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STAFF

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Dr. R.L. Eshleman
Vibration Institute
Suite 206
101 West 55th Street
Clarendon Hills, Illinois 60514

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Code 5804, Naval Research Laboratory
Washington, D.C. 20375

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordan Showalter

Carol Healey

Elizabeth A. McLaughlin

SVIC NOTES

FIBER OPTICS IN SHOCK AND VIBRATION INSTRUMENTATION

Vibration engineers today should be aware of the possible applications of fiber optics in the instrumentation of dynamic systems. These fibers are used mostly as low-loss high band-pass data communication channels. In that mode they have some advantages over coaxial cables. Their diameter and weight is small, allowing them to be used when the mass or routing of a big cable would be a problem. It is also easier and safer to penetrate a pressure vessel wall with a smaller diameter cable.

Fiber optic data links can be used in adverse environments where conventional cables fail. Examples include high electromagnetic fields or the environment in a nuclear reactor. Furthermore, fiber optics are beginning to be applied in the machinery vibration field. Once-per-rev signals can be picked off the shafts of rotating equipment using a piece of reflective tape and a fiber optic (FO) probe. FO probes have also been used to detect the mechanical signatures of defective bearings.

Coherent bundles of optical fibers can be used to transmit pictures. Many people are aware of applications in medicine where optical fibers are used to transmit pictures from inside a human body. The same techniques are now being used to observe the operation of mechanical components inside rotating machinery. Since the FO probes are thin and can be routed into tight places, they should prove to be useful in shock and vibration instrumentation.

Various transducer schemes are being investigated which use optical techniques to sense a signal directly. The advantage in this is that the signal can then be transmitted over an optical data link with no conversion from an optical to a conventional electrical signal. One group has developed an accelerometer * and another has developed a temperature probe **. The transducer developments are presently at the research stage, but they may be commercially available within a few years. I am encouraged by the prospects for future applications of fiber optic data links and transducers in shock and vibration instrumentation.

J.G.S.

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* A.B. Tveten, A. Dandridge, C.M. Davis, and T.G. Giallorenzi, Naval Research Laboratory, Code 6570, "A Fiber Optic Accelerometer," submitted for publication to Electronics Letters, Stevenage England.

** Developed by Dr. J.P. Dakin, Electronic Systems Research Division of Plessey (UK).

EDITORS RATTLE SPACE

EVOLUTION OF ELECTRONICS FOR INSTRUMENTATION AND COMPUTATION

Much of the credit for the current state of vibration technology is due to the evolution and development of electronic instrumentation. The quality of measurement, computation, and analysis of the vibration characteristics of machines, vehicles, and structures has increased by an order of magnitude in the past 20 years. The theory was developed years ago, but the means for implementing it to solve practical vibration problems had to await development of adequate instrumentation. Hardware developments in electronics – sensors, analyzers, filters, and computers to name a few – fulfilled this need.

Solid state electronics has brought us unbelievable computational power – power that is packaged in small minicomputers. Existing theory and numerical methods can be used to predict the vibration behavior of physical systems on the computer; mathematical models are used. These techniques are now being applied to design, development, and fault diagnosis. Often the same hardware can be used for reduction and analysis of experimental data.

There is a problem, however: instrumentation for vibration measurement has enhanced our ability to monitor, trend, and analyze vibration data beyond our understanding of the physics of the systems being used. Sensors are now available that can detect vibrations with sensitivity in all frequency ranges, in most locations, on our machines, vehicles, and structures. Fast Fourier analyzers are capable of fine resolution in the frequency domain. This capability has allowed the utilization of sidebands for analysis. In general, therefore, electronic signal processing capability far exceeds that available five years ago.

Thus, the availability of electronic equipment provides us the means to solve vibration problems. In addition, the basic theory of vibration of equipment has been developed. What is now needed is a better understanding of the relationships between the basic behavior of equipment – wear, performance,and integrity – and the signals being measured and analyzed.

R.L.E.

Announcement and Call for Papers

52nd SHOCK AND VIBRATION SYMPOSIUM

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CHAIN AND BELT DRIVES - A REVIEW

J.N. Fawcett*

Abstract. *Surveys of papers relating to the specific problems of chain drives and of belt drives are presented in chronological order. The papers are grouped as follows: the general problem of axially moving materials appropriate to the spans of both chain and belt drives, chain drives, and belt drives.*

Chains and belts in various forms have been widely used for transmitting power for hundreds of years. They have performed reliably, and continuous development has resulted in higher load carrying capacity and increased life. The standard forms of roller chain have been supplemented by various designs of inverted tooth chain. Flat belt drives were superseded many years ago by V-belts. Interest now centers on new types of flat belts that are highly efficient and can be used at high speeds. The toothed belt, or timing belt, has recently been introduced.

Chain and belt drives are of similar basic construction: both consist of a continuous flexible element that passes around two pulleys. Belt drives rely on friction to transmit the load from the pulley to the belt and vice versa; chains provide a positive drive via the teeth on the sprockets. A toothed belt drive, which also relies on the teeth on the pulley and belt to transmit the load, can be used in place of chains or when the cumulative positional errors that arise due to slip in other forms of belt drive are unacceptable.

This review is divided into three sections:

- papers relating to the general problem of axially moving materials which is appropriate to the spans of both chain and belt drives
- papers relating to chain drives
- papers relating to belt drives

The papers relating to chains and belts cover a number of areas including vibration, noise, material properties, and pulley-belt interaction, but the number of papers on any one topic is quite small. The papers reviewed are therefore presented in chronological order in preference to splitting each section into a number of small subsections.

Computer searches of the literature have failed to provide large numbers of relevant references. The author hopes that no significant works have been missed and would, of course, be pleased to hear of any additional papers that should have been included.

AXIALLY MOVING MATERIALS

The motion of a chain or belt span can be approximated by assuming that it behaves as a traveling inelastic string. An improved model can be formulated by including the effects of elasticity and flexural rigidity. Much of the large body of fundamental work on these topics applies to the behavior of moving threadlines, high-speed magnetic and paper-tape drives, and the vibration of band saws. The end conditions assumed in these analyses are usually much simpler than those encountered in belt and chain drives, but a review of this work is essential to the study of chain and belt vibration.

A comprehensive survey of fundamental work pertaining to band-saw vibration has recently been published [1]. No mention is made of viscoelastic effects, however, which can be important in belt drives. No studies of moving viscoelastic beams have been located, but the vibration of stationary viscoelastic beams has been considered [2, 3].

CHAIN DRIVES

The basic construction of a roller chain drive is such that the ratio of input velocity to output velocity

*Department of Mechanical Engineering, University of Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU, United Kingdom

is not co~~tant. This effect is often referred to as polygon.!, or chordal, action. Another consequence of the basic geometry is that an impact occurs as the driving sprocket picks up a roller from the chain span. Kinematic and dynamic studies have shown that the performance of a drive is significantly influenced by these effects.

Binder and Covert [4] derived expressions for the relative velocity between the roller and the sprocket at impact. They showed the way in which the position of the contact point on the tooth influences the magnitude of the impact. They discussed the effect of the impact velocity on roller life and presented experimental data on roller failure. The transverse vibration of the chain span was considered by Binder and Mize [5]. A stationary, light, inelastic string that carried discrete masses to represent the chain links was used to model the chain span; the natural frequencies of the system were calculated. Experimental tests showed that, when tooth impact frequency was equal to a natural frequency, significant vibration of the span occurred. Agreement between calculated and experimental results was good at low speeds but deteriorated with increasing speed.

Stamets [6] considered the fatigue life of chains; the study was based upon a loading cycle that fluctuates between tight and slack side tensions. The effects of centrifugal stresses were taken into account, but impact and other dynamic loadings were not included. An expression for optimum chain speed to give maximum life was derived.

A kinematic analysis of a roller chain drive in which the drive was considered as a series of four bar linkages was described by Morrison [7]. He presented graphs to show the effects of the numbers of teeth on the driving and driven sprockets upon velocity ratio and output acceleration. The influence of sprocket center distance was discussed.

Both kinematic and dynamic effects were considered in detail by Binder [8]. Many aspects of chain behavior were analyzed, including polygonal action, roller velocity at impact, chain loading, friction, vibration, and power capacity; elastic effects were not included in the analyses.

Mahalingham [9] showed that the dynamic loading caused by polygonal action is similar to a simple forced vibration; he considered that the chain had flexibility only in the longitudinal direction. He predicted that the dynamic load in the chain span would become large when the frequency of tooth engagement coincided with the natural frequency of the system at which the chain behaved as a light spring. Only the first harmonic of polygonal action was assumed to be significant.

A kinematic analysis of a chain drive by Bouillon and Tordion [10] indicated that, for least variation in velocity ratio, the tangent span -- i.e., the tangent to the sprocket pitch circles – should contain an integer number of chain pitches and that variations increase rapidly as the center distance deviates from its optimum value. Test results at a speed of one rev/min, at which dynamic effects are negligible, were also presented.

Ryabov [11] considered the impact between a roller and a sprocket tooth; he showed that the effective mass of chain involved in the impact is about equivalent to that of two links of chain. The effect of sprocket speed on the life of a chain drive was discussed by Janulis [12]. He showed that the type of failure changes as speed increases. Link plates fail at low speeds, but at higher speeds, when impact effects dominate, fatigue failure of the rollers and bushes occurred.

Davies and Owen [13] described the development of a roller chain power transmission for automobiles. They compared roller and inverted tooth chains in a number of applications.

The propagation velocity of elastic waves in transmission chains has been considered [14]. Theoretical and experimental values were compared; the importance of elastic wave effects in the evaluation of dynamic loads was mentioned.

Turnbull and Fawcett [15] developed equations to describe the dynamic behavior of a chain drive in which the chain span is modeled as a series of masses, the number of which varies as a link is added to or removed from the span. Results from the dynamic analysis were compared with those from a simple kinematic analysis. Elastic effects were not considered.

An analysis of chain and sprocket interaction has been given [16]; proper design of the teeth to allow liberal manufacturing tolerances while providing optimum dynamic performance was shown. Such common malfunctions as jumping and wedging were also discussed.

A design method based on both theoretical and experimental investigations has been developed for calculating the endurance of the rollers of a chain drive [17]. Service life was shown to be affected by the parameters of the drive. The application of British and American standards to the design of chain drives has been discussed [18], as have unusual applications of chain drives in power transmission.

An approximate kinematic analysis was used to show the effects of tooth ratio and center distance on the magnitude of the harmonics present in the sprocket motion [19]; the excitation of vibration by polygonal action was discussed. The optimum center distance for minimum vibration depended upon whether longitudinal or transverse vibration was likely to occur.

Avramidis [20] described a system developed to measure the loads in timing chains of automotive engines. Results obtained using roller chain and silent chain were compared.

A chain with comparatively small applied tension can experience a variation in tension along its length due to the effects of gravity. Shimizu and Sueoka [21] showed that these effects significantly influence the natural frequencies and mode shapes of the system. They predicted nonlinear vibration with characteristics similar to those due to a hardening spring.

An experimental investigation [22] using a drive operating at constant speed and torque showed that elastic effects dominate the behavior and that they must therefore be included in any realistic mathematical model. A high frequency vibration caused by impact between the sprocket tooth and the roller being removed from the span was the most significant vibration and the major source of noise in experiments. Further investigations, using the same test rig [23] showed that lubrication affects the magnitude of the impact at roller pickup.

A method has been described for eliminating the impact at roller pickup [24]; the high frequency noise produced in a constant torque drive is greatly reduced. Experimental measurements on the modified test rig showed significant reductions in noise and vibration. Methods for predicting the natural frequencies of the different types of vibration encountered in chain drives have been presented by Nicol and Fawcett [25]; possible sources of excitation were discussed.

The distribution of load on sprocket teeth has been analyzed [26]; elasticity of both tooth and chain were taken into account. Rating and life of transmission and conveyor chains have been discussed by Moxon [27]. He concluded that manufacturers ratings provide a good guide for most applications.

A mathematical model of a roller chain drive that can be used to predict sprocket accelerations due to longitudinal vibration of the chain span has been developed by Fawcett and Nicol [28]. This model, based upon their experimental work, indicated that impact can be the major source of vibration. The optimum center distance for minimum vibration was not always the one that gave an integer number of pitches in the common tangent. The optimum center distance, therefore, cannot be decided from kinematic considerations alone. Noise measurements on a chain drive showed the importance of impact noise [29].

Fawcett and Nicol [30] compared experimental results with those from an earlier theoretical paper. Results confirmed that longitudinal vibration of the span, excited by polygonal action and impact, are the most significant modes of vibration and that fractional pitch has little influence on performance.

A description of the development of an automobile transfer drive using three staggered roller chains running in parallel has been given [31]. Noise measurements were compared with those obtained from a conventional gear drive.

BELT DRIVES

The classical relationship between belt tension and coefficient of friction was developed by Euler. However, the very simple model he used is not capable of accurately predicting the behavior of belt drives for which slip and elastic, dynamic, and geometric effects are important. Various aspects of belt drive construction and behavior have been dealt with in the literature. Problems encountered in designing adjustable ratio V-belt drives have been considered by Worley [32], who presented comprehensive design data.

V-belt life has been investigated [33]. A design method was based on the stress analysis of rubber-textile structures and a large body of experimental fatigue tests on running belts. A method was proposed for predicting the tensions in and the equation of belt curvature for a fixed center V-belt drive [34]. The method provides good agreement with experimental results but is rather difficult to apply.

Chukanov [35] derived an equation for predicting the arcs of contact and slip and limiting tractive loads for flat belts running on rubber coated pulleys as used in conveying systems. Losses due to transverse compression and radial sliding, or wedging, in V-belt drives have been considered [36]. Experimental studies [37] showed that the principal losses in a V-belt drive are due to radial slip and transverse compression; bending and aerodynamic losses were of secondary importance.

The vibration of V-belt drives used for driving automobile engine accessories has been studied by Goyal and Bentley [38]. Design procedures that allowed prediction of the effects of belt parameters and torque characteristics were compared with experimental results.

Keller and Wilson [39] described tests on variable speed V-belt drives; they showed that the coefficient of friction can vary appreciably with belt construction and ingress of sand and other foreign matter. Their results agreed with predicted values of tension and axial force on the moving sheaves. Design criteria for a torque-controlled sensing mechanism for a variable speed V-belt drive have been presented [40]. Experimental work was described from which suitable values for the coefficient of friction could be recommended.

A theory for predicting power loss, belt motion, axial force, and slip was developed by Gerbert [41]. He considered force-deformation characteristics of the belt required for use in the formulas and compared results with experimental values. The results showed good agreement except in the power-dependent part of the total power loss. Gerbert [42] extended his theory to show the way in which power loss is influenced by different belt and drive properties. He also showed that losses can be minimized by appropriate combinations of power transmitted and pre-tension.

Palmer [43, 44] considered the properties of materials used in flat belt drives and the characteristics of electrical resistance strain gages when used on these materials. Creep measurements on belt materials were described [45], as was the development of a probe for measuring the electrostatic charge produced on a flat belt drive [46, 47]. Results under static and service conditions were compared.

The effects of belt elasticity, flexural rigidity, and variation in the coefficient of friction along the contact arc were used to derive an expression for the tight and slack side tension ratio in a flat belt [48].

Oliver, Hornung and Shapiro [49] described the design of an automatic transmission using an asymmetrical V-belt. Theoretical prediction of the performance was confirmed by experimental results. An analysis of the vibration of V-belt drives has been presented by Houser and Oliver [50]. They considered bending and axial stiffness and centrifugal effects and compared their theoretical results with experimental tests. Lateral and torsional natural frequencies were considered, but they used the word torsional to refer to pulley vibration caused by longitudinal vibration of the belt rather than torsional vibration of the belt itself.

Simple mathematical models of belt drives have been used by Pronin and Petrov [51] to obtain equations of motion that include the effects of pulsating loads. They considered the effects of elastic slip and skidding.

Slip in V-belt drives for the region in which slip is known to increase rapidly has been discussed [52]. Experimental and theoretical results were presented.

Palmer and Jarvis [53] described a photoelastic technique for measuring the tension distribution in a flat belt. Later the same year they described a test rig for simulating the load in a running belt [54]. An investigation of the mechanical efficiency of a variable speed V-belt drive showed that a figure of 90 percent could be achieved [55]. Analytical relationships for tension and deflection in flat belts have been given and optimal values for initial tension recommended [56]. In an extension of his earlier work on belt slip, Gerbert [57] presented a detailed analysis of the large slip region. He suggested that the point of transition to rapidly increasing slip should be used as a design point for drives.

An analysis of load distribution in toothed belts was used to show that the ratio of tooth stiffness to cord stiffness is an important parameter [58]. A finite element approach was used to predict tooth loading; satisfactory agreement between theory and tests on different belts was obtained although the load measured on the first tooth was consistently higher than predicted.

Zaiss [59] discussed tooth profile, capacity, and some practical aspects of the application of toothed belts for power transmission. Examples of the application of toothed belts for camshaft drives in reciprocating engines and of the development of belts with higher power transmission values have been given [60].

The tension variation with time in flat belt materials under simulated load conditions has been investigated [61]. The force between a flat belt and its pulley has been measured [62]; the behavior of belts with nylon and glass fiber tension members was compared. The dynamic response of a flat belt used in an impact line printer and subjected to impulsive loads has been studied [63].

Some practical aspects of the use of toothed belts have been discussed [64]. The effect of pitch tolerances of toothed belts on the distribution of load among the teeth in contact with the pulley has been investigated [65]. The effect was significant and depended upon such belt parameters as service tension and modulus of elasticity. A study of the fatigue life of toothed belts showed that the type of fracture was load dependent; no endurance limit was found for the belts used in the tests [66].

Gerbert [67] considered in detail various aspects of V-belt behavior, including radial penetration, slip in variable speed drives, arc of contact, and axial forces. He found good agreement between theoretical results and those obtained from experimental investigations. Drive efficiency has been related to belt slip and internal and surface temperatures [68]. Results obtained from a large test program were used to predict operating temperatures and slip of the belt.

Horowitz [69] compared different types of continuously variable power transmissions. He described a new metal V-belt; claims have been made that the belt has advantages over current systems. Simple experiments on the transverse vibration of a static toothed belt indicate that nonlinear effects might be significant [70].

CONCLUSION

Over the last ten years there has been increasing interest in chain and belt drive performance. As designers move toward narrower, lighter, and higher speed drives this interest should continue to increase, particularly in the areas of dynamic behavior and performance under fluctuating load conditions. Further work is needed on toothed belts, especially in the study of tooth-pulley impact, vibration and noise, and load-life characteristics.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles inlcude 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 the response of nonlinear mechanical systems to random excitation.

Dr. J.B. Roberts of the University of Sussex, Sussex, England has written the second part of his two-part survey; the first appeared in the April 1981 issue of the DIGEST. The first part discussed Markov methods for solving nonlinear stochastic problems in dynamics. This second part considers a number of alternative approximate methods, including equivalent linearization, perturbation, functional series representation, and simulation.

RESPONSE OF NONLINEAR MECHANICAL SYSTEMS TO RANDOM EXCITATION
PART 2: EQUIVALENT LINEARIZATION AND OTHER METHODS

J.B. Roberts*

Abstract. Part I of this survey discussed Markov methods for solving nonlinear stochastic problems in dynamics. This second part considers a number of alternative approximate methods, including equivalent linearization, perturbation, functional series representation, and simulation.

The first part of this survey discussed Markov methods based on the Fokker-Planck-Kolmogorov equation [1]. A principal advantage of these methods is that it is possible to obtain exact solutions in certain cases. Unfortunately, however, the range of practical problems, involving the response of nonlinear systems to random excitation, to which these exact solutions can be applied, is very restricted. A variety of alternative, approximate methods have therefore been developed, particularly in the last two decades. This second and concluding part of the review describes the development of the most important of these methods. The applicability of these methods is emphasized. The objective is to convey general trends in current research, rather than to give an exhaustive bibliographic review.

EQUIVALENT LINEARIZATION

Because linear systems are so much easier to analyze than nonlinear ones, a natural method of attacking nonlinear problems is to replace a given set of nonlinear equations by an equivalent set of linear ones; the difference between the sets of equations is minimized in some appropriate sense. The first development of a suitable equivalent linearization procedure for randomly excited nonlinear systems is usually attributed to Booton [2, 3] and Caughey [4], who generalized the deterministic linearization methods of Krylov and Bogoliubov [5] to the stochastic case. Here attention is focused on the application of equivalent linearization methods to nonlinear mechanical and structural systems. It is worth pointing out, however, that a considerable body of related literature exists in the field of control engineering [6, 7].

Single Degree of Freedom System.

A very general form of the equation of motion for a nonlinear oscillator is as follows:

$$g(\underset{\sim}{X}) = F(t) \tag{1}$$

$\underset{\sim}{X}$ is the vector $[\ddot{X}, \dot{X}, X]$; $X(t)$ is the displacement, $\dot{X}(t)$ is the velocity, and $\ddot{X}(t)$ is the acceleration response; $g(\underset{\sim}{X})$ is an arbitrary nonlinear function of $\underset{\sim}{X}$. $F(t)$ is the input; initially it is taken to be a stationary random process with zero mean.

The method of equivalent linearization replaces Equation (1) with the equivalent linear form

$$m\ddot{X} + \beta\dot{X} + kX = F(t) \tag{2}$$

Subtract Equation (2) from Equation (1) to obtain the minimization error given by

$$\varepsilon = g(\underset{\sim}{X}) - m\ddot{X} - \beta\dot{X} - kX \tag{3}$$

The quantity ϵ must be minimized in some convenient way. The usual method is to minimize the mean square of ϵ. Other minimization criteria are possible [8] but do not appear to offer significant advantages. For mean square minimization

$$\frac{\partial}{\partial m} E\{\varepsilon^2\} = \frac{\partial}{\partial \beta} E\{\varepsilon^2\} = \frac{\partial}{\partial k} E\{\varepsilon^2\} = 0 \tag{4}$$

A combination of equations (3) and (4) gives the set of equations

School of Engineering and Applied Sciences, University of Sussex, Falmer, Brighton, Sussex, England, BN1 9QT.

$$\underset{\sim}{M}\,\underset{\sim}{p} = \underset{\sim}{q} \tag{5}$$

in which

$$\underset{\sim}{p} = \begin{bmatrix} m \\ \beta \\ k \end{bmatrix}, \quad \underset{\sim}{q} = E\{\underset{\sim}{X}g\} \tag{6}$$

and $\underset{\sim}{M}$ is the covariance matrix for $\underset{\sim}{X}$ -

$$\underset{\sim}{M} = E\{\underset{\sim}{X}.\underset{\sim}{X}'\} \tag{7}$$

E { }denotes the expectation operator.

Equation (5) represents a set of three simultaneous equations for the required parameters m, β, and k. Use Equation (2) to evaluate $\underset{\sim}{M}$. If F(t) is Gaussian, $\underset{\sim}{X}$ – for the equivalent linear system – is jointly Gaussian [9]; $\underset{\sim}{M}$ and $\underset{\sim}{q}$ can thus be evaluated in terms of $\underset{\sim}{p}$. This procedure converts Equation (5) into a set of nonlinear algebraic equations for the required parameters. The equations can be solved by an iterative scheme.

This rather clumsy technique can be simplified to some extent by using a result for Gaussian processes proved by Atalik and Utku [10] and others [11, 12]. If $\underset{\sim}{X}$ is Gaussian,

$$E\{\underset{\sim}{X}g\} = \underset{\sim}{M}\,E\{\underset{\sim}{\nabla}g\} \tag{8}$$

in which

$$\underset{\sim}{\nabla}' = \left(\frac{\partial}{\partial \ddot{X}}, \frac{\partial}{\partial \dot{X}}, \frac{\partial}{\partial X}\right) \tag{9}$$

Combine equations (5) and (8) to obtain

$$\underset{\sim}{p} = E\{\underset{\sim}{\nabla}g\} \tag{10}$$

that is,

$$m = E\{\frac{\partial g}{\partial \ddot{X}}\}, \quad \beta = E\{\frac{\partial g}{\partial \dot{X}}\}, \quad k = E\{\frac{\partial g}{\partial X}\} \tag{11}$$

This concise formulation is deceptively simple, however. In general, the expectations in Equations (11) will involve the parameters m, β, and k. Thus, in general, Equations (11) represent a set of complex nonlinear equations. However, Equations (11) will usually be substantially easier to solve than Equation (5) and in some cases will lead to closed form solutions.

As an example, consider an oscillator with an equation of motion such that

$$g(\underset{\sim}{X}) = \ddot{X} + \gamma\dot{X}\left[1 + \epsilon\dot{X}^2\right] + \omega_o^2 X \tag{12}$$

where γ and ϵ are constant. For simplicity F(t) is taken to be a white noise with correlation function

$$E\{F(t)\;F(t+\tau)\} = K\delta(\tau) \tag{13}$$

K is a constant, and δ ( ) is Dirac's delta function. Apply Equations (11); m = 1, k = ω_o^2, and

$$\beta = \gamma\left[1 + 3\epsilon\;E\{\dot{X}^2\}\right] \tag{14}$$

For the linearized oscillator the mean square velocity $E\{\dot{X}^2\}$ is given by

$$E\{\dot{X}^2\} = \frac{K}{2\beta} = \sigma^2\omega_o^2 = \frac{\gamma}{\beta}\,\sigma_o^2\omega_o^2 \tag{15}$$

in which $\sigma^2 = E\{X^2\}$ and σ_o is the value of σ for $\epsilon = 0$ [9]. Combine results to obtain

$$\frac{\beta}{\gamma} = 1 + 3\,\epsilon^*\,\frac{\gamma}{\beta} \tag{16}$$

where $\epsilon^* = \epsilon\omega_o^2\sigma_o^2$. This is a nonlinear algebraic equation for β. In this case the equation is quadratic and is easily solved to give the closed form solution

$$\frac{\beta}{\gamma} = 6\;\epsilon^*/\left[(1 + 12\;\epsilon^*)^{\frac{1}{2}} - 1\right] \tag{17}$$

A closed form solution can also be found for a Duffing oscillator excited by white noise [9, 13, 14] and a number of other special cases [10]. A numerical technique is sometimes required to solve the nonlinear equations for the parameters. For example, if the term $\dot{X}^2$ in Equation (12) is replaced by $|\dot{X}|$, so that the oscillator has linear and quadratic damping, a third order equation of σ is obtained [15]. Other examples of the application of statistical linearization to single-degree-of-freedom systems with a wide-band input are available [16-26].

A number of authors [27-29] used the equivalent linearization technique to examine the response of a Duffing oscillator to narrow-band random excitation. Of particular interest is the possible occurrence of the jump phenomenon, which is well known for the case of harmonic excitation [30]. Richard [29], in a comprehensive study of this problem, showed that the occurrence of jumping depends critically on the bandwidth of the excitation process.

Systems with Hysteresis.
For system with hysteresis, the function $g(\underset{\sim}{X})$ in Equation (1) depends not only on the instantaneous value of $\underset{\sim}{X}$ but also on the history of the response. One suitable modification of the equivalent linearization procedure has been given by Caughey [4, 31]; it is based on the averaging principle of Krylov and Bogoliubov [5].

A nonlinear hysteretic oscillator can be modeled by Equation (18)

$$\ddot{X} + G(X,\dot{X},t) = F(t) \tag{18}$$

G depends on the history of the motion. Equation (5) can be solved fairly easily (let m = 1)

$$\beta = E\{\dot{X}G\}/E\{\dot{X}^2\} \tag{19}$$

$$k = E\{XG\}/E\{X^2\} \tag{20}$$

If the energy dissipation per cycle is relatively small, the response will be narrowband in nature, and the response motion will resemble a sinusoid with slowly varying amplitude and phase. Hence,

$$\begin{aligned} X &= A \sin(\omega_e t + \phi) \\ \dot{X} &= -A\omega_e \cos(\omega_e t + \phi) \end{aligned} \tag{21}$$

A and ϕ are, respectively, the slowly varying amplitude and phase; ω_e is an equivalent frequency such that $\omega_e^2 = k$. Substitute Equation (21) into Equations (19) and (20); average over one cycle of oscillation (assuming that A and ϕ are sensibly constant over such a cycle) to obtain [4, 31]

$$\beta = \frac{2}{\omega_e} \frac{E\{C(A)\}}{E\{A^2\}} \tag{22}$$

$$k = \omega_e^2 = \frac{2\,E\{S(A)\}}{E\{A^2\}} \tag{23}$$

in which

$$C(A) = \frac{1}{2\pi} \int_0^{2\pi} A\,G \cos\theta \, d\theta \tag{24}$$

$$S(A) = \frac{1}{2\pi} \int_0^{2\pi} A\,G \sin\theta \, d\theta \tag{25}$$

If p(A) is the density function for A, then

$$E\{C(A)\} = \int_0^{\infty} C(A)\, p(A)\, dA \tag{26}$$

and similarly for S(A). For the corresponding linear system the amplitude is Rayleigh distributed. Expressions for C(A) and S(A) can thus be obtained in terms of the mean square response σ^2. Combining results leads to a nonlinear algebraic equation for σ^2 that can be solved graphically or numerically.

This averaging method was first applied to the case of an oscillator with bilinear hysteresis. This approach subsequently was applied to oscillators with different kinds of hysteresis, and various modifications have been proposed [32-35]. The method is related to some extent to Karnopp's power balance technique [36, 37].

As shown by a number of authors [38] the energy dissipation in hysteretic structures can sometimes be relatively large. The response process then has a wide-band character rather than the narrow-band character assumed in the averaging method. An *interesting method of overcoming this difficulty* was recently proposed by Wen [39]. The method avoids the need to introduce an averaging approximation. Wen represents the hysteretic force $G(X, \dot{X}, t)$ as

$$G(X,\dot{X},t) = h(X,\dot{X}) + Z(X) \tag{27}$$

where h is a non-hysteretic component – i.e., a function of the instantaneous amplitude and velocity – and Z is a hysteretic component related to X through the first order equation

$$\dot{Z} = -\gamma\ |\dot{X}|Z|\dot{Z}|\ -\ \beta\dot{X}|Z|^n + A\dot{X} \qquad (28)$$

where γ, β, A, and n are constants. As first noted by Bonc [40], for the case n = 1, Equation (28) gives a hysteretic relationship between Z and X. The constants can be adjusted to obtain a wide variety of hysteretic force characteristics [41]. Combining Equations (18), (22), and (28) results in a third order system with non-hysteretic components. This system can be linearized by using a slight extension of Equation (10). The third order linear system is readily solved to give the mean square response.

Multi-Degree-of-Freedom Systems.

The equivalent linearization procedure has one great advantage over Markov methods [1]: it can be extended fairly easily to cope with multi-degree-of-freedom systems. The earliest applications to systems with more than one degree of freedom were given by Caughey [42, 43]. A number of generalized formulations have subsequently been proposed [44-53].

If a system has n degrees of freedom, a straightforward generalization of Equation (1), for the equations of motion, is

$$\underset{\sim}{g}(\underset{\sim}{Y}) = \underset{\sim}{F}(t) \qquad (29)$$

Here

$$\underset{\sim}{g} = \begin{bmatrix} g_1 \\ g_2 \\ \cdot \\ \cdot \\ \cdot \\ g_n \end{bmatrix} \qquad \underset{\sim}{F} = \begin{bmatrix} F_1 \\ F_2 \\ \cdot \\ \cdot \\ \cdot \\ F_n \end{bmatrix} \qquad (30)$$

are n vectors containing, respectively, the internal and external forces. The 3n vector $\underset{\sim}{Y}$ is defined as

$$\underset{\sim}{Y} = [\ddot{\underset{\sim}{X}}',\ \dot{\underset{\sim}{X}}',\ \underset{\sim}{X}']' \qquad (31)$$

$\underset{\sim}{X}$ is the n vector of displacement, $\dot{\underset{\sim}{X}}$ is the n vector of velocities, and $\ddot{\underset{\sim}{X}}$ is the n vector of accelerations.

