracks in unnotched axially loaded specimens and long cracks in more conventional fracture mechanics specimens.

84-376

Fatigue Damage Mechanisms and Short Crack Growth

I. LeMay

Dept. of Mech. Engrg., Saskatchewan Univ., Saskatoon, Canada, 11 pp (Apr 1983) (from 'Behaviour of Short Cracks in Airframe Components, Conf. Proc., Mtg. AGARD Structures Materials Panel (55th), Toronto, Canada, Sept 19-24, 1982,' AD-A131 159, pp 2-1 - 211)

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.

84-377

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.

84-378

A Linear Elastic Fracture Mechanics Evaluation of High-Cycle Fatigue in a Variable Load Environment

J.N. Reed
Stone & Webster Engrg. Corp., Boston, MA, ASME Paper No. 83-PVP-95

Key Words: Fatigue life, Piping systems

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.

84-379

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

D.M. Holford
Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TR-82125, DRIC-BR-87777, 23 pp (Dec 1982)
AD-A130 112

Key Words: Fatigue tests, Aircraft

The concept of displaying the accumulation of fatigue damage against time into flight is described. Two distinct modes of presentation are described. Examples drawn from operational aircraft loads data are used to demonstrate the usefulness of the display.

84-380

Fatigue Tests of 8-yr. Weathered A588 Steel Weldment

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

Key Words: Welded joints, Steel, Fatigue tests

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.

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.
NASA Langley Res. Ctr., Hampton, VA, 26 pp (Apr 1983) (From "Behaviour of Short Cracks in Airframe Components," Conf. Proc., Mtg. AGARD Structures and Materials Panel (55th), Toronto, Canada, Sept 19-24, 1982, AD-A131 159, pp 6-1 - 6-26)
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.

84-383

Dynamic Kinking of a Crack in Plane Strain

P. Burgers
Dept. of Mech. Engrg. and Appl. Mechanics, 111 Towne Bldg./D3, Univ. of Pennsylvania, Philadelphia,

PA 19104, Intl. J. Solids Struc., 19 (10), pp 735-752 (1983) 5 figs, 20 refs

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

Chevron Oil Field Res. Co., P.O. Box 446, LaHabra, CA 90631, J. Mech. Phys. Solids, 31 (4), pp 287-305 (1983) 9 figs, 19 refs

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

Gibbs and Hill, Inc., New York, NY 10001, J. Appl. Mech., Trans. ASME, 50 (3), pp 630-636 (Sept 1983) 3 figs, 3 tables, 13 refs

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. Bufler and H. Kennerknecht

Inst. f. Mechanik, Universität Stuttgart, D-7000 Stuttgart, Fed. Rep. of Germany, Acta Mech., 48 (1-2), pp 1-30 (1983) 10 figs, 27 refs

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

Dept. of Applied Mathematics, Calcutta Univ., 92, Acharyya Prafulla Chandra Rd., Calcutta-700 009, India, J. Appl. Mech., Trans. ASME, 50 (3), pp 506-510 (Sept 1983) 1 fig, 8 refs

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

Systems Applications, Sperry Res. Ctr., Sudbury, MA 01776, Wave Motion, 5 (4), pp 399-411 (Aug 1983) 14 figs, 7 refs

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.

84-389

Application of the Theory of Generalized Rays to Diffractions of Transient Waves by a Cylinder

Y.-H. Pao, G.C.C. Ku, and F. Ziegler
Dept. of Theoretical and Applied Mechanics, Cornell Univ., Ithaca, NY 14853, Wave Motion, 5 (4), pp 385-398 (Aug 1983) 7 figs, 12 refs

Key Words: Wave diffraction

The theory of generalized rays which was developed to analyze transient waves in layered media where incident circular or spherical waves are reflected and refracted by plane boundaries has been extended to analyze the diffraction of transient waves by a spherical or a cylindrical boundary. In this paper the generalized ray integrals, which represent the Fourier transformed diffracted waves, are formulated for the diffraction of an incident spherical pulse by a circular cylinder.

84-390

The Singularity Expansion Method as Applied to the Elastodynamic Scattering Problem

G. Bollig and K.J. Langenberg
Fraunhofer-Institut f. zerstörungsfreie Prüfverfahren, Universität des Saarlandes, D-6600 Saarbrücken, Fed. Rep. Germany, Wave Motion, 5 (4), pp 331-354 (Aug 1983) 19 figs, 51 refs

Key Words: Wave scattering, Acoustic waves, Elastodynamic response, Nondestructive tests, Singularity expansion method

The singularity expansion method, originally developed for broadband electromagnetic scattering by arbitrarily shaped targets, proves essentially useful in predicting and understanding impulsive scattering of ultrasound. It also seems possible to parametrize experimentally obtained time records in a sense which is physically intuitive. Several theoretically derived singularity patterns are presented for various body shapes and material compositions.