Equation (29) is replaced by the set of linearized equations

$$\underset{\sim}{m}\ddot{\underset{\sim}{X}} + \underset{\sim}{\beta}\dot{\underset{\sim}{X}} + \underset{\sim}{k}\underset{\sim}{X} = \underset{\sim}{F}(t) \qquad (32)$$

where $\underset{\sim}{m}$, $\underset{\sim}{\beta}$, and $\underset{\sim}{k}$ are nxn mass, damping, and stiffness matrices, respectively. The procedure outlined for the case n = 1 is used to find that minimization of the mean square error between equations (29) and (32) gives Equation (5) again [10]; now $\underset{\sim}{M}$ is the covariance matrix for $\underset{\sim}{Y}$

$$\underset{\sim}{M} = E\{\underset{\sim}{Y}.\underset{\sim}{Y}'\} \qquad (33)$$

and

$$\underset{\sim}{p} = \begin{bmatrix} \underset{\sim}{m} \\ \underset{\sim}{\beta} \\ \underset{\sim}{k} \end{bmatrix}, \qquad \underset{\sim}{q} = E\{\underset{\sim}{Y}\ \underset{\sim}{g}'\} \qquad (34)$$

In practice usually only the damping and stiffness terms need be linearized. Equation (5) then reduces to a set of 2n simultaneous equations. Because $\underset{\sim}{M}$ and $\underset{\sim}{q}$ depend implicitly on $\underset{\sim}{p}$, these equations are actually nonlinear. Foster [45, 46] proposed an iterative numerical scheme for solving Equation (5) and quoted typical computer times. Evidently because a 2nx2n matrix inversion is required at each step in the iteration, the computer time involved can be prohibitive if n is large.

A considerable reduction in computation is possible in special cases. Caughey [4] showed that, under suitable conditions, the linear part of the equations can be uncoupled; the modal matrix and the transformed equations linearized can be used separately. Iwan and Yang [47-49] considered the case

$$g(Y) = m\ddot{X} + f(X,\dot{X}) \qquad (35)$$

and assumed that the i^{th} component of f can be expressed as

$$f_i = \sum_{i=1}^{n} h_{ij}(y_{ij}, \dot{y}_{ij}) \qquad (36)$$

in which

$$y_{ij} = X_i - X_j \qquad (37)$$

are relative displacements. This is a suitable representation for systems consisting of a series of interconnected springs and dampers. The overall square error is minimized if each nonlinear element h_{ij} is replaced by a linear element

$$\gamma_{ij}\dot{y}_{ij} + \mu_{ij} y_{ij} \qquad (38)$$

where

$$\mu_{ij} = E\{h_{ij}\dot{y}_{ij}\}/E\{\dot{y}_{ij}^2\}$$
$$\gamma_{ij} = E\{h_{ij} y_{ij}\}/E\{y_{ij}^2\} \qquad (39)$$

This replacement rule is identical to that for a single-degree-of-freedom system, equations (19) and (20). A special case of this result has been derived [46].

For the general case of Equation (29), Atalik and Utku [10, 50] showed that the Equation (5) can be simplified by using the Gaussian identity of Equation (8), but replacing X with Y. The elements of M, β, and k are given by

$$m_{ij} = E\{\frac{\partial g_i}{\partial \ddot{X}_j}\}$$
$$\beta_{ij} = E\{\frac{\partial g_i}{\partial \dot{X}_j}\} \qquad (i,j = 1,2 \ldots, n) \qquad (40)$$
$$k_{ij} = E\{\frac{\partial g_i}{\partial X_j}\}$$

This is a generalization of Equation (11) for the case n = 1. Equation (40) gives a true (global) minimum if M is nonsingular; otherwise the solution is not unique but will be as good as any other solution [52]. It has been shown [10] that the matrices M, β, and k will always be symmetric if the nonlinearities possess potentials; i.e., if the i^{th} element of $g(Y)$, $g_i(Y)$ can be expressed as

$$g_i(Y) = \frac{\partial W}{\partial \ddot{X}_i} + \frac{\partial V}{\partial \dot{X}_i} + \frac{\partial U}{\partial X_i} \quad (i = 1,2, \ldots n) \qquad (41)$$

$W = W(\ddot{X})$, $V = V(\dot{X})$, $U = U(X)$ are potential functions.

In addition to these general formulations of the equivalent linearization procedure, a number of specific applications have been made to the random vibration of nonlinear beams [25, 54], plates [26], and shells [55]. Multi-degree-of-freedom systems with hysteresis have also been considered [56, 57].

Nonstationary Response.
An advantage of the equivalent linearization procedure is that it can be extended fairly readily to nonstationary problems. In most cases the systems are initially at rest and respond to either a suddenly applied stationary input or more generally to a pulse of random excitation of the earthquake type. Because nonlinear systems are usually linear for sufficiently small response amplitudes, a step-by-step linearization procedure is used in which the param-

eters in the linearized equations are treated as time-dependent quantities [58-64].

In practice the inertial terms are usually linear at the outset, and it is necessary to evaluate the parameters β_{ij} and k_{ij} in Equations (40). Gaussian identities may be used to relate the right hand sides of these equations to the elements of the covariance matrix

$$\underset{\sim}{S} = E\{\underset{\sim}{Z}.\underset{\sim}{Z}'\} \tag{42}$$

$\underset{\sim}{Z}$ is the vector

$$\underset{\sim}{Z} = [\underset{\sim}{X}',\dot{\underset{\sim}{X}}']' \tag{43}$$

An expression for $\underset{\sim}{S}$ can be found by writing Equation (32) as the first order matrix equation

$$\frac{d\underset{\sim}{Z}}{dt} = \underset{\sim}{h}\,\underset{\sim}{Z} + \underset{\sim}{f} \tag{44}$$

where

$$\underset{\sim}{h} = \begin{bmatrix} \underset{\sim}{0} & \underset{\sim}{I} \\ -\underset{\sim}{M}^{-1}\underset{\sim}{k} & -\underset{\sim}{M}^{-1}\underset{\sim}{\beta} \end{bmatrix}, \quad \underset{\sim}{f} = \begin{bmatrix} \underset{\sim}{0} \\ \underset{\sim}{M}^{-1}\underset{\sim}{F} \end{bmatrix} \tag{45}$$

The $\underset{\sim}{S}$ that satisfies the differential equation is obtained from Equation (44)

$$\frac{d\underset{\sim}{S}}{dt} = \underset{\sim}{h}\,\underset{\sim}{S} + \underset{\sim}{S}\,\underset{\sim}{h}' + \underset{\sim}{B} \tag{46}$$

$\underset{\sim}{B}$ is related to the expected values of the product of the vectors $\underset{\sim}{f}$ and $\underset{\sim}{Z}$.

The step-by-step linearization method involves the repeated use of equations (40) and (46). The time axis is divided into a number of equally spaced intervals Δt; and the parameters β_{ij} and k_{ij} are assumed to be constant within each interval. From rest β_{ij} and k_{ij} are known (linear system); thus $\underset{\sim}{S}$, at time $t = \Delta t$, is found by numerically integrating Equation (46). Substitution of $\underset{\sim}{S}$ back into Equations (40) gives the new values of β_{ij} and k_{ij} in the next interval, and so on.

The method is particularly simple if f(t) is a modulated white noise because $\underset{\sim}{B}$ then depends only on the instantaneous time [53, 39]; $\underset{\sim}{Z}$ is then Markov. For non-white excitation the method is more complicated. Wen [39] obtained f(t) by filtering white noise and combining the filter with the original system. This increases the dimension of the vector $\underset{\sim}{Z}$, which becomes Markov again. An alternative approach used by Sakata and Kimura [58, 59] is to evaluate $\underset{\sim}{B}$ by a recursive algorithm at each step.

Note that, for stationary excitation, Equation (46) reduces to the Liapanov matrix equation

$$\underset{\sim}{h}\,\underset{\sim}{S} + \underset{\sim}{S}\,\underset{\sim}{h}' + \underset{\sim}{B} = 0 \tag{47}$$

that can be combined with Equations (40) to form the basis of an iterative numerical scheme for estimating the stationary response.

Accuracy.

Although theoretical studies of the accuracy of the equivalent linearization method are limited in scope [65], accuracy can be gauged by comparing results with known exact solutions, perturbation solutions, and simulation estimates.

For a single-degree-of-freedom oscillator with an equation of motion of the form

$$\ddot{X} + \beta\dot{X} + q(X) = F(t) \tag{48}$$

an exact stationary solution can be found from the Fokker-Planck-Kolmogorov equation if F(t) is a white noise [1]. If $q(X) = \alpha x^3$, the exact standard deviation of the response is [10]

$$\sigma_x = 0.8222\left(\frac{K}{2\beta\alpha}\right)^{1/4} \tag{49}$$

K is the strength of the white noise input; see Equation (13). Apply the equivalent linearization method to obtain the result [10]

$$\sigma_x = 0.7600\left(\frac{K}{2\beta\alpha}\right)^{1/4} \tag{50}$$

Comparison of equations (49) and (50) shows that the error in the approximate solution is less than 7.5%. Comparisons with other forms of stiffness nonlinearity [25, 48] reveal errors of similar magnitude. For the case of nonlinear damping the equation of motion was considered [10]:

$$\ddot{X} + \beta(\dot{X}^2 + \alpha X^2)\dot{X} + \alpha X = F(t) \tag{51}$$

Again F(t) is white noise. The exact solution – obtained from the Fokker-Planck-Kolmogorov equation by Caughey [66] for the standard deviation of X(t) – is within 5% of the equivalent linearization solution, independent of paramter β. For the general case of nonlinear damping an exact solution is not available, but approximate solutions obtained by the stochastic averaging method have been shown to agree very well with the corresponding equivalent linearization results [67].

For systems with a very small degree of nonlinearity, perturbation solutions (described in the following section) are available for comparison purposes. A typical example of such a comparison is that of Crandall [19], who considered the spectrum of the response of an oscillator with a small degree of nonlinear stiffness. He found that the results of equivalent linearization and perturbation methods were identical to the first order in the nonlinearity parameter. A similar result has been obtained for oscillators with nonlinear damping [9, 67]. In general, however, the equivalent linearization method will not be correct to the second order in the nonlinearity parameter [68].

Finally, many authors [38, 39, 53, 58, 59, 67, 69] have compared results obtained by the equivalent linearization method with digital or analog simulation estimates. In general these comparisons are favorable and indicate that the method is sufficiently accurate for engineering purposes.

PERTURBATION

If the nonlinearities in a system are sufficiently small, the perturbation method of solution can be used. This approach has been well known in deterministic vibration theory for many years [70] and was generalized to the case of stochastic excitation by Crandall [71].

The method can be illustrated by an oscillator with an equation of motion – see Equation (1) – such that

$$g(\underset{\sim}{X}) = \ddot{X} + \gamma\dot{X} + \omega_o^2 X + \varepsilon\eta(X, \dot{X}) \tag{52}$$

where γ, ω_o and ϵ are constants, with ϵ assumed small.

The idea is to expand the solution to Equation (1) as a power series in ϵ; i.e.,

$$X(t) = X_o(t) + \varepsilon X_1(t) + \varepsilon^2 X_2(t) + \ldots \tag{53}$$

Substitute Equation (53) into the equation of motion and group terms having the same power of ϵ to obtain a set of linear equations for X_o, X_1, etc. Thus

$$\ddot{X}_o + \gamma\dot{X}_o + \omega_o^2 X_o = F(t) \tag{54}$$

$$\ddot{X}_1 + \gamma\dot{X}_1 + \omega_o^2 X_1 = -\eta_o(t) \tag{55}$$

where

$$\eta_o(t) = \eta(X_o, \dot{X}_o) \tag{56}$$

Use the normal convolution integral; it follows that

$$X_o(t) = \int_{-\infty}^{\infty} h(t-\tau)\, F(\tau)\, d\tau \tag{57}$$

$$X_1(t) = \int_{-\infty}^{\infty} h(t-\tau)\, \eta_o(\tau)\, d\tau \tag{58}$$

in which h ( ) is the impulse response function for the linear system ($\epsilon = 0$).

Equations (57) and (58) can be used to compute the various statistical moments of X(t). For example, the mean value of X(t) is given by

$$m = E\{X(t)\} = E\{X_o\} + \varepsilon\, E\{X_1\} + \ldots \qquad (59)$$

in which

$$E\{X_o\} = \int_{-\infty}^{\infty} h(t-\tau)\, E\{F(\tau)\} d\tau \qquad (60)$$

$$E\{X_1\} = \int_{-\infty}^{\infty} h(t-\tau)\, E\{n_o(\tau)\} d\tau \qquad (61)$$

and so on. The calculations are usually lengthy and become progressively tedious as the order of ϵ increases. In practice results are usually obtained only to the first order in ϵ.

The perturbation method has been applied to oscillators with nonlinear damping [72] to obtain the moments of the response. In addition, the spectrum of the response of nonlinear oscillators has been studied using this technique [19, 73-76]. Extensions of the analysis to the case of discrete, multi-degree-of-freedom systems [71, 77, 78] and to the case of transient response [79] have been given. A continuous system has also been treated [80].

FUNCTIONAL SERIES

A linear system with an input F(t) and a response X(t) gives the convolution integral relationship

$$X(t) = \int_{-\infty}^{\infty} h_1(t_1)\, F(t-t_1) dt_1 \qquad (62)$$

where $h_1(t_1)$ is the impulse response function of the system. See also Equation (57).

For nonlinear systems an appropriate generalization of Equation (62) is as follows [81-84]

$$X(t) = \sum_{n=1}^{\infty} \iint_{-\infty}^{\infty} \cdots \int h_n(t_1, t_2, \ldots t_n) F(t-t_1) F(t-t_2) \ldots F(t-t_n)\, dt_1 dt_2 \ldots dt_n \qquad (63)$$

This is usually called a Voltera series expression. For a time-invariant system the kernels h_n depend only on time differences and are completely symmetrical in their arguments [82, 83]; h_n can be regarded as the n^{th} degree impulse response function. It is related to the n^{th} degree frequency response function H_n by the Fourier transform pair

$$h_n(t_1, t_2, \ldots, t_n) = \frac{1}{(2\pi)^n} \iint_{-\infty}^{\infty} \cdots \int H_n(\omega_1, \omega_2, \ldots, \omega_n) e^{i[\omega_1 t_1 + \omega_2 t_2 + \ldots + \omega_n t_n]} d\omega_1 d\omega_2 \ldots d\omega_n \qquad (64)$$

and

$$H_n(\omega_1, \omega_2, \ldots, \omega_n) = \iint_{-\infty}^{\infty} \cdots \int h_n(t_1, t_2, \ldots t_n) e^{-i[\omega_1 t_1 + \omega_2 t_2 + \ldots + \omega_n t_n]} dt_1 dt_2 \ldots dt_n \qquad (65)$$

H_n are also symmetric with respect to their arguments.

The harmonic input method of Bedrosian and Rice [83] can be used to evaluate the functions h_n and H_n for a system with a known equation of motion. F(t) of the form

$$F(t) = \sum_{k=1}^{\infty} e^{i t \omega_k} \qquad (66)$$

is substituted into Equation (63). The resulting expression for X(t) is substituted into the equation of motion. An analysis of the resulting expressions leads to formulas for H_n in terms of the system parameters. A detailed example has been given by Dalzell [84], who considered an equation of motion of the form

$$A_1\ddot{X} + A_3\ddot{X}^3 + B_1\dot{X} + B\dot{X}_1^3 + C_1X + C_3X^3 = F(t) \qquad (67)$$

He showed that $H_n = 0$ for n even and evaluated H_1, H_3, and H_5. The first two terms are

$$H_1(\omega_1) = \frac{1}{(-\omega_1^2 A_1 + i\omega_1 B + C_1)} \qquad (68)$$

and

$$H_3(\omega_1, \omega_2, \omega_3) = -D_3(i\omega_1\omega_2\omega_3) H_1(\omega_1 + \omega_2 + \omega_3) H_1(\omega_1) H_1(\omega_2) H_1(\omega_3) \qquad (69)$$

in which

$$D_3(\omega) = A_3\omega^2 + B_3\omega + C_3 \qquad (70)$$

The expression for H_5 is considerably more complicated [84]. After H_n have been determined, h_n can be evaluated from Equation (64). Note that H_1 is the usual linear frequency response function.

After h_n have been evaluated, Equation (63) can be used to compute statistics related to X(t). For example, the spectrum of X(t) can be related to the spectrum of F(t) [83]. In practice it is necessary to truncate the series of Equation (63) to a finite number of terms and to assume that higher order terms have a negligible effect. Dalzell [84] assumed that the series could be truncated at n = 3; he used equations (68) and (69) to obtain an approximate expression for the spectrum of X(t) for the system defined by Equation (67). Comparisons with simulation results suggested that this approach was useful only for small degrees of nonlinearity [84] and that for strong nonlinearities higher terms in Equation (63) must be considered.

The functional series method yields results that resemble those obtained by the perturbation method; further work is required to establish the precise relationship between these two approaches.

SIMULATION

The simulation approach is used to generate sample functions of the excitation process. Corresponding sample functions of the response process are computed. Statistical processing of the output process then yields the required information. Lengthy processing is needed to reduce the statistical uncertainty of the results to acceptable limits. The method is simplified for stationary, ergodic processes because only one input (and output) realization of sufficient duration need be generated. For nonstationary problems an ensemble averaging procedure is necessary.

One method is to use a random signal generator and filters to generate the excitation and an analog computer system to produce the output waveform; [38, 85-93]. However, many workers now prefer to perform simulation studies in a digital computer.

Digital simulation is particularly simple if the excitation can be modeled as a white noise because appropriate sample functions can then be generated directly from a sequence of independent random numbers [94-99]. For non-white excitation a digital filter can be constructed to operate on a sequence of random numbers; sample functions of the required spectrum are produced [100-103].

An alternative approach is to generate the excitation by summing sine waves. There are various possibilities; for example, the Rice representation [104]

$$F(t) = \sum_{n=1}^{N} (a_n \cos \omega_n t + b_n \sin \omega_n t) \quad (71)$$

where $\omega_n = n\Delta\omega$ are equally spaced. The coefficients a_n and b_n are independent random variables and are distributed normally about zero with a standard deviation of $[S(\omega_n)\Delta\omega]^{1/2}$ where $S(\omega)$ is the required spectrum of F(t).

Another possibility is to use

$$F(t) = \sum_{n=1}^{N} C_n \cos(\omega_n t + \theta_n) \quad (72)$$

in which θ_n are uniformly distributed between 0 and 2π; $C_n = [2S(\omega_n)\Delta\omega]^{1/2}$ are fixed amplitudes [104]. Yet another method is to use [105, 106]

$$F(t) = \sigma(\frac{2}{N})^{\frac{1}{2}} \sum_{n=1}^{N} \cos(\omega_n t + \theta_n) \quad (73)$$

in which σ is the standard deviation of F(t); ω_n are independent random frequencies distributed with a probability density function proportional to $S(\omega)$.

The advantage of this kind of representation is that it can be readily extended to the case of multidimensional and multivariate processes [106-118]. If the frequencies are equally spaced, implementation on a digital computer can be made considerably more efficient by using the FFT algorithm [108, 119, 120].

Note that for nonlinear systems driven by white noise, it is possible to develop algorithms for generating sample functions of the response directly [21].

CONCLUDING REMARKS

Of the analytical methods considered here the equivalent linearization technique is the one that has been most extensively developed and is probably the most useful from an engineering point of view. It gives good results for even strongly nonlinear systems, whereas perturbation and functional series methods are useful only for slightly nonlinear systems. However, it must be borne in mind that all these methods give only very limited information on response statistics. In practice not only the mean square of the response, for example, but also its distribution are required. Distribution information is vital for estimating probabilities of system failure. Simulation methods have the advantage that they are more flexible and can yield distribution information. However, considerable computation is required if the probability of exceeding high amplitude levels is to be reliably estimated by the simulation method. Simulation methods also play a valuable role as a means of assessing the validity of approximate theoretical methods.

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BOOK REVIEWS

STRUCTURAL DYNAMICS THEORY AND COMPUTATION

M. Paz
Van Nostrand Reinhold Co., New York, New York
1980, 480 pp, $29.95

This book is an excellent presentation of structural dynamics. It is organized as a textbook and would appear to be excellent for that purpose. It is written clearly with a consistently developed nomenclature and minimal references. One anticipates that this book will serve as an excellent text for students. Each chapter includes a set of problems appropriate for assignment. Practicing engineers will find it a useful reference – it follows the pattern of early vibration books that served many of us well for many years.

The book is organized into three parts. Part 1: Structures Modeled as a Single-Degree-of-Freedom System has eight chapters. It begins with undamped systems and introduces damping, harmonic loading, and general dynamic loading. Fourier analysis, generalized coordinates, and nonlinear response are considered, and the response system is introduced and developed.

The second part deals with multistory shear buildings -- a relatively simplistic approach to buildings. All of the masses are assumed to be concentrated in rigid floors; a building is thus reduced to a multi-degree-of-freedom problem with as many degrees of freedom as the number of floors. Free vibration as well as forced and damped motions are considered. The final chapter considers dynamic matrices.

The third part considers framed structures – beams, plane frames, three-dimensional frames, and trusses – modeled as multi-degree-of-freedom systems. General techniques for handling nonlinear responses of multi-degree-of-freedom systems are given. Dynamic analysis of systems with distributed properties and an approach to continuous systems using discrete elements are also described. The Appendix contains 16 computer programs.

This book is strongly recommended as a textbook for undergraduate and graduate courses and as a reference book for engineers faced with dynamic problems. It is easily read and would be a valuable addition to professional libraries.

K.E. McKee
Engineering Division
IIT Research Institute
10 W. 35th Street
Chicago, Illinois 60616

WIND EFFECTS ON STRUCTURES

E. Simiu and R.H. Scanlan
John Wiley & Sons, New York, New York
1980, $33.50

This book might not tell you "everything you have ever wanted to know about wind engineering," but it certainly provides a good introduction. Both authors have been involved with the ASCE Committee on Wind Engineering. Dr. Simiu is with the National Bureau of Standards Centers for Building Technology; Dr. Scanlan is Professor of Civil Engineering at Princeton University. It is clear that the authors know their subject: they have made use of a variety of sources and have provided many references.

Part A of the book contains three chapters describing atmospheric circulations, boundary layers, and wind climatology. This part presents basic terminology, equations, and results. The reader is introduced to a range of wind phenomena and data. A criticism here and throughout the book is the mixed use of units; i.e., miles per hour and meters per second for measuring wind velocity. One would wish that the authors had selected a single set of units and used them consistently or, alternately, that they had provided conversions in parentheses when they chose to deviate. After several quick, approximate conversions, this reviewer resorted to preparing a crib sheet for converting units.

Part B covers wind loads and their effects on structures. The first three chapters cover fundamentals. A long chapter describes bluff body aerodynamics and provides techniques for calculating wind load on a variety of structures. Structural dynamics is treated in a 22-page chapter that is rather superficial. A number of good books are available on structural dynamics, and the chapter was probably not necessary. A chapter on aeroelastic phenomena provides a good overview.

The final five chapters relate to design application. Techniques are provided for estimating wind and structural responses in the direction of the wind. In addition, cross wind and torsional responses are considered. The wind tunnel is introduced as a design tool – because appropriate tunnels are limited in number and in capability, this section can, at best, provide most readers with an idea of when it might be appropriate to recommend a wind tunnel test.

This reviewer found the chapter on wind-induced discomfort in and around buildings particularly interesting and *informative*. This reviewer had been exposed to a number of case studies on this subject, but the authors presented a 40-page general description of the problem. The final chapter is an introduction to tornadoes. Finally there are appendices on probability theory and random processes.

This book would be a very usable text for a course on wind engineering. It would also be valuable to engineers involved in designs in which wind must be considered. The user is likely to find the needed information in one or two chapters. The book is well prepared and edited and would be a worthwhile addition to any engineering library.

K.E. McKee
Engineering Division
IIT Research Institute
10 W. 35th Street
Chicago, Illinois 60616

NONLINEAR OSCILLATIONS

A.H. Nayfeh and D.T. Mook
John Wiley & Sons, New York, New York
1979, $38.50

Nonlinear Oscillations is a new addition to the "Pure and Applied Mathematics" series published by Wiley-Interscience. It deals with the analysis of a wide spectrum of problems pertaining to nonlinear oscillatory systems. These include single- and multi-degree-of-freedom systems in which the nonlinearities give rise to different types of resonances.

This extensive volume (over 700 pages) contains eight chapters and a bibliography of more than 1500 references. The authors give an exhaustive survey in the beginning of each chapter and in each main section. Each chapter ends with a challenging set of problems. An overview of the contents of the book is contained in the first chapter.

The second and third chapters treat autonomous systems with a single degree of freedom. The free response of conservative systems with stiffness nonlinearity is described using three classical examples. The behavior of such systems is given qualitatively (using the phase plane) and quantitatively (using perturbation techniques). Chapter three deals with nonconservative systems. Positive and negative damping mechanisms are analyzed and discussed.

Non-autonomous single-degree-of-freedom systems are investigated for two classes of excitation: forced excitation in chapter four and parametric excitation in chapter five. Treatment of forced excitation includes quadratic and cubic nonlinearities, sources of self-excitation, multi-frequency excitations, and excitations generated by a nonideal source of energy. For parametrically excited systems – that is, systems whose motions can be described by differential equations with time-varying coefficients – the dynamic stability is examined in the light of Floquet theory as applied to single- and multi-degree-of-freedom systems. This chapter also covers a number of theories concerning parametric stability including Hill's infinite determinant and the methods of strained parameters and multiple scales. The effects of damping and gyroscopic and nonlinear forces are also examined. The response of systems with repeated frequencies is described in detail.

The behavior of autonomous and non-autonomous systems having a finite number of degrees of freedom is discussed in chapter six. The analysis includes the response in the neighborhood of internal-resonance conditions, referred to as autoparametric resonance by some authors. The influence of quadratic and cubic nonlinearities on the response is graphically demonstrated. The phenomena of saturation, non-existence of periodic motions, and energy exchange among modes are explained.

Chapter seven examines the resonance vibrations of such nonlinear continuous structural systems as beams, strings, plates, membranes, discs, and shells. Natural sources of nonlinearities – such as geometry, inertia, and material properties – are considered in the course of deriving the governing equations of motion.

The last chapter deals with dispersive and non-dispersive traveling waves. The distinction between the two classes is based on the types of solutions rather than the types of governing equations. The authors explain the physical phenomena associated with this problem with two examples: transverse waves along a beam supported on a nonlinear elastic foundation and longitudinal waves along a rod with nonlinear elastic properties.

The reviewer notes that the bibliography, although extensive, lacks hundreds of recent and fundamental papers published in foreign periodicals. A remarkable feature of the book, however, is the substantial amount of new material presented including, for the first time, multi-frequency excitations and continuous systems. The book will be very useful to students, teachers, and researchers in the area of nonlinear vibrations. The authors should be commended for successfully simplifying the material of such a difficult topic and making it readable and understandable.

R.A. Ibrahim
Dept. of Mechanical Engineering
Texas Tech University
Lubbock, Texas 79409

SHORT COURSES

MAY

BASIC INSTRUMENTATION SEMINAR

Dates: May 5-7, 1981
Place: Edmonton, Alberta
Dates: September 15-17, 1981
Place: New Orleans, Louisiana
Dates: October 20-22, 1981
Place: Houston, Texas
Dates: October 27-29, 1981
Place: Pittsburgh, Pennsylvania

Objective: This course is designed for maintenance technicians, instrument engineers, and operations personnel - those individuals responsible for installation and proper operation of continuous monitoring systems. An in-depth examination of probe installation techniques and monitoring systems including types, functions, and calibration procedures is provided. Also presented is an overview of some of the instrumentation used to acquire data for vibration analysis, including oscilloscopes, cameras, and specialized filter instruments.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

OPTIMIZATION TECHNIQUES

Dates: May 6-9, 1981
Place: Gatlinburg, Tennessee

Objective: The ultimate goal of the industrial experimenter is optimum operating conditions in the laboratory and in the plant. This course will deal with the problem of miximizing product quality while minimizing product cost. The various experimental designs discussed in the course will enable the experimenter to do this both efficiently and economically. Industrial applications with industrial examples will be emphasized throughout the course.

Contact: ASQC, Industrial Seminars, c/o R.E. DeBusk, Box 3803, Kingsport, Tennessee 37664 - (615) 245-6793.

THE IBRAHIM TIME DOMAIN (ITD) MODAL VIBRATION TESTING TECHNIQUE

Dates: May 18-19, 1981
Place: Virginia Beach, Virginia

Objective: This course is designed for engineers and scientists who are involved in modal identification and testing of all types of structures. Flutter-testing dynamicists will also find this technique useful. The workshop will present an in-depth study of the ITD method including in-class computer demonstration. Participants will also receive the latest complete computer program of the ITD method and subroutines.

Contact: School of Continuing Studies, Operations Division, Old Dominion University, Norfolk, Virginia 23508 - (804) 440-4243.

ROTORDYNAMICS OF TURBOMACHINERY

Dates: May 18-20, 1981
Place: College Station, Texas

Objective: To provide a bridge between dynamics theory and the typical hands-on vibrations/instrumentation short course for the engineer who needs a basic understanding of practical turbomachinery rotordynamics. The course will treat balancing, rotordynamic instability, and torsional vibration problems. Fundamentals of each area will be followed up by case histories from engineering practice.

Contact: Dr. John M. Vance, Dept. of Mechanical Engineering, Texas A&M University, College Station, Texas 77843 - (713) 845-1251.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: May 18-22, 1981
Place: Syosset, New York
Dates: August 24-28, 1981
Place: Santa Barbara, California
Dates: October 5-9, 1981
Place: Bournemouth, England

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 St., Santa Barbara, CA 93105 - (815) 682-7171.

COMPUTER SIMULATION OF HIGH VELOCITY IMPACT

Dates: May 26-28, 1981
Place: Baltimore, Maryland
Objective: Seminar provides an overview of physical response of materials and structures to intense impulsive loading and surveys computer programs for wave propagation and impact studies. Numerous applications are discussed together with guidelines for program selection, implementation and effective use.

Contact: Computational Mechanics Assoc., P.O. Box 11314, Baltimore, Maryland 21239.

JUNE

VIBRATION DAMPING

Dates: June 1-4, 1981
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, and problem solving sessions.

Contact: Michael L. Drake, University of Dayton Research Institute, Dayton, Ohio 45469 - (503) 229-2644.

MACHINERY DATA ACQUISITION

Dates: June 1-5, 1981
August 3-7, 1981
September 28 - October 2, 1981
December 7-11, 1981
Place: Carson City, Nevada
Objective: This seminar is designed for people whose function is to acquire machinery data for dynamic analysis, using specialized instrumentation, and/or that person responsible for interpreting and analyzing the data for the purpose of corrective action on machines. Topics include measurement and analysis parameters, basic instrumentation review, data collection and reduction techniques, fundamental rotor behavior, explanation and symptoms of common machinery malfunctions, including demonstrations and case histories. The week also includes a lab workshop day with hands-on operation of the instrumentation and demonstration units by the participants.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

FINITE ELEMENTS: A FIRST COURSE

Dates: June 1-5, 1981
Place: Austin, Texas
Objective: This course is designed to introduce the participants to the fundamental concepts of the finite element method, its underlying mathematical basis, implementation in computer codes, and application to problems in engineering. No prior experience in formal finite element courses is required; our intention is to equip the participants with the basic skills needed to understand and use the method. Each day will be comprised of lectures followed by tutorial and problem-solving sessions. Computer time and the opportunity to use existing TICOM programs will be available to supplement the activities. Our approach to the subject is not tied to a specific field. Practical application will include problems in solid mechanics, fluid mechanics, and heat transfer.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, Texas 78712 - (512) 471-3396.

NOISE-CON SEMINAR

Dates: June 4-6, 1981

Place: Raleigh, North Carolina

Objective: An intensive short course on principles and applications of noise control. The course will cover the fundamentals of noise control, in-plant noise control, techniques for noise measurement, acoustical standards used in noise measurements, design of facilities for noise control and data reduction.

Contact: Institute of Noise Control Engineering, P.O. Box 3206, Arlington Branch, Poughkeepsie, New York 12603 - (914) 462-6719.

COMPUTER-AIDED DESIGN OF DYNAMIC SYSTEMS

Dates: June 15-19, 1981

Place: East Lansing, Michigan

Objective: This course presents a structured approach to model building, formulation of state equations, and computer-aided analysis of the models. Applications are drawn from mechanical, electrical, hydraulic, thermal, and mixed-energy systems.

Contact: Dr. Ronald C. Rosenberg, Program Director of the A.H. Case Center for Computer-Aided Design, College of Engineering, Michigan State University, East Lansing, Michigan 48824 - (517) 355-8296.

COMPUTER-AIDED METHODS FOR MODAL ANALYSIS

Dates: June 22-26, 1981

Place: East Lansing, Michigan

Objective: This course introduces both finite elements and modal testing, emphasizing this common theory and pointing out the particular advantages of each method. Hardware includes the GenRad 2507, the Hewlett Packard 5423, and the PRIME 750. Software includes ANSYS, MODAL PLUS, and SUPERTAB.

Contact: Dr. James E. Bernard, Director for the Case Center for Computer-Aided Design, College of Engineering, Michigan State University, East Lansing, Michigan 48824 - (517) 355-6453.

MECHANICS OF HEAVY-DUTY TRUCKS AND TRUCK COMBINATIONS

Dates: June 22-26, 1981

Place: Ann Arbor, Michigan

Objective: The heavy truck or truck combination is a complex pneumatic-tired system. This course presents analysis programs, parameter measurement methods and test procedures useful in understanding and designing a vehicle. The course describes the physics of heavy-truck components that determine the braking, steering and riding performance of the total system.

Contact: University of Michigan, College of Engineering, Continuing Engineering Education, 300 Chrysler Center, North Campus, Ann Arbor, Michigan 48109 - (313) 764-8490.

FUNDAMENTALS OF NOISE AND VIBRATION CONTROL

Dates: June 22-26, 1981

Place: Cambridge, Massachusetts

Objective: This one week program is designed to provide a background in those aspects of sound and vibration that are important to noise control engineering. The general approach will be based on engineering concepts rather than theoretical analysis. The program is designed for the working engineer who has become involved in noise problems and seeks to deepen his/her understanding of the subject.

Contact: Director of Summer Session, Room E19-356, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

JULY

12TH ANNUAL INDUSTRIAL PRODUCT NOISE CONTROL INSTITUTE

Dates: July 6-10, 1981

Place: Schenectady, New York

Objective: For engineers, designers, environmental health specialists and managers concerned with noise and vibration control. This course will provide information on the theory, measurement and economics of noise reduction. It will cover the latest information on the nature of sound and noise control, including noise criteria, airborne sound distribution, vibration control, and noise signature analysis. Other topics include how noise is produced by different types of engineering equipment such as compressors, electric motors, fans, valves, and transformers.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

6TH ANNUAL APPLIED INSTRUMENTATION AND MEASUREMENTS ENGINEERING

Dates: July 6-10, 1981

Place: Schenectady, New York

Objective: Designed for technicians, engineers and managers involved in the field of instrumentation and measurements. It will present a comprehensive view of the instrumentation system from transducer to readout, including a major emphasis on computer interfacing techniques. Principal topics will include: philosophy of measurements, transducer operating principles and selection criteria, static and dynamic data acquisition sytems, occurrence and prevention of noise in measu ement sytems, data reduction methods, digital tec'iniques, and statistical treatment of data. "Hands-o.i" lab experience will be offered.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

COMPUTER-AIDED DESIGN OF CONTROL SYSTEMS

Dates: July 6-10, 1981

Place: East Lansing, Michigan

Objective: This course presents an introduction to time and frequency domain techniques for the computer-aided design of control sytems. Both classical (transfer function) and modern (state variable) methods will be developed and applied, thus bringing participants up to current best practice.

Contact: Dr. Ronald C. Rosenberg, Program Director of the A.H. Case Center for Computer-Aided Design, College of Engineering, Michigan State University, East Lansing, Michigan 48824 - (517) 355-8296.

INSURANCE INDUSTRY SEMINAR

Dates: July 7-9, 1981

Place: Carson City, Nevada

Objective: This course is designed for personnel from the insurance industry or self-insured companies who are responsible for inspection of plants that use large, high-speed rotating machinery. Features in the seminar include: discussion of the economics of machine monitoring and predictive maintenance; presentation of machine types that should be considered, and minimum standards necessary for effective machine protection diagnosis; information and the presentation of catastrophic failure by use of proper maintenance methods and malfunction diagnosis techniques; and survey of state-of-the-art methodology.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

PLANNING A DIGITAL DATA ACQUISITION AND CONTROL COMPUTER SYSTEM

Dates: July 20-23, 1981

Place: Schenectady, New York

Objective: The course covers the interconnection of a multitude of devices from sensors to final control elements with ultimate output of system conditions on the man-machine interface devices; the sensing of temperature, pressure, level, flow, speed, weight, torque, vibration and electrical parameters such as: volts, amps, watts, vars, power factor, frequency and motor load. The flexibility and utilization of data presentation via dynamic, colored graphic and tabular CRT displays, is presented as an optimum man-machine interface. System components/hardware and their interconnection are discussed in depth. Staging, on-site testing and as-built documentation are the final steps in the planning of a digital acquisition and control computer system.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

12TH ANNUAL CONFERENCE ON FRACTURE MECHANICS I AND ITS APPLICATION TO FRACTURE CONTROL

Dates: July 20-24, 1981

Place: Schenectady, New York

Objective: Material covered will benefit anyone in an engineering related position who is concerned with the application of fracture mechanics to the prevention of brittle fracture such as pressure vessels for power generation, malleable iron castings, structural steel fabricated frameworks and ASME Pressure Vessel code applications. Included are: engineering approach to component failure; failure analysis of pressure vessels; fracture mechanics based toughness criteria in ASME Pressure Vessel code; examples and case histories of code fracture mechanics applications; elasto-plastic analysis; computer aids for calculating remaining cyclical life; crack initiation and propagation, life prediction, and nondestructive testing methods and capabilities.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

COMPUTATIONAL WORKSHOP IN LINEAR AND NONLINEAR STRUCTURAL AND SOLID MECHANICS

Dates: July 27-31, 1981

Place: Schenectady, New York

Objective: For those interested in applications to current technological problems such as earthquake analysis, pipe whip dynamics and fluid-solid interaction, as well as other areas. The following will be covered: structural dynamics techniques for both linear and nonlinear many-degree-of-freedom systems; incremental loading into the plastic range and finite element methods in fracture mechanics; random vibration methods; response spectrum methods for many-degree-of-freedom systems. A nonlinear dynamics computer program as well as eigenvalue and sinusoidal analysis programs will be available for workshop use. Relative merits of ANSYS, SAP, ADINA, etc., programs will be discussed. Computer graphics for input generation and output presentation will be available.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

COMPUTER WORKSHOP IN FINITE ELEMENT METHODS OF ANALYSIS FOR STRESS AND OTHER FIELD PROBLEMS

Dates: July 27-31, 1981

Place: Schenectady, New York

Objective: For those interested in applications to current technological problems such as thermal and stress analysis of nuclear vessel nozzle, 3D pipe intersection, turbine blade application, water mass of nuclear fuel channels, as well as other areas. The following will be covered. finite element techniques for 2D and 3D structural analysis and dynamics; both 2D and 3D programs, including listings; generalization of finite element methods to heat transfer and fluid flow with programs in each discipline; incremental loading into the plastic range and finite element methods in fracture mechanics; relative merits of ANSYS, SAP, ADINA, etc., programs. Computer graphics for input generation and output presentation will be available.

Contact: Union College, Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Schenectady, New York 12308 - (518) 370-6288.

AUGUST

FOUNDATIONS OF ENGINEERING ACOUSTICS

Dates: August 10-21, 1981

Place: Cambridge, Massachusetts

Objective: This summer program is a specially developed course of study which is based on two regular MIT subjects (one graduate level and one undergraduate level) on vibration and sound in the Mechanical Engineering Department. The program emphasizes those parts of acoustics - the vibration of resonators, properties of waves in structures and air - the generation of sound and its propagation that are important in a variety of fields of application. The mathematical procedures that have been found useful in developing the desired equations and their solutions, and the processing of data are also studied. These include complex notation, fourier analysis, separation of variables, the use of special functions, and spectral and correlation analysis.

Contact: Director of Summer Session, Room E19-356, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

PYROTECHNICS AND EXPLOSIVES

Dates: August 17-21, 1981

Place: Philadelphia, Pennsylvania

Objective: The seminar combines the highlights of Pyrotechnics and Solid State Chemistry, given the last twelve summers, and Explosives and Explosive Devices that made its successful appearance ten years ago. Similar to previous courses, the seminar will be practical so as to serve those working in the field. Presentation of the theory is restricted to that necessary for an understanding of basic principles and successful application to the field. Coverage emphasizes recent effort, student problems, new techniques, and applications.

Contact: Mr. E.E. Hannum, Registrar, The Franklin Research Center, Philadelphia, Pennsylvania 19103 - (215) 448-1236/1395.

MECHANICAL ENGINEERING

Dates: August 31 - September 4, 1981

Place: Carson City, Nevada

Objective: This course is designed for the mechanical or maintenance engineer who has responsibility for the proper operation and analysis of rotating machinery. Working knowledge of transducers, data acquisition instrumentation and fundamental rotor behavior is a prerequisite. The course includes: a guest speaker in the field of machinery malfunctions; descriptions and demonstrations of machinery malfunctions; discussions of the classification, identification, and correction of various machine malfunctions; a one day rotor dynamics lab with individual instruction and operation of demonstration units; and emphasis on the practical solution of machinery problems rather than rotor dynamic theory.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

SEPTEMBER

10TH ADVANCED NOISE AND VIBRATION COURSE

Dates: September 14-18, 1981

Place: Southampton, England

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

Contact: Mrs. O.G. Hyde, ISVR Conference Secretary, The University, Southampton S09 5NH, England - (0703) 559122 X 2310/752, Telex 47661.

OCTOBER

DESIGN OF FIXED OFFSHORE PLATFORMS

Dates: October 5-16, 1981

Place: Austin, Texas

Objective: This course is dedicated to the professional development of those engineers, scientists, and technologists who are and will be designing fixed offshore platforms to function in the ocean environment from the present into the twenty-first century. The overall objective is to provide participants with an understanding of the design and construction of fixed platforms, specifically the theory and processes of such design and the use of current, applicable engineering methods.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, Texas 78712 - (512) 471-3506.

VIBRATION CONTROL

Dates: October 12-16, 1981

Place: University Park, Pennsylvania

Objective: The seminar emphasizes principles, general approaches and new developments, with the aim of providing participants with efficient tools for dealing with their own practical vibration problems.

Contact: Debra A. Noyes, 410 Keller Conference Center, University Park, Pennsylvania 16802 - (814) 865-8820, TWX No: 510-670-3532.

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

INTER-NOISE '82
May 17-19, 1982
San Francisco, California

INTER-NOISE '82, the eleventh International Conference on Noise Control Engineering will be held at the Jack Tar Hotel in San Francisco on May 17-19, 1982. The conference is sponsored by the International Institute of Noise Control Engineering and will be organized by the Institute of Noise Control Engineering of the United States of America.

The conference will be held ten years after the enactment of the Noise Control Act of 1972, and the theme will be "Noise Control: Ten Years Later."

INTER-NOISE '82 will feature an exhibition of materials and equipment for noise control. Technical papers in all areas of noise control engineering will be presented during the three-day conference. A special feature of INTER-NOISE '82 will be the presentation of both retrospective and prospective dialogues on noise control engineering and its impact on society. It is hoped that the retrospective and prospective viewers will bring the delegates to the conference solid evidence of past progress and future hope.

For further information, contact: Conference Secretariat, Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, New York 12603.

INTER-NOISE '80 PROCEEDINGS AVAILABLE

More than 600 engineers concerned with noise control attended INTER-NOISE '80, the 1980 International Conference on Noise Control Engineering which was held in Miami, Florida on December 8-10, 1980. The meeting covered a very wide variety of topics, including machinery noise control, impact noise, land use planning around airports, instrument calibration and certification, rapid transit system noise control, building noise control, valve noise, active noise attenuators and many other subjects in noise control engineering.

The papers presented at the conference have been collected into a two-volume set of Conference Proceedings which contain a total of 1,296 pages. The book, edited by Dr. George C. Maling, Jr., is a comprehensive summary of the state of the technology in noise control. Copies of the Proceedings are available for $49.50.

For further information, contact: Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, New York 12603.

Call For Papers

MECHANICAL FAILURES PREVENTION GROUP
34th SYMPOSIUM
October 21-23, 1981
"Designing for Damage Prevention in the Transportation Environment"

The Mechanical Failures Prevention Group (MFPG), under the sponsorship of the National Bureau of Standards, will hold its 34th Symposium at the National Bureau of Standards, Gaithersburg, Maryland, October 21-23, 1981.

This symposium is seeking papers that will discuss:

- The damage sustained by transported goods during shipment on the ground and in the air arising from the dynamic transportation environment (shock, vibration, temperature, pressure, humidity, etc.)
- Control of the environment through improvements in vehicle and road design, mechanical handling gear, personnel training
- Measurements of the dynamic environment
- Stowing and packaging techniques and design
- Human factors
- Economics - damage prevention and insurance

Proceedings will be published by the National Bureau of Standards. Closing date for abstracts is June 1, 1981. Abstracts should be sent to Jesse E. Stern, Trident Engineering Associates, 1507 Amherst Road, Hyattsville, MD 20783 (301-422-9506), or to Dr. J.C. Shang, General American Research Division, General American Transportation Corporation, 7449 North Natchez Avenue, Niles, IL 60648 (312-647-9000).

INFORMATION RESOURCES

THE PLASTICS TECHNICAL EVALUATION CENTER (PLASTEC)

MISSION

PLASTEC is one of 20 information analysis centers sponsored by the Department of Defense to provide the defense community with a variety of technical information services applicable to plastics, adhesives, and organic-matrix composites. Since 1960 PLASTEC (which is assigned to the U.S. Army Armament R&D Command in Dover, NJ) has been supplying this community with authoritative information and advice in such forms as engineering assistance, responses to technical inquiries, special investigations, field trouble-shooting, failure analysis, literature searches, state-of-the-art reports, data compilations, and handbooks. PLASTEC is also heavily involved in standardization activities.

Evaluation and Analysis

The significant difference between a Library and a Technical Evaluation Center is the quality of the information provided the user. PLASTEC uses its data base "library" as a means to an end – to provide succinct and timely information which has been carefully evaluated and analyzed. Examples of this activity include recommendation of materials, counseling on designs, and performing trade-off studies between various materials, performance requirements, and costs. Applications are examined consistent with current manufacturing capabilities; market availability of new and old materials alike is considered. PLASTEC specialists can reduce raw data to the user's specifications and supplement them with unpublished information which updates and refines published data. Use of personal contacts in leading high technology companies opens doors to new developments. PLASTEC works to spin-off the results of government sponsored R&D to industry and similarly to utilize commercial advancements to the government's benefit; a realization of the highly sought technology transfer goal.

THE STAFF

The staff includes chemical engineers, mechanical engineers, and chemists, all of whom have worked for or with material suppliers, manufacturers, the Department of Defense, and other agencies and departments of the Government. They have had extensive personal experience in research, component design and development, as well as in testing and evaluation.

It should also be mentioned that PLASTEC is backed up by the CDC 6500/6600 computers at U.S. ARRADCOM and by the staff resources of ARRADCOM's Organic Materials Branch. Prototype design, development, fabrication, and testing are carried on in one major area of the Branch, and adhesives engineering and development in the other. The Branch's capabilities are being strengthened in elastomers, fluids, and lubricants technology. Well equipped laboratories complement the diverse technical skill of the staff.

THE DATA BASE

Library

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

ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 950, 951, 1091, 1115, 1162)

81-867

Vibration of a Rotating Uniform Beam, Part 1: Orientation in the Axis of Rotation

H.F. Bauer
Fachbereich Luft- und Raumfahrttechnik, Hochschule der Bundeswehr, München, West Germany,
J. Sound Vib., 72 (2), pp 177-189 (Sept 22, 1980) 6 figs, 2 tables, 22 refs

Key Words: Beams, Rotors, Natural frequencies, Boundary condition effects

The vibrational behavior of a beam rotating with constant spin about its longitudinal axis has been investigated for all possible combinations of free, clamped, simply-supported and guided boundaries. The natural frequencies for all these cases are shown either to decrease or increase linearly with increasing spin frequency. In addition the response to harmonically forced oscillations of the beam is presented.

81-868

Dynamic Stability of Rotating Shafts

A. Tylikowski
Warsaw Tech. Univ., Narbutta 84, 02524 Warszawa, Poland,
Ing. Arch., 50 (1), pp 41-48 (1981) 6 refs

Key Words: Shafts, Stochastic processes

In the paper, using the direct method, stability of elastic rotating shafts (beams, pipes) working in different conditions is analyzed. A constant axial force as well as a uniformly distributed load in the case of long shafts are considered. The case of conservative load (e.g. dead weight) as well as nonconservative load acting tangentially to the shaft axis is considered. The case when the applied force is a wide-band Gaussian stochastic process is also discussed.

81-869

A Theoretical-Experimental Comparison of the Synchronous Response of a Bowed Rotor in Five Different Sets of Fluid Film Bearings

R.D. Flack and J.H. Rooke
Dept. of Mech. and Aerospace Engrg., Univ. of Virginia, Charlottesville, VA 22901,
J. Sound Vib., 73 (4), pp 505-517 (Dec 22, 1980) 10 figs, 3 tables, 21 refs

Key Words: Rotors, Fluid film bearings

A comparison of theoretical and experimental synchronous unbalance responses of a bowed Jeffcott rotor in fluid film bearings has been completed. A transfer matrix method was used to predict theoretically the response of a 25·4 mm shaft in fluid film bearings and results were compared to data from a previous experimental study. Four bearing types were used: two axial groove, pressure dam, tilting pad and four-lobe. Very good agreement was found for all bearing types at the rotor critical speed (3000 rpm). Differences less than 15% in peak response were found and the theoretical and experimental peaks were found to occur within 200 rpm. Worst agreement was found for the preloaded four-lobe bearings, and this disagreement was found for speeds other than the critical speed. Also, for equal bow and unbalance the tilting pad and four-lobe bearings were found to produce the least and most damping at the critical speed, respectively.

81-870

Solution Method for Eigenvalue Problem of Rotor-Bearing Systems (Part 1: Undamped Systems with Isotropic Supports)

O. Matsushita, K. Kikuchi, S. Kobayashi, and M. Furudono
Mech. Engrg. Res. Lab. of Hitachi Ltd., 502, Kandatsu-MACHI, Tuchiura-SHI, IBARAKI, Japan,
Bull. JSME, 23 (185), pp 1872-1878 (Nov 1980) 11 figs, 1 table, 8 refs

Key Words: Rotors, Eigenvalue problems, Critical speeds

An equation of motion for general rotating shaft systems with many disks and bearings is formulated by the finite element method and a consistent gyroscopic matrix is derived. In this report, undamped eigenvalue and critical speed analyses for a rotor supported by isotropic bearings are discussed. An algorithm for an eigenproblem solution is presented. Using the algorithm developed, approximate eigenvalues and eigenvectors converge iteratively to the exact values, based on the asymptotic method. The procedure leads to a perfect orthogonality of eigenvectors. Numerical results are demonstrated for typical rotor-bearing systems.

81-871

The Vibration of a Multi-Bearing Rotor

J.L. Nikolajsen and R. Holmes
School of Engrg. Appl. Sciences, Univ. of Sussex, Brighton BN1 9QT, UK, J. Sound Vib., 72 (3), pp 343-350 (Oct 8, 1980) 5 figs, 1 table, 4 refs

Key Words: Numerical methods, Rotors, Influence coefficient method

A numerical method based on the use of influence coefficients is described for the free and forced vibration analysis of a general rotor/bearing system. The method is found to combine the numerical speed of the transfer matrix method with the accuracy and versatility of the finite element method. The paper describes the prediction of the vibration performance of a four-bearing rotor with which experimental results compare satisfactorily.

81-872

Aeroelastic Stability of Wind Turbine Rotors

P.C. Hensing
Dept. of Aerospace Engrg., Delft Univ. of Tech., The Netherlands, Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. Southampton, Vol. II, pp 631-639, 11 figs, 5 refs

Key Words: Rotors, Wind turbines, Flutter, Aeroelasticity

This paper deals with the aeroelastic stability of wind turbine rotors with low blade torsional frequency as for instance tipvane rotors. Several types of instability as two-degrees-of-freedom flutter, stall-flutter and torsional divergence are found. A comparison between theoretical flutter boundaries and experimental values is attempted.

81-873

Analysis and Correlation of Test Data from an Advanced Technology Rotor System

D. Jepson, R. Moffitt, and J.B. Hilzinger
Sikorsky Aircraft, Stratford, CT, Rept. No. NASA-CR-152366, 169 pp (July 1980)
N80-33351

Key Words: Rotors, Blades, Vibration excitation

The performance and blade vibratory load characteristics for an advanced rotor system as predicted by analysis and as measured in a 1/5 scale model wind tunnel test are reported. A full scale model wind tunnel test and flight test were compared. The 1/5 scale model rotor predicted conservative full scale rotor performance as expected due to Reynolds number effects. Although blade vibratory moment trends with advance ratio were predicted by the 1/5 scale model, the absolute values of the blade vibratory moments were underpredicted.

81-874

A Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics. Part 1: Analysis Development

W. Johnson
NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-81182, 442 pp (June 1980)
N80-28296

Key Words: Rotors, Helicopters, Rotary wings, Wind induced excitation, Computer programs

Structural, inertia, and aerodynamic models were combined to form a comprehensive model of rotor aerodynamics and dynamics that is applicable to a wide range of problems and a wide class of vehicles. A digital computer program is used to calculate rotor performance, loads, and noise; helicopter vibration and gust response; flight dynamics and handling qualities; and system aeroelastic stability. The analysis is intended for use in the design, testing, and evaluation of rotors and rotorcraft, and to be a basis for further development of rotary wing theories.

81-875

Off-Design Correlation for Losses Due to Part-Span Dampers on Transonic Rotors

W.B. Roberts, J.E. Crouse, and D.M. Sandercock
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TP-1693, E-309, 24 pp (July 1980)
N80-28352

Key Words: Fans, Dampers, Damper locations

Experimental data from 10 transonic fan rotors were used to correlate losses created by part-span dampers located near the midchord position on the rotor blades. The design tip speed of these rotors varied from 419 to 425 m/sec, and the design pressure ratio varied from 1.6 to 2.0. Additional loss caused by the dampers for operating conditions between 50 and 100 percent of design speed were correlated with relevant aerodynamic and geometric parameters. The resulting correlation predicts the variation of total-pressure-loss coefficient in the damper region to a good approximation.

81-876

Parametrically Excited Torsional Vibrations in Systems of Engines and Driven Machines with Periodically Varying Moments of Inertia (Parametrische Drehschwingungen bei der Kopplung von Kraft- und Arbeitsmaschinen mit periodisch veranderlichen Massentragheitsmomenten)

G. Dittrich and H. Krumm
Institut f. Getriebetechnik u. Maschinendynamik der RWTH, Aachen, Germany, Forsch. Ingenieurwesen, 46 (6), pp 181-195 (1980) 23 figs, 4 tables, 10 refs
(In German)

Key Words: Engine vibration, Variable material properties, Torsional vibration, Rotors

In systems of elastically coupled rotating machinery with variable moments of inetia, vibrations may occur, which are not merely forced by external loads and inertia forces but -- to a substantial amount - are caused by parametric excitation. An algorithm and a computer program are presented for the steady-state vibrations of those systems with up to 19 degrees of freedom; expressing the excitations and the response by Fourier-series. This method allows correlation between causes and results.

81-877

A Computer Aided Engineering Approach in the Design of Impellers

J.J. Suarez and R.D. Bennetts
Industrial Systems Consulting Services, Structural Dynamics Res. Corp., SAE Paper No. 801171, 16 pp, 13 figs, 8 refs

Key Words: Impellers, Computer aided techniques, Design techniques

Computerized Aided Engineering (CAE) techniques currently used in the design of impellers is presented. Both computerized flow performance analysis and structural integrity analysis methods are discussed. Computer graphic capabilities used in the design cycle are also listed. An approach to evaluate the structural integrity of impellers under steady state and dynamic loading is given. Correlation between analytical and test results is presented. The emphasis of the paper is placed on the structural integrity aspects.

RECIPROCATING MACHINES

81-878

Analysis of Vibration of Cylinder Block by Reduced Impedance Method

A. Nagamatsu, Y. Hayashi, and A. Ishihara
Tokyo Inst. of Tech., Meguroku, Tokyo, Japan, Bull. JSME, 23 (185), pp 1879-1883 (Nov 1980) 14 figs, 2 tables, 5 refs

Key Words: Diesel engines, Cylinders, Mechanical impedance, Finite element technique, Natural frequencies, Mode shapes

Vibrations of cylinder blocks of diesel engines with 4 and 6 bores are analyzed by the reduced impedance method proposed by the authors. A cylinder block is divided into some component structures, and the mechanical impedances of each component are calculated by the finite element method. The natural frequencies are detected experimentally, using the Fourier translations of the measured impact waves of the force and the acceleration. The natural modes are observed by the holographic technique with an argon gas laser. The calculated results agree well with the experimental ones.

POWER TRANSMISSION SYSTEMS

81-879

Minimizing Noise in Transmissions

R.J. Drago
Boeing Vertol Co., Philadelphia, PA, Mach. Des., 53 (1), pp 143-148 (Jan 8, 1981) 13 figs

Key Words: Gear drives, Power transmission systems, Noise reduction

Even when noise-reducing measures are employed during the initial design of a transmission, a drive may require further silencing after it is built. Various acoustical treatments can be applied experimentally to reduce both airborne and structure-borne noise.

METAL WORKING AND FORMING

81-880

Optimization of Machine Tool Structures Using Structural Modelling Techniques

A.R. Whittaker and M.M. Sadek
Dept. of Mech. Engrg., Univ. of Birmingham, Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed.,

Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 211-223, 13 figs, 14 refs

Key Words: Machine tools, Chatter, Optimization, *Mathematical models*

A technique is developed for improving the dynamic characteristics of existing machine tool structures by adding masses or stiffeners at strategic points using modal analysis. The technique is illustrated by its application to a small horizontal milling machine.

STRUCTURAL SYSTEMS

BRIDGES

(Also see No. 1099)

81-881

Investigation of the Vibrational Behavior of a Cable-Stayed Bridge under Wind Loads

J.W.G. van Nunen and A.J. Persoon

Flight Dynamics Div., Nat. Aerospace Lab., Amsterdam, The Netherlands, Rept. No. NLR-MP-79004-U, 15 pp (Feb 12, 1979)

N80-31672

Key Words: Bridges, Cable stiffened structures, Wind-induced excitation, Flutter, Vortex shedding, Wind tunnel tests

Wind tunnel tests were carried out on a two dimensional model to establish the flutter stability of the bridge and to determine resonance vibrations due to vortex shedding. During construction of the actual bridge, vibration measurements were performed and the wind-induced vibrational behavior of the structure was observed. Measured resonance vibration agreed very well with the values for the model tests in the tunnel.

BUILDINGS

(Also see No. 1004)

81-882

A Simple Model for Nonlinear Seismic Analysis of Reinforced Concrete Structures

M. Saiidi

Civil Engrg. Dept., Univ. of Nevada, Reno, Nevada, Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 579-586, 4 figs, 2 tables, 7 refs

Key Words: Buildings, Reinforced concrete, Seismic analysis, Mathematical models

The present paper introduces a simple nonlinear model (called the Q-Model) for displacement-time analysis of multi-story reinforced concrete structures subjected to strong ground motions. The model has been successful in reproducing the experimental response histories of eight small-scale ten-story test structures.

81-883

Prediction of Seismic Damage in Reinforced Concrete Frames. Seismic Behavior and Design of Buildings, Report No. 3

H. Banon, J.M. Bigg. and H.M. Irving

Dept. of Civil Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. R80-16, NSF/RA-800121, 188 pp (May 1980)

PB81-103640

Key Words: Frames, Buildings, Reinforced concrete, Seismic response

Development and testing of a rigorous model to identify and predict local damage in reinforced concrete frames under seismic loads are reported. Analytical models for inelastic behavior of reinforced concrete members were used to analyze a set of static load tests under a variety of loading conditions. Other damage indicators such as dissipated energy and cumulative plastic rotation were measured for each test. Results of the sample were used to develop a stochastic model of damage for reinforced concrete members. The stochastic model computes probabilities of member failure under inelastic load cycles. The model was applied to inelastic dynamic analysis of a 4-story and an 8-story *building frame under several earthquake motions. Final* results are presented by probabilities of local failure in a building frame subjected to a given earthquake.

TOWERS

(See No. 1160)

FOUNDATIONS

81-884

Dynamic Stiffness and Seismic Response of Sleeved Piles

A.M. Kaynia and E. Kausel

Constructed Facilities Div., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. MIT-CE-R80-12, NSF/RA-800089, 62 pp (May 1980)
PB80-216633

Key Words: Pile structures, Stiffness coefficients, Seismic response, Finite element technique

An axisymmetric finite element formulation with a consistent transmitting boundary is used to obtain dynamic stiffnesses and seismic response of sleeved piles in linear viscoelastic soil media. A sleeved pile consists of a column within a sleeve of substantially larger diameter which is filled with concrete to some depth below grade level.

81-885

Nonlinear Dynamic Stiffness of Piles

D.C. Angelides and J.M. Roesset

Dept. of Civil Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. R80-13, NSF/RA-800088, 40 pp (Apr 1980)
PB80-221898

Key Words: Pile structures, Interaction: soil-structure, Stiffness coefficients

The effect of nonlinear soil behavior, without slippage or gapping, on the dynamic response of piles is explored. This research uses a finite element model for the soil region adjoining the pile; a consistent boundary matrix at some distance to reproduce radiation effects; and an iterative, equivalent linearization technique to estimate the variation of soil properties with level strain. A cylindrical region of soil surrounding the pile is discretized using toroidal finite elements. The pile is modeled as a series of beam segments attached through rigid links to the finite element nodes. The results consider hollow, floating piles with aspect ratio (length over diameter) equal to 45. The top of the pile is assumed to be free. Comparing the results of this analysis with those obtained using the p-y curves, it seems that the main difference is due to the lack of tension capacity in the soil and the appearance of gaps for larger forces. The results for the horizontal case indicate that as the level of force increases, there is an increase in internal soil damping, but a decrease in radiation. When both effects are combined, the effective damping ratio tends to increase.

81-886

Ground Vibrations from Impact Pile Driving during Road Construction

D.J. Martin

Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-SUPPLEMENTARY-544, 31 pp (1980)
PB81-108672

Key Words: Pile driving, Roads (pavements), Ground vibration

This report describes ground vibration measurements at seven sites generated by impact pile driving during road construction operations. Measurements were carried out to determine the relative magnitudes of the vibration components, the main frequency of the surface waves, and the velocity levels of the ground vibration. Relations were established between the vertical velocity level and the distance between source and receiver for four sheet piling operations. Floor vibration levels in buildings adjacent to piling activities were measured, and the likely effects of impact pile driving was made using criteria proposed elsewhere for architectural damage and human disturbance.

ROADS AND TRACKS

(See No. 886)

POWER PLANTS

(Also see Nos. 1146, 1149)

81-887

Noise Control in Industry

Noise Vib. Control, 11 (9), pp 343-347 (Nov/Dec 1980) 7 figs

Key Words: Power plants, Noise reduction, Industrial facilities, Noise generation

One of the largest most complex noise control projects ever undertaken in the United Kingdom at the combined heat and power station in Hereford is described.

81-888

Dynamic Testing of Nuclear Power Plant Structures – An Evaluation

H.J. Weaver

Lawrence Livermore National Lab., Livermore, CA, SAE Paper No. 801232, 16 pp, 4 figs, 1 table, 9 refs

Key Words: Nuclear power plants, Dynamic tests, System identification techniques

Lawrence Livermore National Laboratory (LLNL) evaluated the application of system identification techniques to the dynamic testing of nuclear power plant structures and subsystems. These experimental techniques involve exciting a structure and measuring, digitizing, and processing the time-history motions that result. The data can be compared to parameters calculated using finite element or other models of the test systems to validate the model and to verify the seismic analysis. This report summarizes work in three main areas: analytical qualification of a set of computer programs developed at LLNL to extract model parameters from the time histories; examination of the feasibility of safely exciting nuclear power plant structures and accurately recording the resulting time-history motions; and study of how the model parameters that are extracted from the data be used to evaluate structural integrity and analyze nuclear power plants.