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

H. Überall, P.J. Moser, J.D. Murphy, A. Nagl, G. Igiri, J.V. Subrahmanyam, G.C. Gaunaurd, D. Brill, P.P. Delsanto, J.D. Alemar, and E. Rosario
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

Materials Characterization, Rockwell Intl. Service Ctr., Thousand Oaks, CA 91360, Wave Motion, 5 (4), pp 299-306 (Aug 1983) 11 figs, 13 refs

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
Holon Technological Inst., P.O. Box 305, Holon 58102, Israel, Intl. J. Solids Struc., 19 (10), pp 785-791 (1983) 4 figs, 21 refs

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.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see Nos. 405, 424)

84-395

On Three Modal Synthesis Variants

A. Curnier
Laboratoire de Mecanique Appliquee, Ecole Polytechnique Féderale 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
Exxon Production Res. Co., Houston, TX, Earthquake Engrg. Struc. Dynam., 11 (5), pp 679-688 (Sept/Oct 1983) 13 figs, 9 refs

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

Analysis of Vibration by Substructure Synthesis Method. Part 1. Basic Approach

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 summarized. 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 SYSTEMS CENTRE-557, 33 pp (1982)

PB83-232488

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 control systems are discussed. A multivariable frequency-response design method for passive adaptive model following control systems is proposed and applied to a 2-input, 2-output 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 spectrometry

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 Dependent 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 techniques, Fiber composites

This investigation concerns the frequency related behavior of delaminations in fiber reinforced composites during vibrothermography, the use of active thermography with a mechanical 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 resonance 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.

84-403
Model Mount System for Testing Flutter
M.G. Farmer
NASA Langley Res. Ctr., Hampton, VA, U.S. Patent Appl. No. 6-481 106, 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 airfoil or aircraft.

DIAGNOSTICS

84-404
The Matrix of Power Spectra Levels of Turned Surfaces Roughness
A.L. Konczakowski
Instytut Technologii Budowy Maszyn, Politechnika Gdanska, ul. Majakowskiego 11/1w, 80-952 Gdansk, Poland, Intl. J. Mach. Tool Des. Res., 23 (2/3), pp 161-167 (1983) 5 figs, 8 refs

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 spectras obtained for combinations of cutting conditions in a turning process. The matrix of power spectra levels as the complex discriminant is presented.

84-405
Prevention of Vibration Damage by Maintenance (Instandhaltung Schwingschäden vermeiden)
H.P. Fuchs
Industrie Anzeiger, 105 (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. Measurement locations are selected in the expected direction of highest vibrations. In some cases, such as turbines, vibration measurement in all three directions may be required. The author discusses in some detail three vibration measurement instruments -- the Vibrocord, the 32V system, and the Vibrex -- which are built to satisfy the requirements of the VDI 2056 Directive, "Evaluation of Mechanical Vibration of Machinery." The article closes with a description of machine diagnostics by means of a frequency method.

MONITORING
(See No. 404)

ANALYSIS AND DESIGN

ANALYTICAL METHODS

84-406
A Conservation Theorem for Simple Nonholonomic Systems
T.R. Kane and A.K. Banerjee
Stanford Univ., Stanford, CA 94305, J. Appl. Mech., Trans. ASME, 50 (3), pp 647-651 (Sept 1983) 1 fig, 5 refs

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.

84-407
Complementary Variational Principles and Their Application to Rheo-Linear and Rheo-Non-Linear Vibrations
J.G. Papastavridis
School of Engrg. Science and Mechanics, Georgia Inst. of Tech., Atlanta, GA 30332, J. Sound Vib., 89 (2), pp 233-241 (July 22, 1983) 12 refs

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 1: Normalization Formulae

L. Hsu

Dept. of Mech. Engrg., COPPE/Universidade Federal do Rio de Janeiro, C.P. 1191, 20000 Rio de Janeiro, FJ, Brazil, J. Sound Vib., 89 (2), pp 169-181 (July 22, 1983) 12 refs

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

Dept. of Mech. Engrg., COPPE/Universidade Federal do Rio de Janeiro, C.P. 1191, 20000 Rio de Janeiro, RJ, Brazil, J. Sound Vib., 89 (2), pp 183-194 (July 22, 1983) 1 table, 10 refs

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-551, 37 pp (May 1982)