81-889

Variability Associated with Seismic Testing Methods

R. Vasudevan and R. Campbell
Engineering Decision Analysis Co., Inc., Palo Alto, CA, SAE Paper No. 801130, 12 pp, 1 fig, 5 tables, 15 refs

Key Words: Nuclear power plants, Seismic response, Testing techniques

Safety related nuclear power plant systems and components are qualified for seismic adequacy by analysis, tests, or a combination of both. These seismic qualification methods are biased towards the conservative side due to the variability associated with the inherent randomness in the phenomenon being simulated and those related to the incomplete knowledge about the simulation. Major sources of variability in the test method of qualification are addressed and their approximate variations are enumerated.

81-890

Seismic Structural Response and Safety of a Large Fossil Fuel Steam Generating Plant

J.L. Bogdanoff and T.Y. Yang
School of Aeronautics and Astronautics, Purdue Univ., Lafayette, IN, Rept. No. NSF/RA-800119, 39 pp (Mar 7, 1980)
PB80-218183

Key Words: Fossil power plants, Boilers, Seismic response, Finite element technique, Computer programs

Seismic response studies using finite element models are summarized for two steam generators and their supporting structures of a 1,200 MW and a 600 MW fossil fuel steam generating plant. Prior to modeling, dynamic behavior analyses were performed on five major subsystems; supporting structure and steam generator; high pressure steam piping; stack; cooling tower; and coal handling equipment. Principal findings and suggested areas for future research for each subsystem are presented. Also included are abstracts of theses and lists of publications and scientific collaborators.

81-891

Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake

R.C. Murray, T.A. Nelson, R.D. Campbell, J.A. Young, and H.A. Levin
Lawrence Livermore National Lab., Livermore, CA, Rept. No. UCRL-53005, 165 pp (Oct 1980)
NUREG/CR-1665

Key Words: Earthquakes, Nuclear power plants, Seismic response, Gas turbines, Equipment response

A dynamic seismic analysis of Unit 4 of the El Centro Steam Plant in El Centro, California, built in 1968, was performed. Unit 4 is an oil-or-gas-fired, steam-driven turbine-generator that was designed to resist a static lateral force equivalent to 20% of the dead and live load applied laterally. The seismic analysis was done to analytically estimate the equipment response, which, when compared to actual observation, will indicate the levels of actual equipment capacity.

81-892

Dynamic Response of Nuclear Reactor Plant Due to Seismic Excitations

J.V. Parker, K.M. Ahmed, and S. Clayton
The Nuclear Power Co. (Risley), Ltd., Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 315-327, 8 figs, 7 tables, 4 refs

Key Words: Nuclear power plants, Seismic excitation, Finite element technique, Computer programs

In this paper the behavior of the Advanced Gas Cooled Reactor (AGR) primary circuit structures is analyzed. This component study includes the use of different finite element

idealizations and allows comparisons to be made between three different computer codes. Furthermore, the time-history response of the system is compared with the response calculated using the response spectrum technique.

81-893
Variability of Dynamic Characteristics of Nuclear Power Plant Structures. Seismic Safety Margins Research Program (SSMRP)

D.A. Wesley, P.S. Hashimoto, and R.B. Narver
Lawrence Livermore National Lab., CA, Rept. No. UCRL-15267, 75 pp (Sept 1980)
NUREG/CR-1661

Key Words: Nuclear power plants, Seismic response, Equipment response

This report presents the results of an investigation of the sources of random variability of the dynamic response of nuclear power plant structures. Sources affecting both the frequencies and dynamic amplification of structures are identified. Numerical values developed for the Zion auxiliary building are presented for sources of inherent randomness. Several sources of uncertainty resulting from lack of knowledge of material properties or approximations in analytical modeling are discussed but are not in general quantified. The evaluation of the dynamic response variability is limited to elastic response levels.

OFF-SHORE STRUCTURES

81-894
Vortex Shedding Forces and the Fatigue Analysis of Offshore Structures

S. Walker and S.G. Brazier
Structural Dynamics Ltd., Southampton, UK, Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 285-304, 10 figs, 17 refs

Key Words: Offshore structures, Vortex shedding, Fatigue life

This paper concentrates on vortex shedding effects and their contribution to the fatigue damage of offshore steel jackets. In addition to vortex shedding forces direct wave, current and wind forces are included in the analysis and 'Kuang' stress concentration factors used for estimation of 'Hot Spot' stress levels. A novel extension of Miner's rule is used to calculate cumulative damage and hence estimate the fatigue life of these structures.

81-895
Dynamic Analysis of Offshore Steel Structures: Measurement and Prediction of Fatigue Life

N. Starsmore and M.G. Hallam
Atkins Res. and Dev., Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 263-283, 21 figs, 3 tables, 15 refs

Key Words: Offshore structures, Fatigue life

The foregoing has demonstrated that the theoretical analysis of offshore platforms is involved and complicated. Poor knowledge of environmental conditions, structural parameters and non-linearities can form the basis of large analytical errors. Nevertheless, methods have evolved to which structures may be designed to a reasonable degree of confidence. As unknowns increase with the expanding frontiers of offshore operations, additional analytical methods will be developed to augment but not replace existing design methods. These are backed up by many years' experience and full-scale empirical feedback to ensure that structural integrity is maintained. In developing additional complexities to the analysis methods, one should always be aware that it is pointless to introduce expensive theoretical refinements which only improve the answer a very small amount compared to the uncertainties in the major design parameters.

81-896
Higher Order Approximations in Stress Analysis of Submarine Pipelines

I. Konuk
Protech Intl. B.V., Schiedam, The Netherlands, J. Energy Resources Tech., Trans. ASME, 102 (4), pp 190-196 (Dec 1980) 2 figs, 1 table, 14 refs

Key Words: Pipelines, Underwater pipelines, Marine risers, Rods, Perturbation theory

A unified three-dimensional formulation of the pipeline or riser problems is developed by following the rod theories. A rigorous singular perturbation technique is used to solve the associated two-dimensional nonlinear problem. The results can be used with a programmable calculator.

81-897
Mechanical Behavior of Marine Risers Mode of Influence of Principal Parameters
C.P. Sparks
The French Petroleum Inst., Rueil-Malmaison, France, J. Energy Resources Tech., Trans. ASME, 102 (4), pp 214-222 (Dec 1980) 9 figs, 3 tables, 6 refs

Key Words: Marine risers, Parametric response, Computer programs, Water waves

This paper attempts to identify the principal parameters that influence the behavior of drilling and production risers and to explain how and why they do so. Clear understanding of these influences enable particular risers to be optimized rapidly without recourse to an inordinate number of computer analyses. The points of greatest concern, to the riser designer, are: stress levels in the main length of riser; angular movement at sea bed (or moment, if the connection is rigid); relative movement at riser/platform connection. The approach used in the paper has been to derive analytical expressions, for simplified riser cases. Conclusions drawn from these expressions have then been checked for validity, by using a dynamic analysis computer program to simulate a wide range of cases.

81-898
Vibrations of Marine Riser Systems
P-T.D. Spanos and T.W. Chen
The Univ. of Texas, Austin, TX 78712, J. Energy Resources Tech., Trans. ASME, 102 (4), pp 203-213 (Dec 1980) 14 figs, 4 tables, 15 refs

Key Words: Marine risers, Multidegree of freedom systems, Parametric response

A discrete multi-degree-of-freedom model is used to study the dynamic response of marine riser systems to loads generated by sea waves and currents. A linearization scheme is used to determine an approximate solution for the system response. A variety of studies regarding the effects of system and environmental parameters on the maximum bending-stress and the maximum bottom angle are presented.

81-899
Electric/Conventional Vehicle Comparison Crash Test
M. Pozzi
Dynamic Science, Inc., Phoenix, AZ, Rept. No. 3057-80-095, DOT-HS-805 438, 124 pp (Apr 1980) PB80-210164

Key Words: Collision research (automotive), Electric vehicles

The report documents results of two tests conducted for NHTSA to compare the safety capabilities of an electric vehicle with those of a conventional internal combustion engine powered vehicle. Each vehicle was impacted into a flat fixed barrier at a nominal speed of 30 mph. Performance relative to Federal Motor Vehicle Standards 208, 212, and 310-75 were determined and the overall crashworthiness of the two vehicles was compared.

81-900
Crash Tests of Single Post Sign Installations Using Subcompact Automobiles
H.E. Ross, Jr. and K.C. Walker
Texas Transportation Inst., College Station, TX, Rept. No. FHWA/RD-80/503, 59 pp (May 1980) PB81-103434

Key Words: Collision research (automotive), Traffic sign structures

Three full-scale crash tests were conducted to evaluate impact behavior of a subcompact vehicle following impact with widely used signpost designs. Each test vehicle weighed 1940 lb (863 kg) and impact speed was approximately 60 mph (96.5 km/h) in each test. Two tests involved impact with a 3 lb/ft (4.5 kg/m) steel U-post and the other test involved 3 lb/ft (4.5 kg/m) steel U-posts bolted together to form a 6 lb/ft (8.9 kg/m) back-to-back section. Impact with the 3 lb/ft post in a dry soil resulted in a vehicle change in velocity above the limiting value. Impact with the same post in a wet soil resulted in an acceptable vehicle velocity change since the post was pulled out of the ground. Impact with the 6 lb/ft post resulted in a vehicle change in velocity that greatly exceeded the limiting value. After impact the vehicle rolled over and was a total loss.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 1093, 1127, 1164, 1165)

81-901
Crash Tests of Rural Mailbox Installations
H.E. Ross, Jr. and K.C. Walker
Texas Transportation Inst., College Station, TX,

Rept. No. 3254-6, FHWA/RD-80/504, 111 pp (May 1980)
PB81-103442

Key Words: Collision research (automotive), Traffic sign structures

Five full-scale crash tests were conducted to evaluate the impact behavior of rural mailbox installations. Three of the five tests involved commonly used wood post supports, two of which were single box installations and the third was a four-box installation. The other two tests involved two promising new support concepts which utilized standard steel pipe. Both tests involved single box installations. Results showed that installations with multiple boxes mounted on boards pose a serious hazard to motorists since the board can easily penetrate the windshield. The results also showed that a pipe support post performs in a more desirable manner than does a wood post. Careful attention must be given to the box-to-post attachment to prevent separation during impact and thus minimize the potential for windshield penetration by the mailbox.

81-902

Vehicle Energy Dissipation Due to Road Roughness

S.A. Velinsky and R.A. White
Dept. of Mech. and Indus. Engrg., Univ. of Illinois at Urbana-Champaign, Urbana, IL 61801, Vehicle Syst. Dyn., 9 (6), pp 359-384 (Dec 1980) 11 figs, 4 tables, 28 refs

Key Words: Road roughness, Interaction: vehicle-terrain, Axle acceleration, Acceleration measurement, Energy dissipation

Road roughness and surface texture are known to affect the tire rolling resistance; however, little emphasis has been placed on the consequent changes in total vehicle energy dissipation due to road roughness. Thus, tire rolling resis-resistance, in isolation from vehicle contributed losses such as dissipation in the suspension, appears to be a weakness in present evaluation procedures as they relate to fuel economy and pollution level testing. Recent work by Funfsinn and Korst has shown that substantial and measurable increases in energy losses occur for vehicles traveling on rough roads. The present investigation uses vehicle axle accelerations as a means of examining various road surfaces. Correlation with computer simulations has allowed the development of a deterministic road roughness model which permits the prediction of energy dissipation in both the tire and suspension as functions of road roughness, tire pressure, and vehicle speed. Comparison to the experiments of Korst and Funfsinn results in good agreement and shows that total rolling loss increases of up to 20 percent compared to ideal smooth roads are possible. The aerodynamic drag coefficient is also found to increase while driving on rough roads.

81-903

Comparison of Ride Comfort Criteria for Computer Optimization of Vehicles Travelling on Randomly Profiled Roads

T. Dahlberg
Div. of Solid Mechanics, Chalmers Univ. of Tech., S-412 96 Gothenburg, Sweden, Vehicle Syst. Dyn., 9 (6), pp 291-307 (Dec 1980) 8 figs, 2 tables, 20 refs

Key Words: Interaction: vehicle-terrain, Ride dynamics, Human response, Mean square response, Suspension systems (vehicles), Optimization

This paper discusses and compares some ride comfort criteria which may be suitable for randomly vibrating vehicles. The criteria consider single-figure measures based on response mean square spectral densities for plane linear combined vehicle-passenger models. Eight different measures divided into three groups are studied. The two vehicle suspension damper stiffnesses are numerically optimized with respect to the eight measures of ride comfort. The results are compared and discussed. Two optimizations with respect to five vehicle parameters are also reported.

81-904

A Parametric Study of Candidate Underride Guard Design Approaches

G.P. McCafferty
The Budd Co., Technical Ctr., SAE Paper No. 801-424, 8 pp, 10 figs

Key Words: Collision research (automotive), Trailers, Automobiles, Energy absorption, Guard rails

A parametric design analysis was performed in order to define the characteristics of protection devices which could be incorporated on the rear end of highway trailers in order to avoid automobile vehicle underride in a crash situation. Of particular concern in this study was the effect of weight and cost of the devices as they relate to parameters such as load capacity, guard height, restriction of the rear sliding bogie movement, and energy attenuation. Four separate design concepts were studied and compared on the basis of weight, cost, and slider restriction. Included were rigid as well as energy absorbing design approaches. Results have generally indicated that the energy absorbing guard

approach has the best potential from a weight efficiency standpoint. The study also points out that significant modifications will be required to the trailer structure to absorb the impact loads under consideration.

81-905

A Development of Truck Rear End Underride Protection

G. Persicke and P.F. Baker
Quinton Hazell, Ltd.
SAE Paper No. 801423, 8 pp, 6 figs

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

Accidents on our roads do happen; although every effort is made to lessen the number, it is still vitally important to try to find better ways of reducing their effect. One such way is the energy absorbing "Underrider" recently developed by Quinton Hazell Ltd. The paper will discuss in some detail how this development can help to improve the present situation. The system is capable of effective injury reduction in underriding impacts to cars of most sizes while eliminating or minimizing the damage suffered by the truck. It will be shown that the design of the unit does not affect the ability of a truck to negotiate steep angles but reduces the effect of impact with road furniture, curbs, ramps, etc. to negligible proportions.

81-906

An Approach to Developing Underride Guard Requirements for Improved Occupants Protection

J.E. Tomassoni and G.K. Bell
National Highway Traffic Safety Admin., SAE Paper No. 801422, 20 pp, 11 figs, 7 tables, 16 refs

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

Initial efforts for developing regulations for improved rear underride protection focused on very high strength (rigid) structures with low ground clearance. To determine optimal performance characteristics for guard structures, a comparative engineering analysis was performed using a car crash simulation model with a variety of guard force-deformation characteristics. From this analysis the risk of injury to occupants of passenger cars was determined based on excessive underride (decapitation potential), and collision forces imparted to the occupant. Variables in the analysis included collision speed, car size, occupant free travel distance, and the rear wheel position of the heavy vehicle, as well as the various force-deformation characteristics representing the different types of underride guard systems.

81-907

Experimental Behaviour of Noise Indices as a Function of Averaging Time

P. Borruso, G.B. Cannelli, and S. Santoboni
Istituto di Acustica "O. M. Corbino," 00189 Roma, Italy, J. Sound Vib., 71 (4), pp 483-488 (Aug 22, 1980) 4 figs, 1 table, 6 refs

Key Words: Traffic noise, Industrial facilities, Noise transmission, Time-dependent parameters

The behavior of noise indices as a function of averaging time has been investigated. Measurements were made on 13 noise samples selected as representative of noises of industrial origin which are rapidly varying in time. It was found that log χ^2 distributions well represent the SPL distributions of the noises; moreover an equivalence between the integration time (T) and the time constant (τ) was achieved when T = 2τ. For noises of rapid time variation the choice of the averaging time is of some importance, while for traffic noise it is fairly uncritical. As regards fluctuation measurements the indices L_{DI} and σ_L show a similar behavior for high time constants and slowly varying noises. On the contrary, for short time constants and rapidly varying noises they have a somewhat different trend.

81-908

Noise Levels in the Vicinity of Traffic Roundabouts

P.T. Lewis and A. James
The Welsh School of Architecture (Research and Development), Univ. of Wales, Inst. Science and Tech., Cardiff CF 1 3 NU, Wales, J. Sound Vib., 72 (1), pp 51-69 (Sept 8, 1980) 13 figs, 5 tables, 4 refs

Key Words: Traffic noise, Noise measurement

An experimental procedure for analyzing roundabout noise is described. Measurement of the noise from accelerating and decelerating traffic streams on the approach roads to roundabouts at a totol of 70 positions at three sites are reported together with a simulation study of noise from central island traffic. The results show that, in general, noise from the accelerating traffic streams is within ±1 dB(A) of the free flow level on the same road and that the noise

from the decelerating stream is equal to or less than the free flow level. The propagation of noise from the central island is expressed in the form of a nomogram. Good agreement between predicted and measured levels was found.

81-909

Measurement of the Effect of Vehicle Ignition Noise on Land-Mobile Voice Channels

W.J. Hartman
Inst. for Telecommunication Sciences, National Telecommunications and Information Administration, Boulder, CO, Rept. No. NTIA-REPORT-80-43, 25 pp (June 1980)
PB80-211451

Key Words: Traffic noise, Noise measurement

Measurements of the noise intelligibility over land-mobile systems in the presence of vehicle noise are presented. These are compared with several statistical noise parameters obtained from measured amplitude probability distributions.

81-910

Analysis of Traffic Noise Abatement Strategies

G.W. Cermak, C.R. von Buseck, J.G. Cervenak, and R.D. Blanchard
Societal Analysis Dept., General Motors Res. Labs., Warren, MI 48090, J. Acoust. Soc. Amer., 69 (1), pp 158-170 (Jan 1981) 4 figs, 10 tables, 24 refs

Key Words: Traffic noise, Noise reduction

Computer simulations of traffic sound levels were performed to evaluate the probable effectiveness of several hypothetical noise abatement strategies in reducing residential exposure to traffic sound. These simulations were performed for 28 actual census tracts in six cities which were chosen to be representative of the urban United States. Results showed that limits on noise levels during acceleration for new automobiles would have only a small effect on traffic noise exposure, while limits on truck-acceleration noise levels would have a greater effect. Nonresidential zoning along arterials was calculated to have a greater effect than automobile-noise limits, but a smaller effect than truck-noise limits. A hypothetical vehicle fleet including large proportions of four-cylinder and diesel-powered automobiles was calculated to produce slightly greater residential noise exposure than at present.

81-911

The Nuisance Due to the Noise of Automobile Traffic: An Investigation in the Neighborhoods of Freeways

C. Lamure and M. Bacelon
NASA, Washington, D.C., Rept. No. NASA-TM-75812, 29 pp (Apr 1980)
N80-28945

Key Words: Traffic noise, Human response, Noise tolerance

An inquiry was held among 400 people living near freeways in an attempt to determine the characteristics of traffic noise nuisance. A nuisance index was compiled, based on the answers to a questionnaire. Nuisance expressed in these terms was then compared with the noise level measured on the most exposed side of each building. Correlation between the nuisance indexes and the average noise levels is quite good for dwellings with facades parallel to the freeway. At equal noise levels on the most exposed side, the nuisance given for these latter dwellings is lower than for others.

81-912

Subjective Effects of Traffic Noise Exposure: Reliability and Seasonal Effects

I.D. Griffiths, F.J. Langdon, and M.A. Swan
Dept. of Psychology, Univ. of Surrey, Guildford GU2 4XH, UK, J. Sound Vib., 71 (2), pp 227-240 (July 22, 1980) 12 tables, 13 refs

Key Words: Traffic noise, Human response

Repeated interview surveys were made in suburban residential areas of London. At six selected sites, four sets of interviews were conducted during summer months. At all sites traffic noise levels were measured over 24 hours at each interview phase with a microphone 1 m from the dwelling facade at first floor level. Seasonal weather data were also collected. In the course of the repeated interviews the initial sample of 364 respondents was reduced to 222. The questionnaire included two types of noise nuisance scale, questions bearing on the typicality of road traffic conditions, and on the opening and closing of windows. The results confirm others already reported but in addition, show that if annoyance scores are averaged over repeated occasions a highly significant increase in reliability is obtained, and the proportion of score variance accounted for by noise increases significantly. No evidence was found of seasonal changes in traffic noise levels and annoyance scores did not vary significantly despite significant differences in the proportion of windows open at different times of the year.

81-913
Evaluation of Passenger Car Noise Nuisance in Urban Traffic
P. Fontanet
Regie Nationale des Usines Renault, France, SAE Paper No. 801432, 16 pp, 18 figs, 7 refs

Key Words: Automobiles, Motor vehicle noise, Traffic noise, Statistical analysis, Noise tolerance

The present paper reports the urban driving statistical survey achieved by CCMC on a twenty-three passenger car sample, driven in four European towns. Statistics of engine speed as well as statistics of power utilized have been worked out and related to mechanical characteristics of the vehicles. From these preliminary works, CCMC has derived the engine speeds and loads which define, at best, the noisiness of the different passenger cars. These engine speeds and loads should be used during certification tests in order to get a better evaluation of their noise nuisance. These works have been used as a basis for the drafting of various practical procedures. One of them has been elaborated in the 8th working group of SC1 TC 43 of ISO and is now proposed as an international standard.

81-914
Towards Quieter Motoring
W. Heining
Sound Vib. Dept., BMW, W. Germany, Noise Vib. *Control*, 11 (9), pp 349, 351-353 (Nov/Dec 1980) 3 figs

Key Words: Motor vehicle noise, Noise measurement

At BMW in West Germany engineers have been investigating the problems of noise and vibration inside private motor cars. This article explains how the recordings were made.

81-915
Structural Dynamics Analysis in Automotive Power-train Systems
J. Osborn
Structural Dynamics Res. Corp., Milford, OH, S/V, Sound Vib., 15 (11), pp 16-18 (Nov 1980) 2 figs

Key Words: Automobiles, Vibration control, Noise reduction

Smaller cars, government regulations, and rapidly changing designs are making it tougher and tougher to keep noise and vibration at acceptable levels in today's vehicles. Fortunately, the technology to help solve these problems is available. Though it still is not a straightforward solution, a combined test/analysis approach to noise problems based on understanding of the internal workings of the structure usually can bring satisfactory results in a reasonable amount of time.

81-916
Problems and Development in Commercial Road Vehicle Fatigue and Testing
P. Michelberger, J. Gedeon, and A. Keresztes
Faculty of Transport Engrg., Tech. Univ. of Budapest, Hungary, Intl. J. Vehicle Des., 1 (5), pp 440-453 (Dec 1980) 6 figs, 3 tables, 14 refs

Key Words: Ground vehicles, Fatigue tests

A good fatigue testing and development program should be based on systematic component tests and on a realistic operation time-table. Road tests for service load measurements have to cover all significant operation processes and events, as well as a sufficient number of loading and road-surface options. A new three-parameter power spectral density formula for road-surface description is introduced. Calculation of the approximate load statistics of vehicles that exhibit linear behavior can be performed on the basis of observations made of different vehicles of similar structure and design, and with the aid of some evident assumptions.

81-917
Shock Environments for Large Shipping Containers during Rail Coupling Operations
C.F. Magnuson
Sandia National Labs., Albuquerque, NM, Rept. No. SAND-79-2168, 74 pp (June 1980)
NUREG/CR-1277

Key Words: Containers, Shipping containers, Rail transportation, Shock response

Sandia National Laboratories participated in a study to define the shock environments to which large, fissile material shipping containers may be exposed during rail-coupling operations. Tests were conducted using impact velocities up to 17.98 km/h (11.17 mph). The cargo on the rail cars consisted of a 36-tonne (40-ton) cask mounted on a skid or a 64-tonne (70-ton) cask. The rail cars were equipped with either standard draft gear, hydraulic end-of-car draft gear, or a sliding center sill cushion underframe. The maximum peak acceleration and its pulse duration were determined for the longitudinal, transverse, and vertical axes of the two casks.

81-918

Dynamic Characteristics of a Long Train of EML Vehicles over Elevated Flexible Guideways

M. Nagai and M. Iguchi

Tokyo Univ. of Agriculture and Tech., Koganei, Japan, Bull. JSME, 23 (184), pp 1663-1669 (Oct 1980) 15 figs, 2 tables, 4 refs

Key Words: Ground effect machines, Magnetic suspension techniques, High speed transportation systems, Interaction: vehicle-guideway, Computer programs

In designing electromagnetic levitation (EML) vehicles as a means of high speed ground transit, it is important to explore the dynamic interactions between a long train of EML vehicles and their guideways. For the numerical analysis of this system, the computer simulation program has been developed, in which vehicle equations are fully coupled with guideway equations through distributed suspension forces. Vehicle motion is assumed to consist of heave and pitch of the vehicle body and heave of two trucks. According to the analysis, there is a difference between variations of the vibration of each truck or each vehicle body, especially in a high speed operation, depending on the velocity parameter, the truck intervals and guideway structures. In some cases, the variations of the vertical accelerations and the clearances between magnets and guideway surfaces at the following vehicles tend to increase to about twice those at the preceding one.

81-919

Noise Control for Rapid Transit Cars on Elevated Structures: Preliminary Investigation of Vehicle Skirts, Undercar Absorption, and Noise Barriers

C.E. Hanson, M. Schafer, D. Towers, and K. Eldred

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. UMTA-MA-06-0099-80-4, DOT-TSC-UMTA-80-22, 61 pp (Apr 1980)

PB80-213077

Key Words: Rapid transit railways, Elevated railroads, Noise reduction, Noise barriers

In the report, procedures to reduce the propulsion system noise of urban rail transit vehicles on elevated structures are studied. Experiments in a laboratory use a scale model transit vehicle to evaluate the acoustical effectiveness of noise barrier walls, vehicle skirts, and undercar absorption. These experiments assume that the propulsion system noise is the only source of noise. Field measurement of urban rail transit vehicles at the Port Authority Transit Corporation (PATCO) in New Jersey provide additional data to compare the noise from elevated-structure and at-grade track sections. The results show that vehicle skirts and undercar absorption can provide a cost-effective noise reduction alternative to noise barriers if the propulsion system is the dominant noise source. The scale model results are only approximate and must be verified by full-scale demonstration tests. However, the potential value of the results can be demonstrated by applying the measured noise reductions in octave bands to the actual measured noise spectrum of the PATCO vehicle.

81-920

Measurement of Wheel/Rail Forces at Washington Metropolitan Area Transit Authority. Volume 1. Analysis Report

C. Phillips, H. Weinstock, R. Greif, and W.I. Thompson

Transportation Systems Ctr., Cambridge, MA, Rept. No. DOT-TSC-UMTA-80-25-1, UMTA-MA-06-0025-80-6, 48 pp (July 1980)

PB80-212772

Key Words: Interaction: rail-wheel, Mass transportation

Under the direction of the Urban Mass Transportation Administration (UMTA), measurements of wheel/rail forces were made in August 1979 by the Transportation Systems Center (TSC) with the assistance of Battelle Columbus Laboratories to determine the causes of excessive wheel/rail wear experiences by the Washington Metropolitan Area Transit Authority (WMATA) Metrorail System during its first three years of operation. In addition to measuring the absolute magnitude of the wheel/rail forces, it was the intent to compare alternative methods for relieving wheel/rail wear at WMATA and other transit properties. Measurements of the wheel/rail forces were made at the Washington National Airport Test Site and the Brentwood Shop Test Site. This report describes the results of that effort.

81-921

Analytical Methods for Freight Car/Truck Dynamic Problems

Martin Marietta Corp., Denver, CO, Rept. No. MCR-80-531, FRA/ORD-80/29, 57 pp (July 1980)

PB80-219389

Key Words: Railroad cars, Interaction: rail-wheel, Hunting motion

The analytical methods used to synthesize mathematical models of an 80-ton open hopper railroad car are presented in this report. This effort was directed toward accurately characterizing the dynamic behavior of this specific railcar configuration. In a larger sense, model formulation and solution using the methods detailed here serve as a potential approach to the characterization of other railcar configurations. The report details the formulation of a nonlinear model including the carbody, trucks, and wheel/rail interactions. In particular hunting stability of the railcar was investigated, and analytical results were compared to actual test data. Test/analytical correlation was very good.

SHIPS

(Also see Nos. 973, 991)

81-922

Evaluation of Virtual Mass Matrices for Ship Hulls Using Fluid Singularities

M.A. Murray, T.J.A. Agar, and A. Jennings

Dept. of Civil Engrg., The Queen's Univ. of Belfast, Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 403-415, 7 figs, 3 tables, 17 refs

Key Words: Ship hulls, Fluid-induced excitation, Interaction: structure-fluid

Ship vibrations caused by the interaction of submerged vibrating surfaces imparting motion to the fluid and thereby altering its pressure and inducing reacting forces are investigated.

81-923

On the Transmission of Audio Frequency Vibration from Multi-Point Mounted Engines to Ship Bottom Structure

M.Ohlrich

The Acoustics Lab., Tech. Univ., DK-2800, Lyngby, Denmark, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 225-234, 12 figs, 8 refs

Key Words: Ship vibration, Engine vibration

This paper attempts to reveal the characteristics and some of the factors which may influence the transmission of vibration to the shipstructure from an engine mounted rigidly in multiple points. Specifically studied is the vibration in the mounting points (baseplate) of engine structures which are (i) free, and (ii) bolted to different types of engine-supporting bedplate structures. Furthermore, the paper discusses the transmission of vibration from the pair of bedplates, on which an engine is mounted, to the ship hull. The results which are presented are derived from experiments on simplified models representing bottom sections of ships and two types of engine structures.

81-924

The Kron Methodology and Practical Algorithms for Eigenvalue, Sensitivity and Response Analyses of Large Scale Structural Systems

A. Simpson

Univ. of Bristol, Aeronaut. J., 84 (839), pp 417-433 (Dec 1980) 11 refs

Key Words: *Eigenvalue problems, Shipboard equipment response*

An exhaustive appraisal of Kron's eigenvalue method, associated eigenvalue algorithms, pyramided solutions, sensitivity analysis and response analysis has been undertaken. The advantages of the Kron methodology in dealing with problems of large dimensionality have been stressed, both generally and in application to the equipment raft problem. It is hoped that this paper will provide an impetus toward the use of Kron's method for the solution of practical large scale structures whose dimensionalities squarely preclude the use of standard methods.

81-925

On the Scaling of Flexible Ship Models

R.E.D. Bishop and W.G. Price

Dept. of Mech. Engrg., Univ. College London, London WC1E 7JE, UK, J. Sound Vib., 73 (3), pp 345-352 (Dec 8, 1980) 15 refs

Key Words: Ships, Scaling, Water waves

Scaling laws for a flexible ship model are derived and discussed. On the basis of these laws the responses of a ship in waves may be estimated by measurements taken from a suitable model. The laws are compatible with those published by Andrews and Church [1], but they are a little more complete and are based on considerations of linear hydroelasticity rather than the naval architect's traditional considerations of "wave bending" (defined for a rigid hull) with correlations for "whipping".

81-926

Airborne Noise Levels on U.S. Navy Ships

D.R. Lambert

Naval Ocean Systems Ctr., San Diego, CA, Rept. No. NOSC/TD-317, 29 pp (Aug 1, 1980)

AD-A089 007/9

Key Words: Ships, Noise generation

This paper presents airborne noise data obtained in Navy shipboard compartments in support of an evaluation of airborne noise criteria on navy ships. Additional reports which interpret these data are being prepared. They will present statistics on the relationship between present noise levels and existing noise limits; they correlate sound levels with subjective ratings of the effects of the noise obtained concurrently by questionnaire; and they recommend noise limits for future use. A-weighted, C-weighted, and octave band sound pressure levels were measured on a not-to-interfere basis in compartments aboard 8 US Navy ships. These ships were the CV-61, CV-64, DD-972, DD-976, DDG-13, FF-1063, LST-1185, and LST-1191.

81-927

Antisymmetric Response of a Flexible Ship in a Seaway

R.E.D. Bishop, W.G. Price, and P. Temarel

Dept. of Mech. Engrg., Univ. College London, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 417-425, 4 figs, 1 table, 15 refs

Key Words: Ships, Hydrodynamic excitation

Antisymmetric responses of lateral bending moment, lateral shear force and torsional moment are presented for a container ship traveling in long-crested irregular bow seas. The estimates are made using a unified dynamic analysis which employs properties of the dry hull and hydrodynamic actions found with two-dimensional strip theory. A standard ITTC sea spectrum is adopted to describe the seaway.

81-928

European-Built Sea Barge Carriers: The Design, Machinery/Hull Interaction and Investigations into Vibratory Behaviour

G.C. Volcy, M. Baudin, C. Andreau, A. Manner, and S. Seppala

Appl. Study and Res., Dept. of Bureau Veritas Marine Departments, The Institute of Marine Engineers, Trans. (TM), Vol. 92, Paper 5, pp 46-57 (1980) 9 figs, 5 tables, 12 refs

Key Words: Ships, Interaction: ship hull-machinery, Finite element technique

The concept of the transport of lighters or barges on board ships – its operational feasibility confirmed on U.S.A.-built vessels – has been also adopted in Europe, and Valmet Shipyard has obtained the order for building two 37,850 tdw ships of this type for the U.S.S.R. Some considerations connected with the design and building of these ships and their machinery, which is the biggest in the world for this class are presented. In order to ensure trouble-free operation, extensive studies concerning static and vibratory interaction of machinery and hull have been undertaken, involving hydrodynamic excitations as well as treatment from static and dynamic point of view simultaneously, of twin-screw propulsive plant and hull steel-work. This called for FEM technique. Some results of the experimental researches and theoretical calculations are presented as well as their correlation with the measurements obtained on the first ship delivered, which proved vibration-free.

AIRCRAFT

(Also see Nos. 874, 947, 953, 1015, 1016, 1033, 1051, 1085 1137, 1147, 1148, 1152, 1153, 1154, 1155, 1159, 1162)

81-929

Flutter Speed Degradation of Damaged, Optimized Flight Vehicles

F.G. Hemmig, V.B. Venkayya, and F.E. Eastep

Air Force Wright Aeronautical Labs., Wright-Patterson Air Force Base, OH, J. Aircraft, 17 (12), pp 833-836 (Dec 1980) 3 figs, 4 refs

Key Words: Aircraft wings, Flight vehicles, Flutter, Stiffness coefficients, Mass coefficients

A study of the effects of mass and stiffness changes on the flutter degradation of optimized wings is presented in this paper. The wings were optimized for weight with constraints on strength, displacement, and flutter speed. The mass and stiffness changes are representative of battle damage. The structural box is idealized by finite elements consisting of membranes, shear panels, and bar elements. The aerodynamic force matrix is generated by incompressible strip theory. Five damage models involving two wing boxes are included. The effect of damage on aerodynamic flow is not treated.

81-930

Crash Tests of Four Identical High-Wing Single-Engine Airplanes

V.L. Vaughan, Jr. and R.J. Hayduk
NASA Langley Res. Ctr., Hampton, VA, Rept. No.
NASA-TP-1699, L-13076, 70 pp (Aug 1980)
N80-30296

Key Words: Crash research (aircraft), Dynamic tests

Four identical four place, high wing, single engine airplane specimens with nominal masses of 1043 kg were crash tested at the Langley Impact Dynamics Research Facility under controlled free flight conditions. These tests were conducted with nominal velocities of 25 m/sec along the flight path angles, ground contact pitch angles, and roll angles. Three of the airplane specimens were crashed on a concrete surface; one was crashed on soil. Crash tests revealed that on a hard landing, the main landing gear absorbed about twice the energy for which the gear was designed but sprang back, tending to tip the airplane up to its nose. On concrete surfaces, the airplane impacted and remained in the impact attitude. On soil, the airplane flipped over on its back. The crash impact on the nose of the airplane, whether on soil or concrete, caused massive structural crushing of the forward fuselage. The liveable volume was maintained in both the hard landing and the nose down specimens but was not maintained in the roll impact and nose down on soil specimens.

81-931

A Review of Propeller Discrete Frequency Noise Prediction Technology with Emphasis on Two Current Methods for Time Domain Calculations

F. Farassat and G.P. Succi
Joint Inst. for Advancement of Flight Sciences, The George Washington Univ., Hampton, VA, J. Sound Vib., 71 (3), pp 399-419 (Aug 8, 1980) 13 figs, 1 table, 30 refs

Key Words: Propellers, Propeller noise, Noise prediction, Time domain method, Computer aided techniques

A review of propeller noise prediction technology is presented which highlights the developments in the field from the successful attempt of Gutin to the current sophisticated techniques. Two methods for the prediction of the discrete frequency noise from conventional and advanced propellers in forward flight are described. These methods developed at MIT and NASA Langley Research Center are based on different time domain formulations. Brief description of the computer algorithms based on these formulations is given. The output of these two programs, which is the acoustic pressure signature, is Fourier analyzed to get the acoustic pressure spectrum. The main difference between the programs as they are coded now is that the Langley program can handle propellers with supersonic tip speed while the MIT program is for subsonic tip speed propellers. Comparisons of the calculated and measured acoustic data for a conventional and an advanced propeller show good agreement in general.

81-932

Predicted Airframe Noise Levels

J.P. Raney
NASA Langley Res. Ctr., Hampton, VA, Rept. No.
NASA-TM-81849, 10 pp (Sept 1980)
N80-34218

Key Words: Aircraft noise, Noise prediction

Calculated values of airframe noise levels corresponding to FAA noise certification conditions for six aircraft are presented. The aircraft are: DC-9-30; Boeing 727-200; A300-B2 Airbus; Lockheed L-1011; DC-10-10; and Boeing 747-200B. The prediction methodology employed is described and discussed.

81-933

Atmospheric Turbulence Effects on Aircraft Noise Propagation

R.L. Chapkis
DyTec Engineering, Inc., Long Beach, CA, Rept. No.
NASA-CR-159325, 55 pp (June 1979)
N80-29095

Key Words: Aircraft noise, Sound transmission, Turbulence

The Brown and Clifford model for the apparent sound attenuation caused by atmospheric turbulence was reviewed and extended. Calculations, based on the model, were made for the predicted sound attentuation for a tower-mounted loudspeaker-type sound source and for an airplane sound source. The important parameters in the model are identified and discussed. A model for sound fluctuations is also presented and a practical experimental program to validate the models described.

81-934

Spatial Patterns in Community Response to Aircraft Noise Associated with Non-Noise Factors

F.L. Hall, S.M. Taylor, and S.E. Birnie
Dept. of Civil Engineering, McMaster Univ., Hamilton, Ontario L8S 4L7, Canada, J. Sound Vib., 71 (3), pp 361-381 (Aug 8, 1980) 13 tables, 16 refs

Key Words: Aircraft noise, Human response, Noise tolerance

Non-noise aspects of airport operations may affect individuals' responses to aircraft noise. Fear of crashes, other forms of pollution, and proximity to the flight path are three such non-noise aspects which have spatial patterns that are closely related to the pattern of noise contours around an airport. If these variables affect response to aircraft noise, they may therefore confound attempts to understand relationships between noise level and community response. Analyses based on data from 673 individuals around Toronto International Airport suggest that these factors do affect annoyance responses, but do not affect reported activity interference. Hence it may prove fruitful, in aggregate analyses of community response data, to control for these variables in order to better understand the noise-annoyance relationships.

81-935

Annoyance Due to Multiple Airplane Noise Exposure

C.A. Powell
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TP-1706, L-13713, 42 pp (Aug 1980)
N80-28946

Key Words: Aircraft noise, Human response, Noise tolerance

A laboratory study was conducted to investigate the annoyance effects of multiple aircraft noise exposure in which 250 subjects judged the annoyance of half-hour periods of airplane noise simulative of typical indoor home exposures. The variables of the aircraft noise exposure were the peak noise level of flyovers, which was constant within each period, and the number of flyovers. Each subject judged 5 of the possible 25 factorial combinations of level and number. Other variables investigated included the experience of the test subjects in making annoyance judgments and their home exposure to airplane noise. The annoyance judgments increased with both noise level and number of flyovers. The increased annoyance produced by doubling the number of flyovers was found to be the equivalent of a 4 to 6 db increase in noise level. The sensitivity of the subjects to changes in both noise level and number of flyovers increased with laboratory experience. Although the means of the annoyance judgments made in the laboratory were found to decrease with the subjects' home exposure to aircraft noise, the subjects' sensitivities to changes in both level and number were unaffected by their home exposure.

81-936

Evaluation of Aero Commander Sidewall Vibration and Interior Acoustic Data: Static Operations

A.G. Piersol, E.G. Wilby, and J.F. Wilby
Bolt, Beranek and Newman, Inc., Canoga Park, CA, Rept. No. NASA-CR-159290; BBN-4016, 92 pp (Oct 1980)
N80-33392

Key Words: Aircraft, Airframes, Vibration measurement, Interior noise

Results for the vibration measured at five locations on the fuselage structure during static operations are presented. The analysis was concerned with the magnitude of the vibration and the relative phase between different locations, the frequency response (inertance) functions between the exterior pressure field and the vibration, and the coherent output power functions at interior microphone locations based on sidewall vibration. Fuselage skin panels near the plane of rotation of the propeller accept propeller noise excitation more efficiently than they do exhaust noise.

81-937

Role of Unsteady Aerodynamics in Aircraft Response

G.J. Hancock
Dept. of Aeromechanical Engrg., Queen Mary College, London, UK, AGARD Spec. Course on Unsteady Aerodyn., 14 pp (June 1980)
N80-33371

Key Words: Aerodynamic loads, Aircraft

Some of the main dynamic situations which arise in aircraft response are illustrated. Major emphasis is placed on overall aircraft performance and structural response.

81-938

Effects of Nonlinearities on Wing-Store Flutter

G. DeFerrari, L. Chesta, O. Sensburg, and A. Lotze
Aeritalia S.p.A., Torino, Italy, AGARD Math. Modeling of Linear and Non-Linear Aircraft Struc., pp 15-32 (July 1980)
N80-31328

Key Words: Wing stores, Flutter

Findings from ground resonance tests and flight flutter tests are presented and an explanation for these test results is

given. Calculations with linear assumptions (parameter variations) were made and the method of harmonic balance for finding these parameters was applied. It is shown that certain levels of excitation must be reached in order to make flight flutter tests reliable for establishing flutter clearance speeds.

81-939
Calculation of Three-Dimensional Unsteady Transonic Flows Past Helicopter Blades
J.J. Chattot
NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TP-1721; A-8024, 32 pp (Oct 1980)
N80-33356

Key Words: Rotary wings, Helicopters, Fluid-induced excitation, Finite difference technique

A finite difference code for predicting the high speed flow over the advancing helicopter rotor is presented. The code solves the low frequency, transonic small disturbance equation and is suitable for modeling the effects of advancing blade unsteadiness on blades of nearly arbitrary planform. The method employs a quasi-conservative mixed differencing scheme and solves the resulting difference equations by an alternating direction scheme. Computed results showed good agreement with experimental blade pressure data and illustrate some of the effects of varying the rotor planform. The flow unsteadiness is shown to be an indispensible part of a transonic solution. Close to the tip at high advance ratio, cross flow effects can significantly affect the solution.

81-940
A Study of the Use of Blocking Masses in Reducing Helicopter Cabin Noise
C.H. Ellen
Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TM-Aero-1838; BR73588, 23 pp (Mar 1980)
N80-31395

Key Words: Helicopter noise, Interior noise, Noise reduction

A brief theoretical examination of the use of blocking masses for application to helicopter structure is presented. The effects of a periodic array of blocking masses are compared with the effect of a single blocking mass for a bending wave on a plate. The significance of the model structure is demonstrated, and the analysis of the excitation of a membrane strip at a point between two blocking masses is used to illustrate how the energy flow varies with frequency of excitation.

MISSILES AND SPACECRAFT
(See No. 1079)

BIOLOGICAL SYSTEMS

HUMAN
(Also see Nos. 911, 912, 934, 935)

81-941
Designing Community Surveys to Provide a Basis for Noise Policy
J.M. Fields
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-80110, 24 pp (June 1980)
N80-28942

Key Words: Noise tolerance, Human response

After examining reports from a large number of social surveys, two areas were identified where methodological improvements in the surveys would be especially useful for public policy. The two study areas are: the definition of noise indexes and the assessment of noise impact. Improvements in the designs of surveys are recommended which would increase the validity and reliability of the noise indexes. Changes in interview questions and sample designs are proposed which would enable surveys to provide measures of noise impact which are directly relevant for public policy.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS
(Also see Nos. 902, 954, 1025, 1029)

81-942
The Acoustics of Plastic Foam
J. Pizzirusso

Scott Paper Co., Foam Div., Chester, PA, Mach. Des., 53 (1), pp 135-139 (Jan 8, 1981) 3 figs

Key Words: Foams, Acoustic absorption

Although pores in plastic foam occur randomly, they can be produced consistently with a specific average size and cellular structure. Thus, foams can be designed so that they either transmit or attenuate sound, and they can be made highly selective with regard to the frequencies they pass or absorb.

81-943

Balsawood -- A Possibility for Enclosures?

R.H. Warring

Noise Vib. Control, 11 (9), pp 355, 357-358 (Nov/Dec 1980) 3 figs, 2 tables

Key Words: Acoustic absorption, Wood, Noise reduction, Enclosures

Recent (limited) laboratory tests on the sound transmission loss of end-grain balsa panels yielded figures substantially higher than the mass law would predict. These data were applied to the design of an enclosure for a large and particularly noisy planning machine. Results proved quite satisfactory, if not entirely achieving the estimated sound transmission loss (which could be due to various leakage paths still being present). From an original figure of 105dB(A) at the input (operator's) end, the sound level was reduced to 90dB(A). At the take-out (operator's) end, the original sound level of 106dB(A) was reduced to 85dB(A). From the side of the machine facing towards the rest of the machine, the original level of 104dB(A) was reduced to 85dB(A). The sound absorption coefficient can be further increased by grooving or blind drilling holes, etc.

81-944

Flexural Wave Baffling Using a Fluid-Viscoelastic Composite

S.-H. Ko

Naval Underwater Systems Ctr., New London, CT Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 485-503, 14 figs, 11 refs

Key Words: Baffles, Viscoelastic properties, Composites, Flexural waves

In the present study, the effectiveness of baffles against flexural wave noise is examined using a plane layer model consisting of an elastic plate and a fluid-viscoelastic composite representing the baffle. The fluid layer of the composite baffle is assumed to be a lossless and nondispersive medium, and the viscoelastic layer of the composite baffle is assumed to be a rubber-like material that has a loss factor associated with the shear modulus.

TIRES AND WHEELS

(Also see Nos. 1097, 1098)

81-945

A Non-Linear Model of a Single Wheelset Moving with Constant Speed on a Purely Straight Track

A.D. dePater

Delft Univ. of Tech., Delft, The Netherlands, Intl. J. Nonlin. Mechanics, 15 (4/5), pp 315-324 (1980) 3 figs, 10 refs

Key Words: Interaction: rail-wheel, Wheelsets, Lateral vibration

Starting from a consistent set of equations the lateral motion of a single wheelset, moving along a tangent track, is investigated. Supposing that the solution has the form of a limit-cycle, expressions for the displacement and force quantities are written down as harmonic time functions and the amplitudes are found by means of Krylov and Bogoljubov's method. For the case of vanishing amplitudes the result is in entire agreement with that of the linear theory.

81-946

Investigation of Castor-Wheel Shimmy

M.N. Brearley

RAAF Academy, Point Cook, Victoria, Australia, Quart. J. Mechanics Appl. Math., 33 (4), pp 491-505 (1980) 10 figs, 4 refs

Key Words: Wheel shimmy, Tires

Castor-wheel shimmy (or flutter) is a rapid forced oscillation of a whole castor-wheel assembly about its pivotal axis, which is commonly vertical when the wheel is running on a horizontal surface. The amplitude of the oscillation can be large, approaching 90° in a severe case. Severe shimmy is accompanied by excessive tire wear and a greatly increased ground resistance to forward motion of the assembly. Large resistance is a great disadvantage if it occurs in a wheel chair, and it can be dangerous in the case of a castoring nose wheel of an aircraft under-carriage. In the latter case the correct approach is to fit dampers which prevent the oscillation, but the weight and cost penalties make this solution inappropriate for wheel chairs. To design against shimmy with confidence, one needs to understand its mechanism. This paper analyzes the problem in sufficient detail to provide practical suggestions for designing a castor-wheel assembly which will not flutter.

81-947

F-15 Nose Landing Gear Shimmy, Taxi Test and Correlative Analyses

D.T. Grossman

McDonnell Aircraft Co., McDonnell Douglas Corp., SAE Paper No. 801239, 16 pp, 18 figs, 5 refs

Key Words: Aircraft, Landing gear, Wheel shimmy, Taxiing effects

F-15 taxi tests and analyses were performed to evaluate the effects of aircraft design changes on nose landing gear shimmy. Preliminary analytical studies indicated that these changes would have an adverse effect on shimmy speed. This was of particular concern because limit cycle shimmy had been experienced on the baseline gear for cases with out-of-tolerance strut torsional freeplay. The tradeoffs considered in the choice of a taxi test over a laboratory dynamometer test are presented. Operational aspects of the taxi test are discussed. Several instances of limit cycle shimmy were encountered during testing and results indicate that shimmy speed is a function of strut torsional freeplay. A description of the math model used in the non-linear analyses is provided. Analytical results are presented in terms of shimmy speed versus strut torsional freeplay. These results confirm the limit cycle nature of the shimmy phenomenon and correlate well with the taxi test results. Additional analyses are presented indicating the sensitivity of the shimmy to changes in tire parameter values and strut frictional coefficients. Assumptions used in the development of an equivalent linear math model are given.

BLADES

(Also see No. 873)

81-948

An Investigation of the Dynamic Stalling Characteristics of Rotating Axial-Flow Compressor Blades

M.R. Sexton

Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 199 pp (1980)
UM 8028161

Key Words: Blades, Compressor blades, Stalling, Fluid-induced excitation, Transfer functions

A multichannel FM telemetry system was employed to measure the dynamic response of compressor rotor blade surface pressure profiles to changes in upstream conditions. Data taken while the experimental compressor was operating with a distortion screen upstream of the rotor was utilized to develop a transfer function to describe the dynamic response of the rotor blade row. The transfer function was developed by considering the dynamic total pressure loss distribution around the rotor to be a response function driven by a quasi-steady total pressure loss distribution as a forcing function. Fourier transforms of both the dynamic and the quasi-steady distributions were calculated. The quotient obtained by dividing the Fourier transform of the response function by the Fourier transform of the forcing function was the desired transfer function. This experimentally-determined transfer function was then used in a new semi-actuator disc model to predict the dynamic response of the experimental compressor. The basis of the model is a mathematical representation of the flow fields upstream and downstream of a compressor rotor. The compressor rotor is represented in the model by a semi-actuator disc. The results of the investigation show that the physical mechanisms which control the onset and propagation velocity of rotating stall in a single-stage compressor can be modeled with the use of a transfer function in a semi-actuator disc model of the compressor. The transfer function represents the dynamic characteristics of the compressor rotor row as an amplitude ratio and a phase shift of the Fourier frequency components of the total pressure loss distribution. This transfer function representation of the dynamic characteristics of the blade row provides important advantages over previous techniques.

81-949

Composite Rotor Blades for Large Wind Energy Installations

A. Kussmann, J.P. Molly, and D. Muser

NASA, Washington, D.C., Rept. No. NASA-TM-75822, 14 pp (Apr 1980) (English transl. of DFVLR Nachr. West Germany, pp 40-44, 1979)
N80-31881

Key Words: Windmills, Rotor blades (turbomachinery), Wind-induced excitation

The design of large wind power systems in Germany is reviewed with attention given to elaboration of the total wind energy system, aerodynamic design of the rotor blade, and wind loading effects. Particular consideration is given to the development of composite glass fiber/plastic or carbon fiber/plastic rotor blades for such installations.

81-950

Influence of Mistuning on Blade Torsional Flutter

A.V. Srinivasan
United Technologies Res. Ctr., East Hartford, CT,
Rept. No. NASA-CR-165137, R80-914545-16, 55 pp (Aug 1980)
N80-31351

Key Words: Fan blades, Blades, Flutter, Torsional vibration, Tuned frequencies

An analytical technique for the prediction of fan blade flutter was evaluated by utilizing first stage fan flutter data from tests on an advanced high performance engine. The formulation includes both aerodynamic and mechanical coupling among all the blades of the assembly. Mistuning is accounted for in the analysis so that individual blade inertias, frequencies, or damping can be considered. Airfoil stability was predicted by calculating a flutter determinant, the eigenvalues of which indicate the extent of susceptibility to flutter. When blade to blade differences in frequencies are considered, a stable system is predicted for the test points examined. For a tuned system, it was found that torsional flutter can be predicted at a limited number of interblade phase angles. Examination of these phase angles indicated that they were 'close' to the condition of acoustic resonance. For the range of Mach numbers and reduced frequencies considered, the so called subcritical flutter cannot be predicted. The essential influence of mechanical coupling among the blades is to change the frequencies of the system with little or no change in damping; however, aerodynamic coupling together with mechanical coupling could change not only frequencies, but also damping in the system, with a trend toward instability.

81-951

A Brief Note on the Interaction of an Actuator Cascade with a Singularity

D. Chamieh, A.J. Acosta, C.E. Brennen, and T.K. Caughey
California Inst. of Tech., Pasadena, CA 91125, Rotordynamic Instability in High-Performance Turbomachinery, Proc. of a workshop held at Texas A&M Univ., College Station, TX, May 12-14, 1980, NASA Conf. Publ. 2133, pp 237-247, 1 fig, 5 refs
AD-088701

Key Words: Rotors, Blades, Fluid-induced excitation

Estimates of steady forces that may be exerted between moving blade rows and stationary blade rows or volutes are recorded. Time averaged forces for estimation of shaft loads and flow asymmetry forces rather than with transient processes are considered. For this purpose the well-known "actuator" model for the blade row in which the flow leaving the row or cascade is assumed to have a constant leaving angle is adopted.

81-952

Bladed Disc Vibrations - A Review of Techniques and Characteristics

D.J. Ewins
Imperial College of Science and Tech., London, UK,
Recent Advances in Structural Dynamics Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 187-210, 25 figs, 53 refs

Key Words: Blades, Turbomachinery blades, Vibration analysis

In this paper, a survey has been made of some of the major techniques used for the study of the highly-complex vibration characteristics of bladed assemblies. In addition, an attempt has been made to review some of the essential characteristics themselves and to explain many of the patterns of behavior which are observed in practice, both in laboratory tests and in service conditions.

81-953

Significance of a Rotor Blade Failure for Fleet Operation, Inspection, Maintenance, Design and Certification

R.J.H. Wanhill, E.A. B. deGraaf, and A.A.M. Delil
Structures and Materials Div., National Aerospace Lab., Amsterdam, The Netherlands, Presented at 5th European Rotorcraft and Powered Lift Aircraft Forum, Amsterdam, Sept 4-7, 1979, Rept. No. NLR-MP-79021-U, 16 pp (Sept 1979)
N80-31392

Key Words: Helicopter rotors, Rotary wings, Blades

The catastrophic fracture of a rotor blade from a large helicopter was analyzed, with essentially immediate conse-

quences for continued fleet operation, inspection and maintenance of the same type of rotor blade.

81-954

Vibration Analysis of Rotor Blades with Pendulum Absorbers

V.R. Murthy and C.E. Hammond
Goodyear Aerospace Corp., Akron, OH, J. Aircraft, 18 (1), pp 23-29 (Jan 1981) 4 figs, 1 table, 8 refs

Key Words: Rotary wings, Blades, Rotors, Helicopters, Absorbers (equipment), Pendulums

A comprehensive vibration analysis of rotor blades with spherical pendulum absorbers is presented. These absorbers are mounted on the blade to attenuate the loads that pass through the rotor shaft at a frequency that is an integer multiple of the blade passage frequency. The spherical pendulum absorber is considered here because such an absorber may be more versatile in controlling the out-of-plane, in-plane, and pitching vibratory loads. A transmission matrix formulation is given to determine the natural vibrational characteristics and a direct transmission matrix method is given to determine the forced response of the rotor blades with pendulum absorbers.

BEARINGS

(Also see No. 1108)

81-955

On the Spring Characteristics of a Ball Bearing (Fluctuation due to Ball Revolution)

H. Tamura and Y. Tsuda
Kyushu Univ., Higashi-ku, Fukuoka, Japan, Bull. JSME, 23 (185), pp 1905-1912 (Nov 1980) 9 figs, 6 refs

Key Words: Bearings, Ball bearings, Spring constants

This paper deals with a theoretical study of the radial spring characteristics of a ball bearing, paying particular attention to their fluctuation due to the ball revolution. The following are clarified and demonstrated: computation of the running accuracy problem by applying the (modified) Newton-Raphson method, a problem first examined by Perret-Meldau, detailed analysis of radial motion of the inner ring and the fluctuation of the two-dimensional derivative stiffness caused by the ball revolution, shown by numerical examples and effects of some system parameters (e.g., radial clearance, radial load, number and the revolution angle of balls, etc.).

81-956

Vacuum Tests on a Rotary/Linear Sleeve Bearing

J. Gillies and R.B. Watters
European Space Tribology Lab., National Centre of Tribology, Risley, UK, Rept. No. ESA-ESTL-42, ESA-CR(P)-1326, 18 pp (Sept 1979)
N80-30761

Key Words: Bearings, Sleeve bearings, Stiffness coefficients

A proprietary 1 inch nominal I/D ROTCLIN linear sleeve bush bearing was tested and compared with angular contact bearings of similar size. The bearing was torque tested in air and in vacuum over small forward and reverse angular and axial movements of the bearing shaft, and under varying conditions of temperature. Thermal conductance of the bearing stiffness was calculated and compared with a similar diameter deep groove or angular contact bearing.

GEARS

81-957

The Probabilistic Analysis of Some Models of Toothed Gears

J. Szopa and A. Kondrat
Dept. of Mathematics and Physics, Silesian Tech. Univ., Gliwice, Poland, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. Southampton, Vol. I, pp 147-156, 3 figs, 11 refs

Key Words: Gears, Stochastic processes, Probability theory

In the paper a method is given for determining the covariance function of the response of linear stochastic differential equations, the coefficients of stochastic process excitation as applied to gears.

FASTENERS

81-958

Self-Locking of Bolt-Nut Joints under Repeated Impacts (Theory and Experiments)

K. Koga and H. Isono
The Inst. of Vocational Training, Sagamihara, Japan, Bull. JSME, 23 (184), pp 1697-1704 (Oct 1980) 15 figs, 2 tables, 9 refs

Key Words: Joints (junctions), Bolts, Nuts, Loosening, Impact response (mechanical)

In a bolted joint receiving repeated impacts, the slip between external and internal threads is the cause of loosening of the employed fastener and subsequent failure of the joint. Selection of the right locking method is important to minimize the detrimental effects of the slip in a joint. In this paper a theoretical formula for self-locking of a threaded fastener has been deduced from the theory of self-loosening process. An equation for critical preload to cope with a certain repeated impact has been derived from the experimental results.

SEALS

81-959

Simulation and Visualization of Face Seal Motion Stability by Means of Computer Generated Movies

I. Etsion and B.M. Auer

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-81581; E-554, 19 pp (1980)
N80-31797

Key Words: Seals (stoppers), Design techniques, Computer aided techniques, Transient response

A computer aided design method for mechanical face seals is described. Based on computer simulation, the actual motion of the flexibly mounted element of the seal can be visualized. This is achieved by solving the equations of motion of this element, calculating the displacements in its various degrees of freedom vs. time, and displaying the transient behavior in the form of a motion picture. Incorporating such a method in the design phase allows one to detect instabilities and to correct undesirable behavior of the seal. A theoretical background is presented. Details of the motion display technique are described, and the usefulness of the method is demonstrated by an example of a noncontacting conical face seal.

STRUCTURAL COMPONENTS

STRINGS AND ROPES

81-960

Propagation of Discontinuities in Vibrating Strings Subject to Solid Friction

H. Cabannes

Laboratoire de Mecanique Theorique (associe au C.N.R.S.), Universite Pierre et Marie Curie, 4, Place Jussieu, 75005, Paris, France, Meccanica, 14 (4), pp 175-179 (Dec 1979) 3 figs, 4 refs

Key Words: Strings, Vibrating structures, Friction

For a vibrating string subject to solid friction the propagation of discontinuities of acceleration and curvature, which correspond to the starting and stopping are studied. Those discontinuities related to the discontinuity of the friction law, propagate with a velocity which, in general, differs from the characteristic velocities. After a general study of the problem, examples are given.

81-961

Galloping of Bundled Power Line Conductors

Y. Nakamura

Res. Inst. for Applied Mechanics, Kyushu Univ., Fukuoka, Japan, J. Sound Vib., 73 (3), pp 363-377 (Dec 8, 1980) 14 figs, 2 tables, 16 refs

Key Words: Transmission lines, Galloping, Flutter

This paper describes an experimental and analytical study of the galloping of a two-dimensional section model of a two-conductor bundle in which ice-accreted conductors are replaced by two identical square prisms, with both vertical and torsional movements allowed but the horizontal one blocked, in a uniform wind tunnel flow. Emphasis is placed on elucidating the vital role played by the aerodynamic coupling in the stability of bundled conductors. It is shown that, apart from galloping type flutter, two other types of instability, namely, torsional and classical type flutter, can also occur for bundled conductors.

CABLES

(Also see No. 1161)

81-962

On Non-Linear Free Vibrations of an Elastic Cable

P. Hagedorn and B. Schafer

Institut f. Mechanik, TH Darmstadt, W. Germany, Intl. J. Nonlin. Mechanics, 15 (4/5), pp 333-340 (1980) 1 fig, 9 refs

Key Words: Cables (ropes), Free vibration, Ritz-Galerkin method, Galloping, Transmission lines

The effect of non-linear terms in the equations of motion on the first normal modes of the oscillations of an elastic flexible cable under the action of gravity is studied. The non-linear equations are derived and approximate solutions are found by the Ritz-Galerkin method. A numerical example is given and the significance of the results is discussed with regard to the galloping oscillations of overhead transmission lines.

81-963

Free Oscillations of a Nonlinear Simple Model of a Suspended Cable

A. Luongo, G. Rega, and F. Vestroni
Istituto di Scienza delle Costruzioni, Univ. of Rome, Italy, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 597-609, 4 figs, 12 refs

Key Words: Cables (ropes), Suspended structures, Free vibration, Finite displacement method, Two degree of freedom systems, Perturbation theory

The study of free oscillations in a finite displacement theory of a hyperelastic cable suspended between two fixed supports has been conducted by analyzing a system of two ordinary differential equations with quadratic and cubic nonlinearities through a simplified cable kinematics. The two degree of freedom problem has been solved by the multiple time scale perturbation method which has enabled an analytical expression of the asymptotic solution to be obtained fairly easily and a quantitative analysis to be made.

BEAMS

(Also see Nos. 867, 1040, 1082)

81-964

Integrals Involving Euler-Bernoulli Flexure and Saint-Venant Torsion Eigenfunctions

N.G. Stephen
Dept. of Mech., Production and Chem. Engrg., Manchester Polytechnic, Manchester M15GD, UK, J. Sound Vib., 71 (3), pp 383-387 (Aug 8, 1980) 5 tables, 7 refs

Key Words: Beams, Free vibration, Coupled response, Rayleigh-Ritz method, Ritz-Galerkin method

Tables of the integrals involving the Euler-Bernoulli and Saint-Venant eigenfunctions respectively are presented for beams with combinations of clamped, pinned and free ends. These integrals arise in application of the Rayleigh-Ritz and Ritz-Galerkin methods to free vibration and dynamic stability problems involving coupled torsion and bending.