PB83-232793

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

European Space Agency, Paris, France, Rept. No. ESA-TT-765, ONERA-NT-1981-4, 265 pp (Feb 1983) (Engl. Transl. of "Les Principes Variationnels Mixtes en Mecan. De Vibration" Onera, Paris Rept. Onera-NT-1981-4, 1981)

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, 105 (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

Constitutive 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 elasto/viscoplasticity 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

Norwegian Hydrodynamic Labs., Trondheim, Norway, J. Energy Resources Tech., Trans. ASME, 105 (3), pp 310-317 (Sept 1983) 4 figs, 17 refs

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 Engrg., 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 Messtechnik, 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

European Space Agency, Paris, France, Rept. No. ESA-TT-780, ONERA-NT-1982-3, 89 pp (Mar 1983) (Engl. trans. of "Une Method d'Identification Dyn. de Struct. Complexes," Onera, Paris Rept. ONERA-NT-1982-3, 1982)
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 vibrations, 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.

84-418

Real-time Parameter Identification in a Class of Distributed Systems Using Lyapunov Design Method Part I. Theory

H. Sehitoglu
Louisiana State Univ., Baton Rouge, LA 70803,
Intl. J. Control, 38 (4), pp 747-756 (Oct 1983) 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.

84-419

Real-time Parameter Identification in a Class of Distributed Systems Using Lyapunov Design Method Part II. Applications

H. Sehitoglu
Louisiana State Univ., Baton Rouge, LA 70803,
Intl. J. Control, 38 (4), pp 757-767 (Oct 1983) 10 figs, 3 refs

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

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)

84-420

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.

84-421

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.

84-422

A 4-Cylinder Stirling Engine Computer Program with Dynamic Energy Equations

C.J. Daniele and C.F. Lorenzo

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1348, NASA-TM-83053, 65 pp (May 1983)

N83-26017

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

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.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

84-423

Annual Meeting of the East German Society of Applied Mathematics and Mechanics (Ges. angew. Mathematic u. Mechanik), Proceedings

Z. angew. Math. u. Mech., 63 (4) (1983)

Key Words: Proceedings, Random vibration

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.

CRITERIA, STANDARDS, AND SPECIFICATIONS

84-424

American National Standard Guidelines for the Preparation of Standard Procedures to Determine the Noise Emission from Sources

Amer. Natl. Standard, ANSI S12.1-1983, Avail: Acoust. Soc. Amer., Back Nos. Dept., Dept. STD, Amer. Inst. Phys., 335 E. 45th St., New York, NY 10017, Price: $35.00

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

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.

84-425

Estimating Airblast Characteristics for Single Point Explosions in Air, with a Guide to Evolution of Atmospheric Propagation and Effects

Amer. Natl. Standard, ANSI S2.20-1983, Avail: Acoust. Soc. Amer., Back Nos. Dept., Dept. STD, Amer. Inst. Phys., 335 E. 45th St., New York, NY 10017, Price: $39.00

Key Words: Standards and codes, Air blast, Explosion effects

The 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.

84-426

Evaluation of Human Exposure to Vibration in Buildings

Amer. Natl. Standard, ANSI S3.29-1983, Avail: Acoust. Soc. Amer., Back Nos. Dept., Dept. STD, Amer. Inst. Phys., 335 E. 45th St., New York, NY 10017, Price: $20.00

Key Words: Standards and codes, Buildings, Vibration effects, Human response

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
Hughes Aircraft Co., Ground Systems Group, Los Angeles, CA, J. Environ. Sci., 26 (5), pp 24-26 (Sept/Oct 1983) 4 figs, 2 tables

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.

AUTHOR INDEX

TECHNICAL NOTES

S.K. Hati and S.S. Rao
Cooperative Solution in the Synthesis of Multidegree-of-Freedom Shock Isolation Systems
J. Vib. Acoust. Stress Rel. Des., Trans. ASME, 105 (1), pp 101-103 (Jan 1983) 1 fig, 2 tables, 3 refs

G.L. McAninch
A Note on Propagation through a Realistic Boundary Layer
J. Sound Vib., 88 (2), 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, 4 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 Parmeter 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
IEEE Trans., Instrum. Meas., IM-32 (2), pp 383-384 (June 1983) 3 figs, 5 refs

I.M. Smith and E. E. Heshmati
Use of a Lanczos Algorithm in Dynamic Analysis of Structures
Intl. J. Earthquake Engrg. Struc. Dynam., 11 (4), pp 585-588 (July/Aug 1983) 2 figs, 4 tables, 3 refs