81-965

Non-Linear Vibrations of a Clamped Beam with Initial Deflection and Initial Axial Displacement, Part I: Theory

N. Yamaki and A. Mori
Inst. High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Sound Vib., 71 (3), pp 333-346 (Aug 22, 1980) 11 figs, 1 table, 16 refs

Key Words: Beams, Nonlinear response, Galerkin method, Harmonic balance method

Theoretical analyses are presented for non-linear vibrations of a clamped beam under uniformly distributed periodic lateral loading, with the effects of both initial deflection and initial axial displacement taken into consideration. Effects of both initial deflection and initial axial displacement on the static deflection as well as the lower natural frequencies are also clarified.

81-966

Non-Linear Vibrations of a Clamped Beam with Initial Deflection and Initial Axial Displacement, Part II: Experiment

N. Yamaki and K. Otomo
Inst. High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Sound Vib., 71 (3), pp 347-360 (Aug 8, 1980) 13 figs, 5 refs

Key Words: Beams, Nonlinear response, Periodic excitation

To compare with the theoretical results of Part I, detailed experimental results have been obtained on the non-linear response of a clamped beam under a uniformly distributed periodic load. A duralumin test specimen was used and tests were conducted by pulsating the base frame with a constant peak acceleration and measuring the relative displacement of the beam to the frame. It is found that the theoretical results are generally in reasonable agreement with the experimental ones, the effects of initial axial displacements being included. Various non-linear responses were observed in connection with the internal resonance, combination resonance and dynamic snap-through phenomena,

for which the present experimental results seem to provide effective data facilitating further theoretical analyses.

81-967
Nonplanar Motions of a Base-Excited Cantilever

M.W. Hyer
Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 621-630, 2 figs, 1 ref

Key Words: Beams, Cantilever beams, Vibrating foundations

The equations governing the nonplanar motion of a base-excited cantilever are derived. The Lagrangian approach is used. Approximate solutions to the governing equations are sought using Galerkin's method to eliminate the spatial dependence from the problem. The numerical results are discussed and interpreted so as to illustrate the character of the beam motion.

81-968
Non-Linear Free Vibrations of Stepped Thickness Beams

H. Sato
Dept. of Mech. Engrg., Kanazawa Univ., Kanazawa, Japan, J. Sound Vib., 72 (3), pp 415-422 (Oct 8, 1980) 5 figs, 1 table, 4 refs

Key Words: Beams, Variable cross section, Free vibration, Nonlinear response, Transfer matrix method

The non-linear free vibrations of stepped thickness beams are analyzed by assuming sinusoidal responses and using the transfer matrix method. The numerical results for clamped and simply supported, one-stepped thickness beams with rectangular cross-section are presented and the effects of the beam geometry on the non-linear vibration characteristics are discussed. The results are also compared with those obtained by a Galerkin method in which the linear mode function of the beam is used.

81-969
Galerkin Finite Element Method for Non-Linear Beam Vibrations

G.R. Bhashyam and G. Prathap
Structures Div., National Aeronautical Lab., Bangalore 560 017, India, J. Sound Vib., 72 (2), pp 191-203 (Sept 22, 1980) 1 fig, 8 tables, 20 refs

Key Words: Beams, Finite element technique, Galerkin method, Nonlinear response

A Galerkin finite element method is presented, for studying non-linear vibrations of beams describable in terms of moderately large bending theory. The transverse displacement alone is used, although several previous attempts to do the same with a Ritz element have failed. This, together with certain assumptions regarding the nature of the vibration, allows an eigenvalue-like quantity characteristic of non-linear vibration to be defined and computed for various amplitudes of vibration. The solution to the non-linear eigenvalue problem is effected in two ways. Numerical results are presented to demonstrate that the governing differential equations of the problem do not admit variables separable solutions (time and space) in the clamped-clamped and simply supported-clamped cases.

81-970
Flexural Wave Propagation Behavior of Lumped Mass Approximations

T. Belytschko and W.L. Mindle
Dept. of Civil Engrg., The Technological Inst., Northwestern Univ., Evanston, IL, Computers Struc., 12 (6), pp 805-812 (Dec 1980) 13 figs, 20 refs

Key Words: Beams, Flexural waves, Wave propagation, Lumped parameter method

The suitability of lumped masses for elastic wave propagation problems in beams is investigated. Dispersion relations are presented for lumped mass Euler-Bernoulli elements and an element with shear correction; for purposes of comparison, the dispersive properties of consistent masses are also given. It is shown that by increasing the rotational mass through a rotational mass factor α, a good approximation can be obtained to the Timoshenko dispersion relation. Comparison with an exact solution for the propagation of a velocity discontinuity shows that the shear correction is required for a good solution and indicates optimal values for α.

81-971
Stochastic Vibrations of Slim Masts Induced by Turbulent Flows - Modal and Integral Covariance Methods in Hybrid Systems

W. Wedig

Inst. for Technical Mechanics, Univ. of Karlsruhe, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 131-146, 6 figs, 8 refs

Key Words: Chimneys, Beams, Cable-stiffened structures, Fluid-induced excitation, Stochastic processes

The dynamic response of structures under distributed excitations has been investigated by means of discretization methods using a normal mode approach or local finite elements. For stochastic systems such methods may also be applied, but the requirement for their numerical evaluation increases enormously. Therefore, an integral covariance analysis based on the introduction of a Wiener field process and the construction of a Green's function is proposed. In the time domain this system possesses the Markov property allowing the application of Ito's formula to set up the associated covariance equations. As shown herein, the stationary solutions of these covariance equations can be calculated simply in a closed analytical form.

81-972

Vibration Models of Steel Chimneys with Added Damping

D.J. Johns, M.G. Milsted, P.M. Bradshaw, and J.E.W. Ogendo

Dept. of Transport Tech., Loughborough Univ. of Tech., Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 305-314, 3 figs, 2 tables, 11 refs

Key Words: Chimneys, Vortex-induced vibration, Steel, Vibration damping

The build-up of vortex-induced vibration in self supporting steel chimneys is effectively inhibited if the total structural damping is high enough. It appears that a safe minimum level can be achieved for a large class of chimney designs by use of a resilient damping layer at the chimney base although care is required in their design to ensure that static deflection limits are not exceeded. Dynamic soil-structure interactions are shown to have a very small effect on the fundamental mode of vibration of chimneys supported on shallow foundations and for the purpose of determining the effects of an added damping treatment these interactions can be neglected.

CYLINDERS

(Also see Nos. 1010, 1021, 1050, 1100)

81-973

On the Frictional Damping of the Rolling of a Circular Cylinder

D. Myrhaug and I.O. Sand

Norwegian Hydrodynamic Labs., Trondheim, Norway, J. Ship Res., 24 (4), pp 244-255 (Dec 1980) 16 figs, 2 tables, 16 refs

Key Words: Cylinders, Cylindrical shells, Shells, Ship hulls, Coulomb friction, Fourier analysis

The frictional damping of the rolling motion of a circular cylinder is nonlinear. Although negligible at full scale, it may be important in model scale. The damping force is calculated using Fourier analysis of the frictional force on the surface of a cylinder with a vertical axis executing simple harmonic oscillations about its axis. Calculations of the velocity profile in the fluid near the oscillating cylinder, needed for the calculations of the frictional force, are carried out in the laminar and turbulent case using the boundary-layer approximation. For Reynolds shear stress modeling, the mixing length concept of Prandtl and an analogy to van Driest's model are used.

81-974

Elastic Waves in a Short Cylinder, Impacted by a Thin Bar

L. Guex and W. Janach

Institut CERAC, CH-1024 Ecublens, Switzerland, J. Sound Vib., 71 (4), pp 489-496 (Aug 22, 1980) 4 figs, 1 table, 16 refs

Key Words: Cylinders, Impact response (mechanical), Elastic waves, Finite element technique

The wave motion resulting from the elastic impact of a semi-infinite steel bar on an aluminium cylinder, of much larger diameter but of finite length, were studied experimentally and numerically. First the strains were measured at different points on the cylinder surface by using semiconductor strain gauges. Subsequently the experimental situation was simulated numerically with a dynamic finite element program on a Hewlett-Packard 300 Computer. Different calculation schemes were evaluated in order to obtain the best agreement with the experimental data. The details shown by both the measured and calculated signals make it possible to identify the arrivals of the compressional, the shear and the Rayleigh waves and some of their initial reflections.

COLUMNS

(Also see No. 1059)

81-975

A Note on Unimodal and Bimodal Optimal Design of Vibrating Compressed Columns

A. Gajewski

Inst. of Physics, Tech. Univ. of Cracow, ul. Podchorazych 1, 30-084 Krakow, Poland, Intl. J. Mech. Sci., 23 (1), pp 11-16 (1981) 5 figs, 6 refs

Key Words: Columns, Flexural vibration, Optimum design

The bimodal optimization with respect to the frequency of transverse vibrations under axial compression is demonstrated on the simple Pragers' model. This model consists of rigid segments that are joined by elastic hinges to each other and to the supports and point masses which are situated in the inner hinges.

FRAMES AND ARCHES

(Also see No. 883, 1081)

81-976

Load-Frequency Relationships for Shallow Elastic Structures

E.R. Johnson, R.H. Plaut, and C.C. Deel, II

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 611-620, 18 figs, 12 refs

Key Words: Arches, Frequency coefficients, Trusses

Three shallow elastic structures are analyzed in this paper: a pinned sinusoidal arch under a sinusoidally distributed load; a pinned circular arch under uniform load; and a seven-bar truss under concentrated loads. As the loads are increased quasi-statically, nonlinear deformations occur. Small vibrations about the equilibrium configuration are considered, and characteristic curves are determined.

81-977

Optimum Distribution of Additive Damping for Vibrating Frames

R. Lunden

Division of Solid Mechanics, Chalmers Univ. of Tech., S-412 96 Gothenburg, Sweden, J. Sound Vib., 72 (3), pp 391-402 (Oct 8, 1980) 7 figs, 3 tables, 19 refs

Key Words: Frames, Vibrating structures, Vibration damping

Redistribution of an initially uniformly applied additive damping is numerically and experimentally investigated for a vibrating plane frame. It is found that an optimum redistribution can reduce amplitudes of resonant responses by up to 60% (with the cost or the weight of the damping treatment kept constant). Optimally selected non-uniform distributions of additive damping may thus be worth considering in many practical cases.

PANELS

(Also see Nos. 1034, 1041)

81-978

Vibrations of Multispan Stiffened Plates via Modified Bolotin Method

I. Elishakoff, A. Sternberg, and T.J. van Baten

Dept. of Aerospace Engrg., Delft Univ. of Tech., The Netherlands, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 37-50, 1 fig, 2 tables, 27 refs

Key Words: Panels, Plates, Stiffened structures, Skin-stringer method, Bolotin method

The modified Bolotin method is applied to dynamic analysis of continuous skin-stringer panels. The number of spans is assumed finite; all panels and interior stringers are identical. The solution procedure involves formulation of two auxiliary problems of the Voigt-Lévy type in conjunction with an eigen-frequency wave-number relationship. The treatment yields a pair of transcendental equations in terms of wave numbers. The method has advantages over other approximate approaches in the sense that the number of spans enters one of the transcendental equations explicitly, so that numerical complexity does not increase with it.

81-979

Acoustic and Vibration Fields Generated by Ribs on a Fluid-Loaded Panel. 1. Plane-Wave Problems for a Single Rib

D.G. Crighton and G. Maidanik

Dept. of Appl. Mathematical Studies, Leeds Univ., UK, Rept. No. DTNSRDC/SAD-270E1-1902, 46 pp (Mar 1980)
AD-A089 077/2

Key Words: Panels, Ribs (supports), Fluid-induced excitation

This paper presents an analytical study of the interaction between incident wave fields and a single rib on fluid-loaded panel. The panel is modeled as an infinite membrane (with frequency dependent tension to partially simulate the dispersion characteristics of a thin elastic plate), and the incident waves are taken as plane structural or acoustic waves at normal and oblique incidence on the rib. The principal concern of this paper is with the structural wave field transmitted across the rib (in the case of the infinite mechanical impedance and finite nonlocal rib impedance) though the nonspecular acoustic field scattered by the panel-plus-rib is also examined.

81-980

Response of Unconstrained Layer Panels to Random Excitation at a Point

C.V.R. Reddy, N. Ganesan, and B.V.A. Rao
Structures Section, ISRO Satellite Centre, Bangalore 560058, India, J. Sound Vib., 73 (3), pp 419-427 (Dec 8, 1980) 6 figs, 4 tables, 6 refs

Key Words: Panels, Random excitation, Harmonic analysis, Point source excitation, Spectral energy distribution techniques

The acceleration response of unconstrained layer rectangular panels under random point force excitation has been investigated theoretically and experimentally. In the theory the layer material was assumed to be viscoelastic in nature. Generalized harmonic analysis was used to evaluate the power spectral density and the rms values of acceleration response analytically. The theoretical results are compared with the results obtained from experiments for "all edges simply supported" and "all edges clamped" panel boundary conditions.

PLATES

(Also see Nos. 978, 1034, 1041, 1049, 1052, 1100)

81-981

Normal Input Admittance of a Disk in a Thin Flat Plate

P.W. Smith, Jr.
Bolt, Beranek and Newman Inc., 50 Moulton St., Cambridge, MA, J. Acoust. Soc. Amer., 69 (1), pp 155-157 (Jan 1981) 1 fig, 1 table, 5 refs

Key Words: Plates, Mechanical admittance

The input admittance for a rigid, massless, circular disk undergoing uniform normal motion in a thin flat plate is found as a function of disk radius, within the limitations of the classical theory for thin-plate dynamics. A modal reciprocity theorem is derived which relates the real part of the input admittance, for any single mode of deformation of the source region, to the mean-square response velocity in that mode when it is excited by an isotropic, homogeneous, stochastic field of waves incident from the plate.

81-982

Dynamic Analysis of Plates by Mixed Elements

C.A. Mota Soares, L.M.T. Campos, and A.F. Viegas Gago
Centre of Mechanics and Materials of the Technical Univ. of Lisbon, Instituto Superior Tecnico, Av. Rovisco Pais, 1000 Lisbon, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 51-60, 5 figs, 7 tables, 12 refs

Key Words: Plates, Natural frequencies, Mode shapes, Mixed element technique

In this paper, two mixed isoparametric elements are developed based on the moderately thick plate theory. The geometric, displacement and moment fields are quadratic and one of the elements is semi-analytical. Models based on the present elements calculate the natural frequencies and modes of vibration, and the transient displacements and moments of plate structures. The results are compared with analytical and finite element solutions. The transient solutions are obtained by the Modal Analysis Technique.

81-983

Vibration Analysis of Rectangular Mindlin Plates by the Finite Strip Method

O.L. Roufaeil and D.J. Dawe
Dept. of Civil Engrg., The Univ. of Birmingham, Birmingham B15 2TT, UK, Computers Struc., 12 (6), pp 833-842 (Dec 1980) 1 fig, 6 tables, 14 refs

Key Words: Plates, Rectangular plates, Finite strip method, Mindlin theory, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects

A finite strip analysis of the vibration of rectangular Mindlin plates with general boundary conditions is described. The normal modes of vibration of Timoshenko beams are used to represent the spatial variation along a strip of the deflection and the two cross-sectional rotations. For the crosswise representation equal-order polynomial interpolation is employed for each of these three basic quantities. The accuracy of the approach is demonstrated by the results of a number of applications to square plates with combinations of simply supported, clamped and free edges.

81-984

Prediction of Natural Frequencies of Vibration of Rectangular Plates with Rectangular Cutouts

R. Ali and S.J. Atwal

Dept. of Transport Tech., Univ. of Tech., Loughborough, LE11 3TU, UK, Computers Struc., 12 (6), pp 819-823 (Dec 1980) 3 figs, 5 tables, 5 refs

Key Words: Plates, Rectangular plates, Hole-containing media, Rayleigh method, Finite element technique

A simplified method for the dynamic analysis of plates with cutouts is presented. The method is based on Rayleigh's principle. Although the method is general, its application has been demonstrated for the case of simply supported square plates with square and rectangular cutouts only. Results obtained by the application of this method to plates with different size cutouts are compared with the results obtained by the application of the finite element technique.

81-985

Free Vibration Analysis of Rectangular Plates with Symmetrically Distributed Point Supports Along the Edges

D.J. Gorman

Dept. of Mech. Engrg., Univ. of Ottawa, Ottawa, Canada, J. Sound Vib., 73 (4), pp 563-574 (Dec 22, 1980) 6 figs, 4 tables, 4 refs

Key Words: Plates, Rectangular plates, Natural frequencies, Mode shapes

In this paper a highly accurate mathematical technique for establishing the eigenvalues and mode shapes of rectangular plates with symmetrically distributed point supports is introduced. Eigenvalues, covering numerous modes and aspect ratios, are tabulated for corner supported rectangular plates. It is seen that with some modifications the method is equally applicable to problems where the point supports are not symmetrically distributed.

81-986

The Flexural Vibration of Welded Rectangular Plates

M.M. Kaldas and S.M. Dickinson

Faculty of Engrg. Science, The Univ. of Western Ontario, London, Ontario, Canada N6A 5B9, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 23-35, 6 figs, 6 tables, 17 refs

Key Words: Rectangular plates, Plates, Natural frequencies, Mode shapes, Welding, Flexural vibrations

A theoretical approach has been developed and outlined for determining the natural frequencies and mode shapes of flexural vibration of rectangular plates subject to one or more weld runs parallel to the plate edges. The validity of the approach has been demonstrated by theoretical/experimental comparisons. Other investigations not reported here due to space limitations, including mode shape comparisons and a comparison of predicted frequencies for some fully clamped plates, experimentally investigated by Jubb have further established the validity of the theoretical approach.

81-987

Free Vibration of Rectangular Plates of Arbitrary Thickness with One or More Edges Clamped

K.T. Sundara Raja Iyengar and P.V. Raman

Dept. of Civil Engrg., Indian Inst. Science, Bangalore 560012, India, J. Sound Vib., 71 (4), pp 463-472 (Aug 22, 1980) 1 fig, 3 tables, 13 refs

Key Words: Plates, Rectangular plates, Natural frequencies, Method of initial functions

Frequencies of free vibration of rectangular plates of arbitrary thickness, with different support conditions, are calculated by using the Method of Initial Functions (MIF), proposed by Vlasov. Sixth and fourth order MIF theories are used for the solution. Numerical results are presented for three square plates for three thickness ratios. The support conditions considered are three sides simply supported and one side clamped, two opposite sides simply supported and the other two sides clamped, and all sides clamped. It is found that the results produced by the MIF method are in fair agreement with those obtained by using other methods. The classical theory gives overestimates of the frequencies and the departures from the MIF results increase for higher modes and larger thickness ratios.

81-988

Analysis of Skew Plate Problems with Various Constraints

T. Mizusawa, T. Kajita, and M. Naruoka
Dept. of Construction Engrg., Daido Inst. of Tech., Hakusuicho-40, Minami-ku, Nagoya, 457, Japan,
J. Sound Vib., 73 (4), pp 575-584 (Dec 22, 1980) 1 fig, 4 tables, 20 refs

Key Words: Plates, Skew plates, Rayleigh-Ritz method, Lagrange equations, Approximation methods

This paper presents the application of the modified Rayleigh-Ritz method with Lagrange multipliers to analyze skew plate problems with various constraints. By this procedure one can satisfy both geometric and natural boundary conditions of skew plates. To demonstrate the accuracy and versatility of the method, several examples of bending, vibration and bucking of skew plates are solved, and results are compared with those obtained by other approximate methods.

81-989

A Mixed Boundary Integral - Finite Element Approach to Plate Vibration Problems

G. Bezine
Laboratoire de Mecanique des Solides E.R.A. 218 - Universite de Poitiers 40, Avenue du Recteur Pineau, 86022 Poitiers, France,
Mechanics Res. Comm., 7 (3), pp 141-150 (1980) 6 figs, 3 tables, 8 refs

Key Words: Plates, Finite element technique, Free vibration

While for static plate problems the boundary integral method is now well known, it has not been used as much as might be expected for vibration problems, due to the complexity of the fundamental solution to the plate vibration differential equation. A treatment of this problem by boundary integral equation method has already been proposed in the works of Vivoli and Filippi through the research of a fundamental solution of the differential equation ($\Delta^2 v - \lambda^2 v = 0$). This formulation involves Hankel functions and its numerical computation is rather awkward. It is the purpose of this paper to represent the inertia loading due to the vibrations by concentrated loads applied at each node of a mesh used to discretize the plate domain. By using the integral representation of the static deflection and that of its normal derivative along the boundary, and simultaneously the representation of the deflection inside the domain, it is possible to eliminate the boundary unknowns, so as to obtain equations which only involve deflections and inertia forces inside the domain. The investigation of free vibrations reduces to computing the eigenvalues and eigenvectors of some matrix. Problems pertaining to clamped, simply supported or cantilever square plates are treated to illustrate the potentialities of this method.

81-990

Space Harmonic Analysis of Periodically Stiffened, Fluid Loaded Plates

B.R. Mace
Inst. of Sound and Vib. Res., Univ. of Southampton,
Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 477-483, 3 figs, 3 refs

Key Words: Plates, Fluid-induced excitation, Stiffened plates, Periodic structures, Harmonic analysis

The vibration and consequent sound radiation from plates with attached stiffeners is a problem of interest in the analysis of aircraft and marine structures. Often the stiffeners are uniformly spaced and the composite structure is then spatially periodic, consisting of identical plate/stiffener elements attached side by side, and this fact can be used to simplify the analysis of the free and forced vibrations of the structure. In this paper the concept of space harmonic decomposition for periodic structures is first reviewed. This method of analysis is particularly suitable for infinite structures loaded by an acoustic fluid because the harmonics are orthogonal over $(-\infty, \infty)$. The response of a periodically stiffened plate to a convected harmonic pressure is then given as a series of space harmonics. The method of deriving the response is briefly summarized. The propagation of free waves is then examined with particular emphasis on free wave propagation in the fluid-loaded structure. Truly propagating waves are seen to exist as well as a class of free waves which propagate but are damped by acoustic radiation.

81-991

Sound Radiation from a Plate Reinforced by Two Sets of Parallel Stiffeners

B.R. Mace

Inst. Sound Vib. Res., Univ. of Southampton, Southampton SO9 5NH, UK, J. Sound Vib., 71 (3), pp 435-441 (Aug 8, 1980) 2 figs, 5 refs

Key Words: Plates, Reinforced plates, Fluid-induced excitation, Point source excitation, Elastic waves, Hulls

A solution is developed for the sound radiation from a point-excited infinite fluid-loaded plate which is reinforced by two sets of parallel stiffeners. The stiffeners are intended to represent the bulkheads and intermediate frames of a hull structure. The solution is found by using Fourier wavenumbber transforms, and the stationary phase approximation is used to find an expression for the far field pressure. The effects of the two sets of stiffeners on the radiated pressure depend primarily on the number of frames between successive bulkheads and on the point of application of the force. The presence of frames and bulkheads away from the point of excitation becomes less important as the frequency of the excitation increases.

81-992

Periodically Stiffened Fluid-Loaded Plates, I: Response to Convected Harmonic Pressure and Free Wave Propagation

B.R. Mace

Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton SO9 5NH, UK, J. Sound Vib., 73 (4), pp 473-486 (Dec 22, 1980) 7 figs, 12 refs

Key Words: Plates, Periodic structures, Stiffened plates, Fluid-induced excitation, Harmonic excitation, Fourier transformation

In this paper several aspects of the vibration of and sound radiation from an infinite fluid-loaded plate stiffened periodically by line supports are studied. The supports may exert both forces and moments on the plate. First the response to a convected harmonic pressure is found by using Fourier transforms and the response is seen to consist of an infinite set of space harmonics whose amplitudes are found explicitly. Certain infinite sums arise and when fluid loading is neglected these are evaluated analytically. A condition is derived for the propagation of free waves. For the fluid loaded case an acoustically damped "propagating" wave is seen to exist. An expression for the response to a general excitation is derived and from this the acoustic pressure in the far field is determined.

81-993

Periodically Stiffened Fluid-Loaded Plates, II: Response to Line and Point Forces

B.R. Mace

Inst. of Sound Vib. Res., Univ. of Southampton, Southampton SO9 5NH, UK, J. Sound Vib., 73 (4), pp 487-504 (Dec 22, 1980) 11 figs, 1 table, 5 refs

Key Words: Plates, Periodic structures, Stiffened plates, Fluid-induced excitation, Line source excitation, Point source excitation

In this paper the response of infinite periodically stiffened fluid-loaded plates is examined for line and point force excitations. The responses are given as a single and double integral, respectively. When fluid loading is neglected the response to a point force then reduces to a single integral. When fluid loading is included the responses are found by numerical integration and efficient methods of evaluating the integrals are discussed. At low frequencies the stiffened plate is seen to behave as an orthotropic plate. The input mobility for both types of excitation is seen to exhibit peaks at certain frequencies due to coherent interference of the reflections from the supports.

81-994

Vibration Analysis of Polar Orthotropic Discs Using the Transfer Matrix Method

R. Bell and J. Kirkhope

Dept. of Mech. and Aeronautical Engrg., Carleton Univ., Ottawa, Ontario, Canada, J. Sound Vib., 71 (3), pp 421-428 (Aug 8, 1980) 1 fig, 5 tables, 10 refs

Key Words: Disks (shapes), Orthotropism, Transfer matrix method

The well known transfer matrix scheme of Ehrich for calculating the vibration characteristics of uniform and varying thickness discs is extended to include polar orthotropic material behavior. The exact deflection equations for an annular element of material are used in the solution. Comparisons with alternative solutions in the literature show excellent agreement for both annular and complete discs of uniform and varying thickness profile.

81-995

Dynamic Response of Isotropic and Anisotropic Panels under Simulated Flight Loading Conditions

C.E. Teh and R.G. White

Inst. of Sound and Vib. Res., Univ. of Southampton, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 727-738, 14 figs, 1 ref

Key Words: Panels, Aluminum, Reinforced plastics, Acoustic tests, Rayleigh-Ritz method

The study of carbon fibre reinforced plastics (CFRP) constitutes a relatively new field of research culminating in application of the material to high performance structures such as aircraft. The free vibration characteristics of fully-clamped rectangular isotropic and anisotropic plates under uniaxial inplane loading may be predicted using the Rayleigh-Ritz approach.

81-996

Elastic Plate Vibrations by Boundary Integral Equations. Part 1. Infinite Phase

R.P. Shaw

Dept. of Engrg. Science Aerospace Engrg. & Nuclear Engrg., State Univ. of New York, Buffalo, NY, Rept. No. TR-109, 14 pp (June 1980)

AD-A089 105/1

Key Words: Plates, Elasticity theory

One of the prime difficulties in developing two dimensional dynamic elastic plate theories from the three dimensional equations of elasticity is the choice of functional dependence on the thickness coordinate. This difficulty may be circumvented by formulating the problem first as a boundary integral equation; then the dependence on the independent variable through the plate thickness follows form as a direct quadrature with no assumptions of functional form required. In particular, the examination of separate symmetric and antisymmetric modes allows the boundary integral equation to be written with unknowns evaluated on a single surface.

81-997

An Accurate, Simple Theory of the Statics and Dynamics of Elastic Plates

M. Levinson

Dept. of Mech. Engrg., Univ. of Maine at Orono, Orono, ME 04469, Mechanics Res. Comm., 7 (6), pp 343-350 (1980) 2 figs, 10 refs

Key Words: Plates, Elastic properties, Equations of motion

A theory for the statics and dynamics of rectangular beams, based on kinematic assumptions, satisfying the shear free boundary conditions on the lateral surfaces is extended to isotropic plates. Although the coupled equations of motion of this theory differ somewhat in form from those of Timoshenko beam theory, it was found that the uncoupled wave equation for the transverse deflection was the same as the equation given by Timoshenko provided that the shear coefficient in Timoshenko's theory is taken as 5/6.

81-998

Vibration Analysis of Composite Plates by Finite Element Technique

M.K. Patra and N.G.R. Iyengar

Dept. of Aeronautical Engrg., Indian Inst. of Tech., Kanpur, India, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 713-726, 7 figs, 3 tables

Key Words: Plates, Composite structures, Layered materials, Fiber-composites, Hole-containing media, Fundamental frequency, Transverse shear deformation effects

A method which takes into consideration the transverse shear deformation was used for free vibration analysis of orthotropic plate with circular as well as square cutouts. It was observed that the fundamental normalized natural frequency increases with the increase in cutout dimension. Furthermore, the response of the plate with fibre orientation is not the same for all natural frequencies. Typical results are presented in tabular and graphical form.

81-999

The Use of Frictional Damping to Control the Vibration of Plates in Structures

C.F. Beards and D.A. Robb

Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 749-760, 9 figs, 2 tables, 12 refs

Key Words: Plates, Layered materials, Coulomb friction, Vibration control

It is shown that the inherent damping and natural frequencies of flat plates may be significantly altered by allowing slip between a plate and its supports, or by fabricating a plate from several thin plates clamped together so as to allow inter-facial slip. Both methods were investigated by using a square plate clamped on two opposite sides. Rigid clamping of the plate supports gave a damping loss factor η = .0029 for the fundamental mode of vibration. Slip between the plate and its supports increased this factor to a maximum of 0.064, but the reduced stiffness caused a 38% reduction in frequency.

81-1000

Frequency Determination and Non-Dimensionalization for Composite Cantilever Plates

E.F. Crawley and J. Dugundji
Dept. of Aeron. and Astron., Massachusetts Inst. of Tech., Cambridge, MA, J. Sound Vib., 72 (1), pp 1-10 (Sept 8, 1980) 3 figs, 2 tables, 5 refs

Key Words: Plates, Cantilever plates, Composite structures, Natural frequencies

A method for estimating the natural frequencies of composite cantilever plates and for non-dimensionalizing frequency data is developed and demonstrated. The scheme is based on a partial Ritz (Kantorovich) analysis, which reduces the problem to a set of uncoupled ordinary differential equations. The solution of these equations yields both the eigenvalues of free vibration and the proper forms of the non-dimensional frequency. Together these can be used to estimate the natural frequencies of laminated plates. In addition the non-dimensional frequency expressions can be used to reduce numerical or experimental vibration data. To demonstrate this the first five frequencies of a representative group of laminated plates are calculated by using a finite element model. The calculated frequencies are then non-dimensionalized by using the expressions derived from the Ritz analysis. The resulting non-dimensional frequencies not only show more consistency than the original data, but are shown to agree well with the eigenvalues of the Ritz analysis.

81-1001

Flexural Vibrations and Elastic Stability of Annular Plates under Uniform In-Plane Tensile Forces along the Inner Edge

G.K. Ramaiah
Institut f. Mechanik, Technische Hochschule Darmstadt, D-6100 Darmstadt, West Germany, J. Sound Vib., 72 (1), pp 11-23 (Sept 8, 1980) 6 figs, 3 tables, 16 refs

Key Words: Plates, Annular plates, Rayleigh-Ritz method, Flexural vibration

The problem of free flexural vibrations and elastic stability of annular plates under uniform internal tension is analyzed by the Rayleigh-Ritz method with simple polynomials as admissible functions for eight different combinations of clamped, simply supported and free edge support conditions. It is found that the critical buckling mode for plates under internal tension never corresponds to the axisymmetric mode and the plate always buckles first with a finite number of circumferential waves.

81-1002

Dynamic Response of an Annular Disk to a Moving Concentrated, In-Plane Edge Load

V. Srinivasan and V. Ramamurti
Dept. of Mech. Engrg., Indian Inst. of Tech., Madras 600036, India, J. Sound Vib., 72 (2), pp 251-262 (Sept 22, 1980) 8 figs, 2 tables, 7 refs

Key Words: Disks (shapes), Annular disks, Moving loads

In-plane dynamic behavior of a thin annular disk with a clamped inner boundary is analyzed. The frequencies of free in-plane vibration with a free outer boundary are first evaluated, by using Lamé potentials, for various radius ratios ranging from 0·2 to 0·8. The steady state dynamic stresses induced by a concentrated load moving at a constant angular speed at the outer boundary are then evaluated through a Galilean transformation. Results are presented for a radius ratio of 0·5.

81-1003

The Forced Oscillation of the Circular Plates

W. Fluegge
Engl. transl. from Z. Tech. Phys., West Germany, v. 13, pp 199-205 (1932), Rept. No. BLL-RTS-12070, 14 pp (July 1980)
N80-33756
Avail: British Library Lending Div., Boston Spa, UK

Key Words: Plates, Circular plates, Forced vibration

The forced oscillation of elastic plates at frequencies considerably different from their natural frequencies was investigated. A circular plate was coupled by a thread at its midpoint to an oscillating system of large mass. Excitation by a periodic single force, some singularities of plate flexure, and the excitation by a higher order singularity were studied. It is concluded that an elastic plate can be forced to oscillate at any frequency.

81-1004

The Response of Elastic Structures to Pressure Waves

A. Kunow-Baumhauer

Technische Hochschule 61 Darmstadt, Fachbereich 6, Mechanik I, West Germany, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 345-354, 11 figs, 7 refs

Key Words: Plates, Shock waves, Buildings, Structural members, Explosion effects

Pressure waves are caused by airplanes or explosions. Thereby stresses can occur which destroy building structures, e.g., by cracking of plaster and of masonry or by bursting windows. Many papers dealt with this subject. Some works gave values for the dynamic load factor of one-mass systems for different types of pressure waves. Further plates and plate-systems were studied and the load function was taken as an impact load. In the field of railway bridge building and of the building of high speed transport systems structures under travelling single forces were studied. For other cases better mechanical models were employed, e.g., the Timoshenko theory. Here the dependence of the system response on the load form is briefly considered. Otherwise this paper is confined to a sudden rising, symmetric, half-cosine wave which is constant vertical to the travelling direction.

SHELLS

(Also see No. 1041)

81-1005

An Experimental and Theoretical Investigation of the Frequencies and Mode Shapes of Axisymmetric Shell Models

R. Delpak and W.M. Hague

Dept. of Civil Engrg., The Polytechnic of Wales, Pontypridd CF37 1DL, Wales, J. Sound Vib., 72 (2), pp 235-249 (Sept 22, 1980) 15 figs, 8 tables, 21 refs

Key Words: Shells, Natural frequencies, Mode shapes, Finite element technique, Domes, Cooling towers

The use of doubly curved isoparametric elements in a finite element analysis enabled successful prediction to be made of the natural frequencies and mode shapes of axisymmetric shell models. The models chosen were in the form of a natural draft cooling tower, part of a large hemispherical dome and part of a smaller hemispherical dome, and all were formed from thermoplastic materials. Several natural frequencies and mode shapes were determined experimentally for all the models. The theoretical predictions compared very favorably with the experimental results.

81-1006

Free Vibration of Submerged Thin-Walled Domes

K.F. Port and C.T.F. Ross

R.A.E., Farnborough, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 427-436, 3 figs, 2 tables, 6 refs

Key Words: Domes, Submerged structures, Natural frequencies, Mode shapes, Computer programs

The main requirement of the investigation, using theoretical and experimental methods, was to determine the natural frequencies and mode shapes of the domes submerged in water together with the pressure distribution in the water at each natural frequency. The natural frequencies and mode shapes of the domes in air were also determined in order that the effect of the water on the natural frequencies could be demonstrated.

81-1007

Transient Response of a Spherical Shell in an Acoustic Medium -- Comparison of Exact and Approximate Solutions

N. Akkas and A.E. Engin

Dept. of Civil Engrg., Middle East Tech. Univ., Ankara, Turkey, J. Sound Vib., 73 (3), pp 447-460 (Dec 8, 1980) 3 figs, 1 table, 29 refs

Key Words: Shells, Spherical shells, Transient response, Approximation methods

The transient response of a spherical shell in an acoustic medium is studied. The exact solution is obtained by expressing the classical spherical wave equation in terms of a residual potential. Approximate solutions are obtained from the use of eight functions; namely, doubly asymptotic approximations, δ-sequence functions, and spherical wave approximations. The advantages and disadvantages of these approximate solutions are pointed out. The third member of the class of the modal doubly asymptotic approximations for a spherical surface and an improved spherical wave approximation are introduced.

81-1008

An Energy Analysis of the Free Vibrations of Isotropic Spherical Shells

V.C.M. de Souza and J.G.A. Croll

Dept. of Civil and Municipal Engrg., Univ. College London, London WC1E 6BT, UK, J. Sound Vib., 73 (3), pp 379-404 (Dec 8, 1980) 11 figs, 5 tables, 26 refs

Key Words: Shells, Spherical shells, Free vibration, Energy methods, Domes

The free vibrations of isotropic spherical shells, having one boundary open and the other either open or closed, are investigated by using a variational development of the equations of motion based upon classical shell theory. Expressions are derived for each of the individual contributions to both the membrane and bending strain energies, and used to obtain the energy profiles for mode-shapes associated with each of the natural vibration frequencies. Results for shell geometries ranging from a shallow cap to a hemispherical dome, for a wide variety of thickness to radius ratios, provide a clearer picture of the nature of the shell's resistance to linear vibrations. Suggestions are made as to how these isotropic energy profiles may be used as an aid for the design of both isotropic and orthotropic shells which embody some prescribed dynamic characteristics.

81-1009

Dynamic Deformations of Thin Spherical Shells Based on Analytical Solutions

B. Göller

Kernforschungszentrum Karlsruhe GmbH, Institut f. Reaktorentwicklung, Postfach 3640, 7500 Karlsruhe, Fed. Rep. of Germany, J. Sound Vib., 73 (4), pp 585-596 (Dec 22, 1980) 6 figs, 8 refs

Key Words: Shells, Spherical shells, Transient excitation, Translational inertia effects, Modal superposition method, Containment structures, Nuclear reactors

The dynamic deformations of a very thin spherical shell under local transient loadings are investigated. Flugge's shell equations, including translational inertia forces, are solved analytically for special boundary conditions by modal superposition. Results are presented for a spherical shell zone of the containment vessel of a nuclear boiling water reactor with a radius of 13•5 m and a wall thickness of 0•02 m. The eigenfrequencies of the shell are very close to each other, which causes a rather local behavior with significant deformations in the loaded shell region only. For a satisfactory description of the local dynamic responses approximately 2000 modes had to be included in the superposition process.

81-1010

Free Vibration of a Cylinder Partially Filled with a Liquid

S.P. Lim and M. Petyt

Inst. of Sound and Vib. Res., Univ. of Southampton, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 447-455, 3 figs, 13 refs

Key Words: Cylinders, Cylindrical shells, Fluid-filled containers, Natural frequencies, Mode shapes, Finite element technique

The natural frequencies and modes of free vibration of a cylinder which is partially filled with a liquid have been predicted using finite element techniques. The cylinder was idealized using an axisymmetric, cylindrical shell element, whereas the fluid effects were represented in two different ways. In the first analysis the virtual mass of the fluid was added to the mass of the cylinder, while in the second the fluid was represented by an assemblage of axisymmetric, acoustic elements. These elements were derived using a displacement potential theory. It was generally found that the acoustic element analysis gave the better agreement with experiment.

81-1011

An Analytical Vibration Study of Thin Circular Cylinders

C.B. Sharma

Univ. of Manchester, Inst. of Science and Tech., Manchester M60 1QD, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 61-72, 5 figs, 3 tables, 10 refs

Key Words: Shells, Cylindrical shells, Vibration analysis, Boundary condition effects

The main objectives of the present paper are: to give a unified treatment of the title problem to encompass various boundary conditions, to compare the analytical frequencies with the observed ones in case of various end conditions, and to study the validity and usefulness of some simple linear formulas which will be found very helpful when tabulating the data for thin shells because exact analyses are often accompanied by an enormous degree of numerical difficulty that is prohibitively costly, if ever workable. By contrast, these simple relations did not present such numerical complexity.

81-1012

Further Experimental Studies on Vibrations and Buckling of Eccentrically Loaded Stiffened Cylindrical Shells

J. Singer and Y. Segal
Dept. of Aeronautical Engrg., Technion - Israel Inst. of Tech., Haifa, Israel, Rept. No. TAE-331, 46 pp (Dec 1978)
N80-31818

Key Words: Shells, Cylindrical shells, Vibration tests

A method for detection of load eccentricity of stringer-cylindrical shells from vibration tests developed earlier was applied to shells with prescribed load eccentricity. Seven shells with outward or zero load eccentricity were tested and analyzed. In the tests, the shells were vibrated at different load levels and finally buckled. The experimental and theoretical results verify the methods of load eccentricity identification and buckling load prediction and extend their applicability.

81-1013

The Sound Pressure Level within a Cylindrical Chamber with a Sinusoidally Driven End Wall

G. Pagliarini and R. Pompoli
Istituto di Fisica Tecnica, Universita di Bologna, Italy, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 457-476, 4 figs, 3 refs

Key Words: Shells, Cylindrical shells, Enclosures, Periodic excitation, Sound pressure levels

Equations are derived for calculating the sound pressure level within a cylindrical chamber with a sinusoidally driven end wall. The theoretical analysis is compared with experimental results and good agreement is shown for the frequencies that were not close to the calculated or measured acoustic and structural frequencies of the cylinder end wall.

81-1014

Transmission of Waves through Discontinuities in Cylindrical Shells

C.R. Fuller
Inst. of Sound and Vib. Res., Univ. of Southampton, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound and Vib., Univ. of Southampton, Vol. I, pp 355-360, 4 figs, 7 refs

Key Words: Shells, Cylindrical shells, Discontinuity-containing media, Flexural vibration, Flexural waves

Although piping systems play an important role in various marine, airborne and industrial applications, they often transmit unwanted energy in the form of structural and acoustical vibrations. Discontinuities in the piping system have the effect of partially reflecting these vibrations and subsequently reducing transmitted energy. It is therefore of interest to predict the degree to which a discontinuity (intentional or not) in the piping system attenuates travelling waves. The present paper considers the effects of axisymmetric discontinuities in the wall of a cylindrical shell on travelling flexural waves. The discontinuities consist of either a change in wall thickness or wall material and theoretical results are obtained for step changes and changes of finite length. The analysis is limited to thin-walled shells and frequencies such that the rotational kinetic energy and transverse deformation of the shell wall may be ignored. The vibration of the pipe is considered "in-vacuo".

81-1015

On Sound Transmission into a Stiffened Cylindrical Shell with Rings and Stringers Treated as Discrete Elements

L.R. Koval
Dept. of Mech. and Aerospace Engrg., Univ. of Missouri, Rolla, MO, J. Sound Vib., 71 (4), pp 511-521 (Aug 22, 1980) 5 figs, 10 refs

Key Words: Shells, Cylindrical shells, Stiffened shells, Stringers, Rings, Sound transmission, Aircraft

In the context of the transmission of airborne noise into an aircraft fuselage, a mathematical model is presented for the transmission of an oblique plane sound wave into a finite cylindrical shell stiffened by stringers and ring frames. The rings and stringers are modeled as discrete structural elements. The numerical case studied was typical of a narrow-bodied jet transport fuselage. The numerical results show that the ring-frequency dip in the transmission loss curve that is present for a monocoque shell is still present in the case of a stiffened shell. The ring frequency effect is a result of the cylindrical geometry of the shell. Below the ring frequency, stiffening does not appear to have any significant effect on transmission loss, but above the ring frequency, stiffeners can enhance the transmission loss of a cylindrical shell.

81-1016

Sound Transmission into a Laminated Composite Cylindrical Shell

L.R. Koval

Dept. of Mech. and Aerospace Engrg., Univ. of Missouri, Rolla, MO, J. Sound Vib., 71 (4), pp 523-530 (Aug 22, 1980) 5 figs, 7 refs

Key Words: Shells, Cylindrical shells, Layered materials, Sound transmission, Aircraft

In the context of the transmission of airborne noise into an aircraft fuselage, a mathematical model is presented for the transmission of an oblique plane sound wave into a laminated composite circular cylindrical shell. Numerical results are obtained for geometry typical of a narrow-bodied jet transport. Results indicate that from the viewpoint of noise attenuation a laminated composite shell does not appear to offer any significant advantage over an aluminum shell. However, the transmission loss of a laminated composite shell is sensitive to the orientation of the fibers and this suggests the possibility of using a laminated composite shell to tailor the noise attenuation characteristics to meet a specific need.

81-1017

Inelastic Response of an Infinite Cylindrical Shell to a Transient Acoustic Wave

T.L. Geers and C.-L. Yen

Palo Alto Res. Lab., Lockheed Missiles and Space Co., Inc., Palo Alto, CA, Rept. No. LMSC/D676214, 45 pp (Mar 1979)

AD-A088 597/0

Key Words: Shells, Cylindrical shells, Acoustic excitation, Transient excitation

An analytical/computational technique has been developed for determining the geometrically and constitutively nonlinear response of an infinite cylindrical shell to a transverse, transient acoustic wave. Shell behavior has been treated through utilization of the nonlinear structural analyzer DYNAPLAS II, while the fluid-structure interaction has been treated in accordance with both the exact residual potential formulation and the doubly asymptotic approximation. Numerical results produced through application of the approximation differ significantly from the corresponding exact results.

PIPES AND TUBES

(Also see Nos. 896, 1014)

81-1018

Acoustic Excitation of Liquid Filled Distorted Pipes

M.J.H. Fox

Central Electricity Generating Board, Berkeley Nuclear Labs., Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 505-519, 9 figs, 2 tables, 6 refs

Key Words: Interaction: structure-fluid, Acoustic excitation, Pipes (tubes), Fluid-filled containers

The effect of the distortion of the pipe on the fluid-structure interaction is investigated. It was found that the departures from perfect circularity of the cross section provide a means by which energy in a lengthwise acoustic resonance of the contained liquid may be transferred to an 'ovalling' mode of the pipe, if the frequencies are close. For very small amounts of distortion the magnitude of the ovalling response increases linearly with distortion. Above a certain level of distortion, dependent on the amount of damping present, however, the response remains almost constant. A model may be expected to reproduce the acoustic-structural coupling characteristics of the full scale system provided both have distortion above this level.

81-1019

Tube Vibration in Industrial Size Test Heat Exchanger

H. Halle and M.W. Wambsganss

Argonne National Lab., Argonne, IL, 64 pp (Mar 1980)

ANL-CT-80-18

Key Words: Tubes, Heat exchangers, Vibration tests

Tube vibration data from tests of a specially built and instrumented, industrial-type, shell-and-tube heat exchanger are reported. The heat exchanger is nominally 0.6 m (2 ft) in dia and 3.7 m (12 ft) long. Both full tube and no-tubes-in-window bundles were tested for inlet/outlet nozzles of different sizes and with the tubes supported by seven, equally-spaced, single-segmental baffles. Prior to water flow testing, natural frequencies and damping of representative tubes were measured in air and water. Flow testing was accomplished by increasing the flow rates in stepwise fashion and also by sweeping through a selected range of flow rates.

The primary variables measured and reported are tube accelerations and/or displacements and pressure drop through the bundle. Tests of the full tube bundle configuration revealed tube rattling to occur at intermediate flow rates, and fluidelastic instability, with resultant tube impacting, to occur when the flow rate exceeded a threshold level.

81-1020

Experimental Observations of the Condensation of Steam on a Vibrating Horizontal Condensing Tube

R.M. Desmond and B.V. Karlekar

Rochester Inst. of Tech., Rochester, NY, ASME Paper No. 80-HT-52

Key Words: Heat exchangers, Tubes, Heat transfer, Vibration effects

Over the years, researchers have suggested that there is an increase in the heat transfer rate from condenser tubes when they are mechanically vibrated. A specific example which is often cited is the ability of condenser units aboard oceangoing vessels to perform above their rated capability. To explore this phenomenon, a single tube condensing unit was built in which the outer shell was made of Pyrex glass. Temperature measurements of the cooling water, the steam, and the condenser tube wall were made and the condensation process was visually monitored while the condensing tube was vibrated at different frequencies ranging from 0 to 50 Hz at a constant amplitude of 1 mm.

81-1021

Unstable Vibrations of a Bundle of Cylinders Due to Cross Flow

H.G.D. Goyder

UKAEA Harwell, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, 533-542, 7 figs, 5 refs

Key Words: Cylinders, Fluid-induced excitation, Heat exchangers, Multibeam systems

Two aspects of the unstable vibration of a bundle of closely spaced cylinders with fluid flowing through them, such as the heat exchangers, are considered in this paper. First some investigations into the mechanisms causing vibration are described which indicate the nature of the fluid forces. It is suggested that instability may be due to the acceleration of the fluid by the vibrating cylinder or alternatively the relative motion of adjacent cylinders. Secondly a theoretical analysis of a single row of cylinders is presented.

81-1022

Seismic Response of a Buried Pipeline. I. Infinite Medium

S.K. Datta and N. El-Akily

Dept. of Mech. Engrg., Colorado Univ. at Boulder, CO, Rept. No. CUMER-80-3, NSF/RA-800107, 29 pp (June 1980)

PB80-211758

Key Words: Pipelines, Underground structures, Seismic response

The study considered three main subject areas: developing the three dimensional equations of motion of the shell taking into account the effects of transverse shear and rotatory inertia; formally solving the equations of motion coupled with those of the surrounding medium; and using the low frequency approximate expression of the traction force on the shell due to the surrounding medium for evaluating the spring constants of the elastic foundation approximating the infinite surrounding medium. These spring constants were shown to be dependent on the wavelength of the exciting waves, the mean radius of the shell, and the material constants of the surrounding medium. In order to facilitate analysis, the surrounding medium was considered to be infinite in extent and the interaction problem was solved for the case of axisymmetry. A model was developed of the general motion of a long straight buried pipe-line due to seismic waves. The special case of the axially symmetric motion of a pipeline excited by a travelling longitudinal wave was solved under the assumption that the inertia effects can be neglected.

81-1023

Control of Parametric Instabilities of a Periodically Supported Pipe with Dynamic Absorbers

A.K. Mallik and S. Narayanan

Indian Inst. of Tech., Kanpur, India, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. of Sound and Vib., Univ. of Southampton, Vol. II, pp 661-676, 6 figs, 5 refs

Key Words: Pipes (tubes), Periodic structures, Parametric response, Absorbers (equipment)

The present paper considers the parametric instabilities of a periodically supported pipe with dynamic absorbers attached to the midpoint of each bay. Thus the periodicity of the overall structure is retained. The wave approach is used to determine the instability zones. Numerical results are presented for single and two span pipes. A short discussion on the situation of the pipeline having a very large number of spans is also included.

81-1024

Resonance and Transient Response of Pressurized Complex Pipe Systems

T. Muto and T. Kanei

Faculty of Engrg., Gifu Univ., Bull. JSME, 23 (184), pp 1610-1617 (Oct 1980) 17 figs, 5 tables, 8 refs

Key Words: Pipelines, Resonant response, Transient response, Branched systems, Fluid-induced excitation

Resonance in pressure conduits is studied on complex pipe systems which are composed of series, branching and parallel piping lines. In such complex systems, shapes of the resonance curves and also resonance frequencies differ remarkably depending on the location of input or output of the lines. It is shown that these phenomena are generally observed in a simple line or in a system with many degrees of freedom. Next, transient response plots are obtained experimentally for conduits lines with various boundary conditions such as open-end, closed-end and some loads. These plots are compared with results of numerical analysis obtained by the characteristic method. Their agreement is good.

81-1025

Combined Longitudinal and Lateral Vibration of a Curved Reinforced Hose

D.K. Longmore and C.W. Stammers

Univ. of Bath, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 521-532, 5 figs, 4 refs

Key Words: Hoses, Reinforced structures, Noise reduction, Hydraulic equipment, Lateral vibration, Longitudinal response

The reduction of noise in hydraulic systems by isolating pumps and valves with reinforced hose from the rest of the pipework was investigated. A theoretical model of the longitudinal and lateral vibration of a reinforced hose predicts changes in the resonant frequencies with hose curvature and in some cases a reduction in peak pressures. The experimental work carried out to date gives general support to these predictions.

81-1026

Beating Noise in Fluid Systems

Engrg. Mtl. Des., 24 (8), pp 44-50 (Sept 1980) 12 figs

Key Words: Hydraulic systems, Noise reduction, Pumps, Valves, Silencers, Fluid induced excitation

Noise control in hydraulic systems incorporating pumps, motors, and valves is described.

81-1027

Beating Noise in Fluid Systems

Engrg. Matl. Des., 24 (9), pp 28-32 (Oct 1980) 4 figs

Key Words: Hydraulic systems, Noise reduction, Hoses

The effect of using hoses and isolators in quieting hydraulic systems is described.

DUCTS

81-1028

A Note on the Interaction between a Helmholtz Resonator and an Acoustic Mode of an Enclosure

F.J. Fahy and C. Schofield

Inst. Sound Vib. Res., Univ. of Southampton, Southampton S09, 5NH, UK, J. Sound Vib., 72 (3), pp 365-378 (Oct 8, 1980) 4 figs, 2 tables, 8 refs

Key Words: Helmholtz resonators, Natural frequencies, Enclosures, Fluid-filled containers

A single Helmholtz resonator is coupled to an enclosure and tuned to the natural frequency of one of its low order acoustic modes. The effect on the free, and forced, vibrations of the fluid in the enclosure is analyzed. The conditions

necessary for the resonator to increase the damping of the two resultant modes, and to control the room response to excitation at frequencies within the range embracing both natural frequencies, are investigated. A simple design graph is presented.

81-1029

Finite Element Applications to Coupled Plate-Acoustic Absorption Systems

A. Craggs and M.G. Lau

Dept. of Mech. Engrg., Univ. of Alberta, Edmonton, Alberta, Canada, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 437-445, 3 figs, 1 table, 5 refs

Key Words: Enclosures, Plates, Acoustic absorption

In this paper a simple rectangular sectioned enclosure is considered, one end bounded by a flat plate and the opposite end by a thick layer of absorbing material. An eight node plate element is used, having three unknowns per node. A twenty node isoparametric element is used for both the air and the absorption. Results are given for a free vibration problem involving only the plate and the air and a forced response of the enclosure due to a harmonic force placed at the centre of the plate; the level of the response inside the cavity being affected by a lining.

81-1030

A Joint Acceptance Function for Enclosed Spaces

G.H. Koopmann and H.F. Pollard

Dept. of Mech. Engrg., Univ. of Houston, Houston, TX, J. Sound Vib., 73 (3), pp 429-446 (Dec 8, 1980) 11 figs, 2 tables, 9 figs

Key Words: Enclosures, Coupled response, Green function

A method is proposed for quantifying the geometric coupling between the acoustic modes of an enclosure and the vibratory motion of the enclosing surfaces. A dimensionless quantity, called the joint acceptance function, is defined which gives the coupling efficiency of an enclosing surface within a range from zero to unity. The joint acceptance function is based on an integral solution to the wave equation which requires a knowledge of the Green function for an enclosed space. Section 2 of the paper is devoted to methods of generating Green functions for enclosed spaces as series expansions in terms of orthogonal eigenfunctions. Computer generated Green functions are shown to compare favorably with those obtained from experiments performed on a hard walled, rectangular box. Section 3 of the paper describes the method of calculating the joint acceptance function for arbitrarily shaped enclosures. Two applications of this function are presented: a rectangular enclosure with surfaces vibrating as simply supported plates, and a practical case involving the reduction of noise in a tractor cabin.

81-1031

Acoustoelasticity: Review and Extension

E.H. Dowell, C. Chao, and D.B. Bliss

Dept. of Mech. and Aerospace Engrg., Princeton Univ., Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 377-402, 6 figs, 9 tables, 33 refs

Key Words: Enclosures, Fluid-induced excitation, Acoustic response, Sound transmission

The interaction between the (acoustic) sound pressure field and the (elastic) flexible wall of an enclosure will be discussed. Such problems frequently arise when the vibrating walls of a transportation vehicle induce a significant internal sound field. The walls themselves may be excited by external fluid flows. Cabin noise in various flight vehicles and the internal sound field in an automobile are representative examples. Briefly considered are a mathematical model, simplified solutions for sinusoidal excitation, damping, random excitation, numerical results including comparison with representative experimental data, and design analysis methodology. An overall conclusion is that reasonable grounds for optimism exist with respect to available theoretical models and their predictive capability.

81-1032

Intensification and Refraction of Acoustical Signals in Partially Choked Converging Ducts

A.H. Nayfeh

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 73 (4), pp 519-531 (Dec 22, 1980) 9 figs, 17 refs

Key Words: Ducts, Acoustic linings, Noise reduction, Aircraft noise, Geometric effects, Sound transmission

A computer code based on the wave-envelope technique is used to perform detailed numerical calculations for the intensification and refraction of sound in converging hard walled and lined circular ducts carrying high mean Mach number flows. The results show that converging ducts produce substantial refractions toward the duct center for waves propagating against near choked flows. As expected, the magnitude of the refraction decreases as the real part of the admittance increases. The pressure wave pattern is that of interference among the different modes, and hence the variation of the magnitude of pressure refraction with frequency is not monotonic.

81-1033

A Feasibility Study of a 3-D Finite Element Solution Scheme for Aeroengine Duct Acoustics

A.L. Abrahamson

Wyle Labs., Inc., Hampton, VA, Rept. No. NASA-CR-159359; Rept-51200, 37 pp (Sept 1980)

N80-34216

Key Words: Ducts, Aircraft engines, Noise generation, Finite element technique

The advantage from development of a 3-D model of aeroengine duct acoustics is the ability to analyze axial and circumferential liner segmentation simultaneously. The feasibility of a 3-D duct acoustics model was investigated using Galerkin or least squares element formulations combined with Gaussian elimination, successive over-relaxation, or conjugate gradient solution algorithms on conventional scalar computers and on a vector machine. A least squares element formulation combined with a conjugate gradient solver on a CDC Star vector computer initially appeared to have great promise, but severe difficulties were encountered with matrix ill-conditioning. These difficulties in conditioning rendered this technique impractical for realistic problems.

81-1034

Acoustic Plane Waves Incident on an Oblique Clamped Panel in a Rectangular Duct

H. Unz and J. Roskam

Dept. of Aerospace, Kansas Univ., Lawrence, KS, Rept. No. KU-FRL-417-14; NASA-CR-163624, 137 pp (Aug 1980)

N80-34215

Key Words: Ducts, Panels, Plates, Elastic waves, Acoustic excitation

The theory of acoustic plane waves incident on an oblique clamped panel in a rectangular duct was developed from basic theoretical concepts. The coupling theory between the elastic vibrations of the panel (plate) and the oblique incident acoustic plane wave in infinite space was considered in detail, and was used for the oblique clamped panel in the rectangular duct. The partial differential equation which governs the vibrations of the clamped panel (plate) was modified by adding to it stiffness (spring) forces and damping forces. The Transmission Loss coefficient and the Noise Reduction coefficient for oblique incidence were defined and derived in detail. The resonance frequencies excited by the free vibrations of the oblique finite clamped panel (plate) were derived and calculated in detail for the present case.

81-1035

A Comparison of Experiment and Theory for Sound Propagation in Variable Area Ducts

A.H. Nayfeh, J.E. Kaiser, R.L. Marshall, and C.J. Hurst

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 71 (2), pp 241-259 (July 22, 1980) 13 figs, 1 table, 20 refs

Key Words: Ducts, Noise reduction

An experimental and analytical program has been carried out to evaluate sound suppression techniques in ducts that produce refraction effects due to axial velocity gradients. The analytical program employs a computer code based on the method of multiple scales to calculate the influence of axial variations due to slow changes in the cross-sectional area as well as transverse gradients due to the wall boundary layers. Detailed comparisons between the analytical predictions and the experimental measurements have been made. The circumferential variations of pressure amplitudes and phases at several axial positions have been examined in straight and variable area ducts, with hard walls and lined sections, and with and without a mean flow. Reasonable agreement between the theoretical and experimental results has been found.

81-1036

Low Frequency Acoustic Radiation from Duct Walls

A. Cummings

Inst. of Environmental Science and Tech., Polytechnic of the South Bank, London SE1 OAA, UK, J. Sound Vib., 71 (2), pp 201-226 (July 22, 1980) 13 figs, 1 table, 9 refs

Key Words: Ducts, Elastic waves, Sound propagation, Low frequencies

The use of line source theoretical models, to predict low frequency radiation from the walls of rectangular ducts, has been investigated in some detail. A model which incorporates two travelling waves has proved successful in predicting both the far field directivity of radiation at discrete frequencies (a relatively severe test of the theory) and the total radiated power in frequency bands, insofar as generally good agreement has been obtained between theory and experiment. A random vibration model is also described here, by contrast to the travelling wave model, although it fails to describe the radiation processes properly.

81-1037

Wave Propagation in a Duct with Boundary Scattering (with Application to a Surface Duct)

H.P. Bucker

Code 5311, Naval Ocean Systems Ctr., San Diego, CA 92152, J. Acoust. Soc. Amer., 68 (6), pp 1768-1722 (Dec 1980) 6 figs, 15 refs

Key Words: Ducts, Sound waves, Wave propagation, Normal modes

Scattering integrals are derived that represent the contribution of boundary scattering in a sound channel. These integrals are added to the normal mode sum which represents the coherent field in the channel. A comparison is made between experimental and calculated sound levels in a surface duct. For the case examined, it is clear that (except for short ranges) surface scattered energy is a significant source of sound at a below duct receiver.

BUILDING COMPONENTS

(Also see Nos. 1081, 1163)

81-1038

Seismic Resistance of Composite Floor Diaphragms

M.L. Porter and L.F. Greimann

Engrg. Res. Inst., Iowa State Univ., Ames, IA, Rept. No. ISU-ERI-AMES-80133, NSF/RA-800123, 187 pp (May 1980)

PB81-102774

Key Words: Floors, Slabs, Composite structures, Seismic response

Research to determine the behavioral and strength characteristics of composite steel deck floor slab diaphragms is reported. Principal characteristics investigated include maximum load, ductility, stiffness, and failure mode. The research program comprises three phases: designing a full-scale research facility for in-plane loading of composite slab diaphragms and conducting two pilot tests; testing of full-scale composite slabs with in-plane loading only; and testing of one-way slab elements with vertical loads to determine the influence of stud shear connectors on shear-bond strength. Initial test results show that the addition of studs increases the flexural load capacity of one-way steel deck reinforced slabs by 10 to 30 percent. Non-studded specimens ultimately fail because of loss of interfacial force in the shear span. Studded specimens ultimately fail due to tearing of the deck near the stud. Two analysis procedures were used, a contributing forces approach and a shear-bond approach. The former was found to be a potential analysis procedure, and results from the shear-bond increase approach demonstrated its feasibility for studded specimens.

81-1039

A New Approach for Developing Dynamic Theories for Structural Elements. Part 2: Application to Thermoelastic Layered Composites

Y. Mengi, G. Birlik, and H.D. McNiven

The Middle East Technical Univ., Ankara, Turkey, Intl. J. Solids Struc., 16 (12), pp 1169-1186 (1980) 8 figs, 2 tables, 15 refs

Key Words: Structural elements, Composite structures, Layered materials, Continuum mechanics

In this study a continuum theory is proposed which predicts the dynamic behavior of thermoelastic layered composites consisting of two alternating layers. In constructing the theory, it is noted that the governing equations for a single layer, derived in Part 1, hold in each phase of the layered composite. The theory is completed by supplementing the equations with continuity conditions and using a smoothing operation. The derivation of the continuity conditions is based on the assumption that the layers are perfectly bonded at interfaces. To assess the theory, spectra from the exact and the derived theory are compared for waves propagating in various directions of the composite. The match between the two is excellent. For waves propagating normal to layering the theory predicts both the banded and periodic structure of the spectra. The region of validity of the theory on the wave number-frequency plane can be enlargened by increasing the orders of the theory and the continuity conditions.

81-1040

Dynamic Plastic Response of Structures

N. Jones

Dept. of Mech. Engrg., Univ. of Liverpool, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 677-689, 4 figs, 47 refs

Key Words: Dynamic plasticity, Transverse shear deformation effects, Rotatory inertia effects, Beams

This article starts with some general comments on the accuracy of rigid-plastic methods of analysis for predicting the dynamic plastic behavior of structures. Recent investigations into the influence of transverse shear and rotatory inertia are then taken up and a new study is presented for the mode III transverse shear response of a simply supported beam subjected to an impulsive velocity distributed within a central zone of arbitrary length. It concludes with a discussion of the results obtained during a recent numerical study into the dynamic plastic buckling of a simple elastic-plastic model which have important implications for numerical studies on more realistic structures.