J.R. Sladek and R.E. Klingner
Effect of Tuned-Mass Dampers on Seismic Response
ASCE J. Struc. Engrg., 109 (8), pp 2004-2009 (Aug 1983) 7 figs, 12 refs

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

13-15 12th Symposium on Explosives and Pyrotechnics [Applied Physics Lab. of Franklin Research Center] San Diego, CA *(E&P Affairs, Franklin Research Center, Philadelphia, PA 19103 - (215) 448-1236)*

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

APRIL 1984

9-12 Design Engineering Conference and Show [ASME] Chicago, IL *(ASME Hqs.)*

9-13 2nd International Conference on Recent Advances in Structural Dynamics [Institute of Sound and Vibration Research] Southampton, England *(Dr. Maurice Petyt, Institute of Sound and Vibration Research, The University of Southampton, S09 5NH, England - (0703) 559122, Ext. 2297)*

30-May 3 Institute of Environmental Sciences' 30th Annual Technical Meeting [IES] Orlando, FL *(IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)*

MAY 1984

1-3 Mechanical Failures Prevention Group 38th Symposium [National Bureau of Standards, Washington, DC] Gaithersburg, MD *(Dr. J.G. Early, Metallurgy Div., Room A153, Bldg. 223, National Bureau of Standards, Washington, DC 20234)*

7-10 30th International Instrumentation Symposium [Instrument Society of America] Denver, CO *(Robert Jarvis, Grumman Aerospace Corp., Mail Stop T01-05, Bethpage, NY 11714)*

7-11 Acoustical Society of America, Spring Meeting [ASA] Norfolk, VA *(ASA Hqs.)*

10-11 12th Southeastern Conference on Theoretical and Applied Mechanics [Auburn University] Pine Mountain, GA *(J. Fred O'Brien, Director, Engineering Extension Service, Auburn University, AL 36849 - (205) 826-4370)*

JUNE 1984

3-7 29th International Gas Turbine Conference and Exhibit [ASME] Amsterdam, The Netherlands *(ASME Hqs.)*

26-28 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] New Orleans, LA *(Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)*

JULY 1984

21-28 8th World Conference on Earthquake Engineering [Earthquake Engineering Research Institute] San Francisco, CA, *(EERI-8WCEE, 2620 Telegraph Avenue, Berkeley, CA 94704)*

AUGUST 1984

6-9 West Coast International Meeting [SAE] San Diego, CA *(SAE Hqs.)*

19-25 XVIth International Congress on Theoretical and Applied Mechanics [International Union of Theoretical and Applied Mechanics] Lyngby, Denmark *(Prof. Frithiof Niordson, President, or Dr. Niels Olhoff, Executive Secretary, ICTAM, Technical University of Denmark, Bldg. 404, Dk-2800 Lyngby, Denmark)*

SEPTEMBER 1984

9-11 Petroleum Workshop and Conference [ASME] San Antonio, TX *(ASME Hqs.)*

11-13 Third International Conference on Vibrations in Rotating Machinery [Institution of Mechanical Engineers] University of York, UK *(IMechE Hqs.)*

30-Oct 4 Power Generation Conference [ASME] Toronto, Ontario, Canada *(ASME Hqs.)*

OCTOBER 1984

8-12 Acoustical Society of America, Fall Meeting [ASA] Minneapolis, MN *(ASA Hqs.)*

9-11 13th Space Simulation Conference [IES, AIAA, ASTM, and NASA] Orlando, FL *(Institute of Environmental Sciences, 940 E. Northwest Hwy., Mt. Prospect, IL 60056 - (312) 255-1561)*

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New York, NY 10019

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335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE: American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME: American Society of Mechanical Engineers
United Engineering Center
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New York, NY 10017

ASTM: American Society for Testing and Materials
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Philadelphia, PA 19103

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INCE: Institute of Noise Control Engineering
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Poughkeepsie, NY 12603

ISA: Instrument Society of America
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Research Triangle Park, NC 27709

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SEE: Society of Environmental Engineers
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Brookfield Center, CT 06805

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> **Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].**
>
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- **abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)**
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- **year of publication in parentheses.**

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., <u>7</u> (7), pp 97-106 (July 1975).

2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., <u>Aeroelasticity</u>, Addison-Wesley (1955).

3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).

4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., <u>27</u> (3), pp 220-231 (1948).

5. Landahl, M., <u>Unsteady Transonic Flow</u>, Pergamon Press (1961).

6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., <u>23</u> (7), pp 671-678 (1956).

7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., <u>24</u> (1), pp 65-66 (1957).

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Volume 16, No. 2 February 1984

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