81-1041

Vibration of Composite Structures

C.W. Bert

School of Aerospace, Mechanical and Nuclear Engrg., The Univ. of Oklahoma, Recent Advances in Structural Dynamics, July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 693-712, 4 tables, 143 refs

Key Words: Composite structures, Composite materials, Damping, Dynamic stiffness, Panels, Curved plates, Shells, Rings, Beams

Some recent contributions to the field of vibration of composite structures are reviewed. The topics treated are: dynamic stiffness and damping of composite materials, beams and curved bars and rings, flat panels, and cylindrically curved panels and shells. Suggestions for future research are also included.

ELECTRIC COMPONENTS

MOTORS

81-1042

Studies of Motor Instability Problems

R.O. Hessler

Thiokol Corp., Huntsville, AL, APL, The 16th JANNAF Combut. Meeting, Vol. 2, pp 399-428 (Dec 1979)

N80-31608

Key Words: Rocket motors, Motors, Oscillation, Geometric imperfection effects, Axial vibration

Each of the three motors discussed was predicted to be stable by comfortable margins in the lower longitudinal modes. Two of the motors exhibited spontaneous oscillations in the axial modes. Data analysis of these motors indicated that the longitudinal modes were indeed stable and that the oscillations were driven by vortexes caused by flow over discontinuities in the propellant geometry.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 908, 912, 934, 1028, 1053, 1087)

81-1043

Nonlinear Surface Acoustic Waves on an Isotropic Solid

N. Kalyanasundaram

Dept. of Appl. Mathematics, Indian Inst. of Science, Bangalore-560 012, India, Intl. J. Engrg. Sci., 19 (2), pp 279-286 (1981) 1 fig, 14 refs

Key Words: Elastic waves, Wave propagation, Nonlinear theories

A systematic derivation of the approximate coupled amplitude equations governing the propagation of a quasi-monochromatic Rayleigh surface wave on an isotropic solid is presented, starting from the non-linear governing differential equations and the non-linear free-surface boundary conditions, using the method of multiple scales. An explicit solution of these equations for a signaling problem is obtained in terms of hyperbolic functions.

81-1044

Finite-Amplitude Love-Waves on an Isotropic Layered Half-Space

N. Kalyanasundaram

Dept. of Appl. Mathematics, Indian Inst. of Science, Bangalore 560012, India, Intl. J. Engrg. Sci., 19 (2), pp 287-293 (1981) 1 fig, 5 refs

Key Words: Elastic waves, Wave propagation, Half space

A pair of semi-linear hyperbolic partial differential equations governing the slow variations in amplitude and phase of a quasi-monochromatic finite-amplitude Love-wave on an isotropic layered half-space is derived using the method of multiple-scales. The analysis of the exact solution of these equations for a signaling problem reveals that the amplitude of the wave remains constant along its characteristic and that the phase of the wave increases linearly behind the wave-front.

81-1045

A Polarization Approach to the Scattering of Elastic Waves - I. Scattering by a Single Inclusion

J.R. Willis
School of Mathematics, Bath Univ., Claverton Down, Bath BA2 7AY, UK, J. Mechanics Phys. Solids, 28 (5/6), pp 287-305 (Dec 1980) 3 figs, 32 refs

Key Words: Elastic waves, Wave diffraction, Discontinuity-containing media

Scattering problems in elastodynamics are formulated in terms of integral equations, whose kernels are obtained from the Green's function for a comparison body. Inhomogeneous, viscoelastic and non-local bodies are used. The novel feature of the formulation is the introduction of a "momentum polarization" to cope with density variations in a way that exactly parallels the stress polarization's correspondence with variations in moduli. To illustrate the use of the equations, scattering by an ellipsoidal inhomogeneity in a generally anisotropic matrix is studied in the Rayleigh limit and an asymptotic formula for its scattering cross-section is given. Detailed results are presented for a spheroidal inhomogeneity in an isotropic matrix, with explicit limiting forms for the scattering cross-sections of penny-shaped cracks, rigid circular discs and rigid needles.

81-1046

A Polarization Approach to the Scattering of Elastic Waves - II. Multiple Scattering from Inclusions

J.R. Willis
School of Mathematics, Bath Univ., Claverton Down, Bath BA2 7AY, UK, J. Mechanics Phys. Solids, 28 (5/6), pp 307-327 (Dec 1980) 7 figs, 26 refs

Key Words: Elastic waves, Wave diffraction, Discontinuity-containing media, Composite material

The integral equation formula given in the accompanying paper is applied to the study of plane waves propagating in a composite material comprising a possibly anisotropic elastic matrix containing aligned elastic inclusions, positioned randomly. An asymptotic solution is given for waves of low frequency. Estimates of the overall moduli that follow from the formulation coincide, for a certain class of composites, with estimates obtainable from the Hashin-Shtrikman variational principle; explicit bounds for the overall moduli of bodies containing aligned penny-shaped cracks, aligned rigid discs and aligned rigid needles follow as by-products of the analysis. Examples show that, at any given frequency, attenuation increases initially with concentration, attains a maximum and then declines as concentration increases further.

81-1047

Sound Energy Calculation of Transient Sound Sources by the Radiation Efficiency Method

R.K. Jeyapalan and P.E. Doak
Inst. Sound Vib. Res., Univ. of Southampton S09 5NH, UK, J. Sound Vib., 72 (3), pp 351-364 (Oct 8, 1980) 2 figs, 12 refs

Key Words: Sound waves, Radiation efficiency method

In this paper theoretical arguments are presented to show that the radiation efficiency method can be used to calculate the sound energy radiated by transient sound sources. Radiation efficiency method results are shown to be strictly applicable to transients as well as steady state. An example is presented to illustrate that for machines of even relatively high damping the radiation efficiency for a transient can be approximated by its value at the ringing frequency, thus permitting simple calculation of acoustic energy output from time-domain data alone.

81-1048

Radiation Impedance of One or Several Real Sources Mounted in a Hard-Walled Rectangular Waveguide

M. Berengier and A. Roure
Laboratoire de Mecanique et d'Acoustique, Centre National de la Recherche Scientifique, 13274 Marseille Cedex 2, France, J. Sound Vib., 71 (3), pp 389-398 (Aug 8, 1980) 9 figs, 7 refs

Key Words: Waveguides, Acoustic impedance

When two or several neighboring sources simultaneously radiate in a waveguide, they interfere. Calculations of their

respective radiation impedances for various source arrangements are studied.

81-1049

The Effect of a Non-Zero Cavitation Tension on the Damage Sustained by a Target Plate Subject to an Underwater Explosion

M.R. Driels
Dept. of Mech. Engrg., Univ. of Edinburgh, Edinburgh EH9 3JL, Scotland, J. Sound Vib., 73 (4), pp 533-545 (Dec 22, 1980) 11 figs, 7 refs

Key Words: Plates, Underwater explosions, Cavitation

The work on the interaction between a target plate and an underwater explosion is developed to include the possibility of the water having a non-zero cavitation tension. The simplified one-dimensional model of the phenomenon initially indicates that the damage sustained is increased but then shows that the well established process of spray reloading has also to be considered in assessing the total damage inflicted. It is concluded that the two mechanisms of a non-zero cavitation tension and spray reloading have opposing influences resulting in an almost constant damage prediction.

81-1050

Experiments on Effective Source Locations and Velocity Dependence of the Broad Band Noise from a Rotating Rod

U.R. Kristiansen
Acoustics Lab., The Univ. of Trondheim, Trondheim 7000, Norway, J. Sound Vib., 72 (3), pp 403-413 (Oct 8, 1980) 8 figs, 1 table, 7 refs

Key Words: Noise source identification, Cylindrical bodies, Rods

Effective acoustic source positions (observed from the far field) have been located for the broad band noise from a cylindrical rod rotated about its mid-point by measuring the cross spectral density function of two microphone signals on the axis of rotation. Local source position Strouhal numbers could thereby be calculated. On the basis of acoustic power measurements it was demonstrated that the noise may be normalized on a rod tip Strouhal number basis, and that the velocity exponent is nearly constant when plotted against this parameter. The results indicate that vortex shedding like that for stationary cylinders in a cross flow is responsible for the high levels of broad band noise in a major peak region.

81-1051

An Experimental and Analytical Study of a New Flap Valve for Generating Simulated Sonic Booms

J.J. Gottlieb
Inst. for Aerospace Studies, Univ. of Toronto, Toronto, Ontario, Canada, J. Sound Vib., 72 (3), pp 283-302 (Oct 8, 1980) 17 figs, 11 refs

Key Words: Sonic boom, Simulation, Valves

The design, operation, and performance of a sonic boom simulator, featuring a radically new dual-flap valve and electromechanical control system, are described. This new flap valve with its large maximum throat area was designed to regulate the air flow from a low pressure reservoir (up to 0·2 atm overpressure) into the apex of a large pyramidal horn where the incoming low speed air flow produces a travelling simulated sonic boom or N-wave with relatively little superposed high frequency noise. As a consequence, the full scale simulated sonic boom is virtually free of superposed jet noise, a major advance over past work with such horn-type simulators. Additionally, an advanced gasdynamic analysis of the reservoir coupled with an advanced acoustic analysis of the wave motion in the horn is presented to predict the characteristics of the simulated sonic boom - wave form, amplitude, duration, and rise time. Predicted and measured overpressure signatures are shown to be in excellent agreement.

81-1052

The Dynamics of Shearing Flow over a Cavity - A Visual Study Related to the Acoustic Impedance of Small Orifices

D. Ronneberger
Univ. Gottingen, D-3400 Göttingen, Germany, J. Sound Vib., 71 (4), pp 565-581 (Aug 22, 1980) 12 figs, 28 refs

Key Words: Plates, Hole-containing media, Holes, Acoustic impedance

A flat plate containing a two-dimensional rectangular cut-out was exposed to laminar grazing flow of water and a small oscillatory flow through the orifice of the cavity was applied resulting in a wave-like oscillation of the interface between the fluid at rest inside the cavity and the external flow. The

interface was visualized by a thin filament of color dye and the oscillation was recorded by means of a cine-camera. The experimental results are compared to the predictions of a model which had been developed in order to explain the effect of grazing flow on the acoustic impedance of small orifices.

SHOCK EXCITATION

(Also see Nos. 886, 1072, 1143, 1144, 1158, 1166, 1167)

81-1053

Non-Linear Propagation of Directional Spherical Waves

S.G. Kelly and A.H. Nayfeh
Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 72 (1), pp 25-37 (Sept 8, 1980) 9 figs, 12 refs

Key Words: Wave propagation, Spherical waves

The method of renormalization is used to determine a uniformly valid expansion for the problem of non-linear waves produced in a fluid by spatially non-uniform simple harmonic motion of the surface of a sphere. The effect of dimensionless quantities upon the acoustic shock-formation distance is examined.

81-1054

An Experimental Investigation of Shock Wave - Boundary Layer Interaction Dynamics

G.W. Braun and W.T. Snyder
Space Inst., Tennessee Univ., Tullahoma, TN, Rept. No. AFFDL-TR-69-103, 121 pp (Oct 1969)
AD-862 496/7

Key Words: Interaction: shock waves - boundary layer, Wind tunnel tests

Wind tunnel tests were performed which simulated the flow pulsations which are sometimes produced in engine inlets by shock-boundary layer interaction. Shock Mach numbers from 1.2 to 1.4 were used and the boundary layer was influenced by air bleeding in or sucking off. The flow was observed by shadowgraph and static and total pressures were measured by means of low frequency and high frequency response instruments. Static wall pressures, boundary layer pressure profiles, and total pressure distributions across several tunnel cross sections were plotted. The data were analyzed with respect to their rms value and power spectral density. A literature survey and an analytical investigation of the pulsations in a diffuser with nonviscous flow are included.

VIBRATION EXCITATION

(Also see No. 1156)

81-1055

Separable Equations for a Cylindrical Anisotropic Elastic Waveguide

W.B. Fraser
Dept. of Applied Mathematics, The Univ. of Sydney, Sydney, New South Wales, 2006, Australia, J. Sound Vib., 72 (2), pp 151-157 (Sept 22, 1980) 23 refs

Key Words: Waveguide analysis, Harmonic waves, Wave propagation

A separable form of the equations of motion for a cylindrical anisotropic elastic waveguide of arbitrary cross-section is derived. From these the orthogonality relation for the modes of harmonic wave propagation in the waveguide is readily derived.

81-1056

Theory and Calculation of Vibrating Structures

R. Valid
Office National d'Etudes et de Recherches Aerospatiales, Paris, France, Presented at CEA/EDF Conf. on Vibrations des Struct. dans le Domaine Ind., Jouy-en-Josas, France, Oct 15-19, 1979, Rept. No. ONERA-P-1980-1, 58 pp (1980)
N80-31849
In French; English summary

Key Words: Vibrating structures, Finite element technique, Linear theories

Finite element methods, linear vibration theory and the calculation of geometrically nonlinear structures are covered. Finite element methods are developed in a simple manner from the displacement method. Details are given about the most commonly used elements. The theory of linear vibrations is treated for the discrete case. Its variational properties are, however, recalled for both discrete and continuous cases. Formulas describing the response to various excitations (transient, harmonic, periodic, and random) are given. Variational form methods for calculating structures with

geometrical nonlinearities are presented together with the algorithms most commonly used for arbitrary excitations. The stability of dynamic systems is introduced.

81-1057

Applications of Identical Aerodynamic Functions

T.S. Beddoes

Aeromechanics Dept., Westland Helicopters Ltd., Yeovil, UK, AGARD Spec. Course on Unsteady Aerodyn., 8 pp (June 1980)

N80-33372

Key Words: Aerodynamic loads, Dynamic structural analysis

Relatively simple means for applying the theoretical results for idealized excitation routine calculations of airloads and structural response are demonstrated. In this context nonlinear system characteristics may be simulated and complex or arbitrary forcing may be included. Initially the aerodynamics are assumed to be more or less linear, that is, the flow is assumed to remain attached but the procedure is intended to provide the parameters required to define the onset of separation.

81-1058

Calculation of the Non-Stationary Mean Square Response of a Non-Linear System Subjected to Non-White Excitation

M. Sakata and K. Kimura

Dept. of Physical Engrg., Tokyo Inst. of Tech., Meguro-ku, Tokyo, Japan, J. Sound Vib., 73 (3), pp 333-343 (Dec 8, 1980) 7 figs, 18 refs

Key Words: Nonlinear systems, Random excitation, Equivalent linearization technique, Mean square response

An approximate method is developed to calculate the nonstationary response of a non-linear system subjected to nonwhite excitation. The method consists in modification of the equivalent linearization technique and the use of the moment equations of the equivalent linear system to evaluate the mean square response. The results obtained by the present method are compared with the corresponding digital simulation results for a Duffing system or a dry friction system.

81-1059

On the Qualitative Study of Combination Resonance in Elastic Systems under Periodic Forces

K. Katayama, T. Katayama, and T. Sekiya

Dept. of Aeronautical Engrg., Univ. of Osaka Prefecture, Mozuumemachi, Sakai, Osaka, 591 Japan, Mechanics Res. Comm., 7 (4), pp 227-232 (1980) 2 figs, 2 refs

Key Words: Combination resonance, Elastic media, Periodic excitation, Columns

In this study, the qualitative estimation with respect to the kind of combination resonances, which occur in elastic systems subjected to periodic forces, is researched. An elastic system undergoes harmonic parametric excitation. Application of the method of weighted residuals with the eigenfunctions in the free vibration problem and its adjoint problem reduces the basic equation to a system of the normal coupled Mathieu equations, to which the instability conditions obtained by Hsu are able to be directly applied.

81-1060

Flexibility Effects in Multibody System Dynamics

R.L. Huston

Dept. of Mech. and Industrial Engrg., Univ. of Cincinnati, Cincinnati, OH 45221, Mechanics Res. Comm., 7 (4), pp 261-268 (1980) 2 figs, 28 refs

Key Words: Flexural stiffness, Dynamic structural analysis

This note presents a method for efficiently including the effects of flexibility and compliance in the dynamic analyses of multibody systems. It is based on the use of Lagrange's form of d'Alembert's principle, Euler parameters, and generalized speeds to obtain the governing equations of motion.

81-1061

Controlling Vibration

Engrg. Mtl. Des., 24 (8), pp 36-40 (Sept 1980) 3 figs

Key Words: Vibration control

Vibration fundamentals, circumstances determining which vibration parameter should be measured, and methods of isolation are discussed.

81-1062

Phase Locking and Chaos in Coupled Limit Cycle Oscillators

P. Holmes

Dept. of Theoretical and Applied Mechanics, Cornell Univ., Ithaca, NY 14853, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 651-660, 3 figs, 19 refs

Key Words: Oscillators, Coupled response

Many physical and biological problems involve long chains of coupled oscillators each of which alone exhibits a stable oscillation. When coupled mechanically, electrically or chemically such oscillator chains can exhibit both regular phase locked behavior and irregular drifting oscillations. In this paper systems of coupled nonlinear oscillators each of which in isolation possesses a single attracting limit cycle are studied. It is shown that systems of two or more oscillators can exhibit both stable phase locked periodic motions and slowly varying, almost periodic motions, and systems of three or more oscillators can exhibit markedly irregular or chaotic oscillations.

81-1063

Response of Self-Excited Oscillators to Multifrequency Excitations, II

K.R. Asfar, A.H. Nayfeh, and D.T. Mook

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 641-650, 11 figs, 4 refs

Key Words: Self-excited vibrations, Forced vibrations

The response of a van der Pol oscillator to two distinct harmonic excitations is considered. It was found that the amplitude of the forced response is dependent upon the amplitudes and frequencies of the excitations.

81-1064

Nonlinear Oscillations of Single-Degree-of-Freedom Systems

B.S. Shaker

King Abdulaziz Univ., Jeddah, Saudi Arabia, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 569-578, 6 figs, 2 refs

Key Words: Single degree of freedom systems, Nonlinear response, Viscous damping

The equation of motion of a forced oscillation of a particle attached to a nonlinear spring under the influence of slight viscous damping is considered. Systems with quadratic and cubic nonlinearity was discussed. This study treats fourth order nonlinearity. An approximate solution of the problem is obtained using the method of multiple scales. The problems are solved by numerical integration and the results are found to compare well with the method of multiple scales.

81-1065

Some Developments in Parametric Stability and Nonlinear Vibration

A.D.S. Barr

Dept. of Mech. Engrg., Univ. of Dundee, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 545-567, 14 figs, 13 refs

Key Words: Parametric vibration, Nonlinear response

Some general observations concerning parametric stability and nonlinear vibration and their appearance and significance in engineering, coupled with a more detailed description of some recent and current research in these areas with which the author is associated are reviewed. The developments in the title are thus private or at least more intimate to the author's experience.

81-1066

The Yielding Behaviour of a Randomly Excited Elasto-Plastic Structure

J.B. Roberts

School of Engrg. and Applied Sciences, Univ. of Sussex, Brighton BN1 9QT, UK, J. Sound Vib., 72 (1), pp 71-85 (Sept 8, 1980) 11 figs, 16 refs

Key Words: Random excitation, Elastic plastic properties, Hysteretic damping, Method of stochastic averaging

The method of stochastic averaging is applied to the case of an oscillator with bilinear hysteresis excited by a stationary random process. It is shown that, if the excitation level is sufficiently low, a simple expression for the response amplitude distribution can be found which is valid for all values of the plastic slope.

81-1067

Simplified Analysis of Linear Fluid-Structure Interaction

W.C. Muller

Elisabethstr. 78, 8044 Lohhof, W. Germany, Intl. J. Numer. Methods Engrg., 17 (1), pp 113-121 (Jan 1981) 1 fig, 2 tables, 6 refs

Key Words: Interaction: structure-fluid, Approximation methods

An approximation method is presented for the analysis of the interaction of a structure with a compressible linear fluid. The method uses the fact that the eigenvalues of the dry structure are higher than the corresponding eigenvalues of a structure in contact with an incompressible fluid, and the corresponding eigenvalues of a structure in contact with a compressible fluid are even lower. The proof of this theorem is given. It is shown that in both the compressible and incompressible cases the number of degrees-of-freedom can be reduced to the number of boundary points which results in a substantial saving of core memory space and computing time. A sample problem is given to demonstrate the good results of the approximation methods for a low quotient of the eigenfrequencies divided by the square of the speed of sound.

81-1068

Free and Forced Wave Propagation in Two-Dimensional Periodic Systems Using Matrix Techniques

A.Y.A. Abdel-Rahman and M. Petyt

Inst. Sound Vib. Res., Univ. of Southampton, Southampton, S09 5NH, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton Vol. I, pp 361-374, 5 figs, 15 refs

Key Words: Periodic structures, Wave propagation, Matrix methods, Free vibration, Forced vibration

This paper presents a method for studying the dynamical behavior of two-dimensional periodic systems by a matrix formulation which can use digital computer techniques for the analysis of complex structures.

81-1069

Techniques for Estimating Structural Response Using Predicted and Measured Data

R.F. Durrans and W.J. Hammill

C.E.G.B. Berkeley Nuclear Labs., Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 249-262, 11 figs, 4 refs

Key Words: Modal analysis, Modal synthesis, Computer programs

This paper describes a program which has been developed to derive modal information from measured transfer functions, and a synthesis method which is used to estimate the forced response of a structure by combining predicted and measured data. Tests on power plant components have demonstrated the ability of the program MIDAS (Modal Identification for the Dynamic Analysis of Structures) to extract modal data rapidly and accurately, thus enabling complex response characteristics to be represented by a small number of modal parameters.

81-1070

Response of Linear Discrete and Continuous Systems to Variable Frequency Sinusoidal Excitations

L. Sung and K.K. Stevens

PCI Engineers, Inc., Houston, TX, J. Sound Vib., 71 (4), pp 497-509 (Aug 22, 1980) 4 figs, 22 refs

Key Words: Damped structures, Linear systems, Periodic excitation

An approximate series solution for the response of damped, linear, time-invariant systems to sinusoidal inputs with slowly varying frequency is presented. The solution is expressed in terms of the time dependent frequency and its time derivatives and the system transfer function and its derivatives with respect to frequency. The solution is developed for single degree of freedom systems and then extended to multiple degree of freedom and continuous systems. Accuracy of the solution is demonstrated by applying it to an example problem of a simple linear oscillator with a linear frequency sweep and comparing the results with those obtained by numerical integration of the equation of motion. Application of the method to continuous systems is illustrated by the example of a viscoelastic cantilever beam subjected to a sinusoidal base motion with logarithmic frequency sweep.

81-1071

Transfer Function Method for Investigating the Complex Modulus of Acoustic Materials: Spring-Like Specimen

T. Pritz

Central Research and Design Inst. for the Silicate Industry, 1034 Budapest, Bécsi ut 126/128, Hungary, J. Sound Vib., 72 (3), pp 317-341 (Oct 8, 1980) 15 figs, 1 table, 35 refs

Key Words: Dynamic modulus of elasticity, Transfer functions, Springs (elastic)

The complex modulus of acoustic materials has to be known as a function of frequency. Among many methods for investigating the complex modulus, it is advantageous to use the transfer function method for detailed frequency analysis. In this method, a cylindrical or prismatic specimen is excited into longitudinal vibration at one end, the other end being loaded by a mass. The complex modulus can be calculated after having measured the transfer function. In this paper the transfer function and its measurability are investigated theoretically and experimentally in that frequency range where the specimen can essentially be modeled by lumped parameter mechanical elements. The role of the measurement errors is analyzed and it is shown that the smaller the loss factor the higher the measurement accuracy that is needed.

81-1072

Nonstationary Random Vibration of a Nonlinear System with Collision

T. Fujita and S. Hattori

Inst. of Industrial Science, Univ. of Tokyo, Tokyo, Japan, Bull. JSME, 23 (185), pp 1857-1864 (Nov 1980) 12 figs, 4 refs

Key Words: Nonlinear systems, Random vibration, Impact response (mechanical), Seismic excitation, Earthquakes

This paper deals with the response of a nonlinear system subjected to a nonstationary Gaussian shot noise which is a simple model of earthquake ground accelerations. The system considered consists of an oscillator and two reflectors at both sides of it, and the oscillator collides with each reflector. The response of the system is analyzed based on Markov-vector approach. Experiments are also carried out to examine the analytical results, and good agreement between the analytical and the experimental results is obtained.

81-1073

Analysis of Systems with Impulsive Parametric Excitation (Analyse von Systemen mit Impuls-Parametererregung)

K. Popp

Institut f. Mechanik, Technische Universitat Munchen, Arcisstr. 21, D-8000, Munchen 2, Bundesrepublik, Deutschland, Ing. Arch., 50 (1), pp 49-60 (1981) 5 figs, 2 tables, 8 refs

(In German)

Key Words: Parametric excitation, Periodic structures

By impulsive parametric excitation we mean those excitations which may be represented in a mathematical model by periodic coefficients consisting of periodic sequences of Dirac functions. Some examples for this type excitation are given. The aim of the paper is the analysis of periodic systems with impulsive parametric excitation regarding deterministic and stochastic disturbances.

81-1074

Non-Gaussian Closure for Random Vibration of Non-Linear Oscillators

S.H. Crandall

Massachusetts Inst. of Tech., Cambridge, MA 02139, Intl. J. Nonlin. Mechanics, 15 (4/5), pp 303-313 (1980) 1 fig, 11 refs

Key Words: Random vibration, Nonlinear systems, Oscillators

An approximate method for determining estimates of stationary response statistics for a non-linear oscillator driven by wide-band random excitation is described. The differential equation of the oscillator is used to generate relations between unknown response statistics. These relations are then used to fix a corresponding number of unknown parameters in a non-Gaussian probability distribution for the response. The method is illustrated by application to the Duffing oscillator. Elementary methods for evaluating the necessary correlations between excitation and response are discussed in an Appendix.

81-1075

On the Oscillation in the Bistable Fluid Amplifier

C. Horikoshi, M. Sano, and Y. Shibata

Faculty of Tech., Shinshu Univ., Bull. JSME, 23 (184), pp 1604-1609 (Oct 1980) 12 figs, 8 refs

Key Words: Amplifiers, Fluid amplifiers, Oscillation, Geometric effects, Design techniques

A phenomenon making the internal flow in the wall-attachment fluid amplifier unstable is discussed. A jet issued from the nozzle exit causes a continuous switching action between two side walls, and attachment of the jet to the walls becomes unstable. This unstable phenomenon is often observed when the fluid amplifier has a relatively large offset distance and a small splitter distance. This seems to be a kind of oscillation since it has almost constant periods. The frequency of the oscillation is low and it is changeable slightly when either the offset distance or the splitter distance changes. Hence, this unstable phenomenon can be used for a low frequency oscillation in practice. Geometrical shapes of the fluid amplifier having this unstable phenomenom are measured and frequencies are also measured.

MECHANICAL PROPERTIES

DAMPING

(Also see No. 1150)

81-1076

A Mathematical Model for Linear Elastic Systems with Structural Damping

G. Chen and D.L. Russell
Mathematics Res. Ctr., Wisconsin Univ., Madison, WI,
Rept. No. MRC-TSR-2089, 32 pp (June 1980)
AD-A089 662/1

Key Words: Damping, Mathematical models

From empirical studies it is known that the natural modes of vibration of elastic systems have damping rates which are roughly proportional to the frequency of vibration. A number of models exhibiting behavior of this type have been proposed in the engineering literature but they are not true dynamical systems nor are they very useful for numerical computations. In this paper a model involving unbounded, self-adjoint operators on a Hilbert space, exhibiting the damping behavior just described, which is known as structural damping is described. Finite dimensional analogs suitable for computation of approximate solutions are also noted.

81-1077

Determination of Velocity-Squared Fluid Damping by Resonant Structural Testing

T.M. Mulcahy and A.J. Miskevics
Components Technology Div., Argonne National Lab., 9700 S. Cass Ave., Argonne, IL 60439,
J. Sound Vib., 71 (4), pp 555-564 (Aug 22, 1980) 6 figs, 11 refs

Key Words: Resonance tests, Viscous damping

A theory is developed for determination of velocity-squared fluid damping from peak amplitude and phase angle data by complex vector methods. Experimental results are presented indicating the usefulness of the theory, especially in identifying whether velocity-squared or viscous damping mechanisms are active.

81-1078

An Analysis of the Distortion Effects of Coulomb Damping on the Vector Plots of Lightly Damped Systems

G.R. Tomlinson
Simon Engrg. Labs., Univ. of Manchester, Manchester M13 9PL, UK,
J. Sound Vib., 71 (3), pp 443-451 (Aug 8, 1980) 4 figs, 1 table, 6 refs

Key Words: Coulomb friction, Damped structures, Single degree of freedom systems

An analysis of the vector plot responses of lightly damped single degree-of-freedom systems with Coulomb damping has been made. The vector plots, as derived by using both an exact and an approximate method (the method of harmonic balance) are compared and it is shown that the distortion of the normally circular vector locus is due to the Coulomb damping.

81-1079

Mathematical Formulation of Damping for Structural Response Analysis

H.H. Ottens
Structs. and Materials Div., National Aerospace Lab., Amsterdam, The Netherlands,
Rept. No. NLR-MP-79010-U, 12 pp (Feb 27, 1979)
N80-31842

Key Words: Damping, Spacecraft

A survey is presented of damping models that are commonly used in structural response analysis of aerospace structures. The models are evaluated with respect to the required knowledge of structural damping, the mathematical complexity, and the accuracy of the calculated response. The survey is

limited to linear damping models and special attention was given to models which represent lightly damped structures.

Technological Inst., Northwestern Univ., Evanston, IL, Rept. No. TR-1980-2, 29 pp (Aug 1980)
AD-A089 686/0

Key Words: Critical damping, Free vibration, Beams, Continuous beams, Axial vibration, Flexural vibration, Torsional vibration

Free damped vibrations of linear elastic structures composed of uniform beam elements with a continuous distribution of mass are studied. Axial, torsional and flexural vibrations are considered. The amount of damping, which can be either internal or external viscous type, varies among the various beam elements of the structure resulting in many critical damping possibilities. A general method is developed, which, with the aid of dynamic stiffness influence coefficients defined for every element, determines the 'critical damping surfaces' of the system. These surfaces represent the loci of combinations of amounts of damping leading to critically damped motion and thus separating regions of partial or complete underdamping from those of overdamping. Three examples are presented in detail to illustrate the proposed method for determining critical damping and demonstrate its importance.

81-1080

Optimum Design of a Lanchester Damper for a Viscously Damped Single Degree of Freedom System Subjected to Inertial Excitation

V.A. Bapat and P. Prabhu

Dept. of Mech. Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Sound Vib., 73 (1), pp 113-124 (Nov 8, 1980) 8 figs, 4 refs

Key Words: Dampers, Single degree of freedom systems, Harmonic excitation

The problem of designing an optimum Lanchester damper for a viscously damped single degree of freedom system subjected to inertial harmonic excitation is investigated. Two criteria are used for optimizing the performance of the damper: minimum motion transmissibility; minimum force transmissibility. Explicit expressions are developed for determining the absorber parameters.

81-1081

Estimating Damping of Reinforced Concrete Members and Structures

R. Flesch

Vienna Inst. of Tech., Austria, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 739-748, 11 figs, 9 refs

Key Words: Damping, Reinforced concrete, Structural members, Frames, Multistory buildings

Several damping mechanisms active in reinforced concrete members are considered. First a single degree of freedom system consisting of an elasto-dissipative reinforced concrete tension-compression member and a mass is investigated. Second the damping behavior of an elasto-dissipative reinforced cantilever element is studied. Finally, the application of this concept to multistory frames is discussed.

81-1082

Critical Damping in Certain Linear Continuous Dynamic Systems

D.E. Beskos and B.A. Boley

FATIGUE

(Also see No. 916)

81-1083

A One-Pass Method for Counting Range Mean Pair Cycle for Fatigue Analysis

R.C. Fraser

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL-Struc-Note-454; AR-001-746, 34 pp (June 1979)
N80-33781

Key Words: Fatigue life, Fatigue tests

A one pass method for counting Range Mean Pair cycles is described. The Range Mean Pair Table which was used to represent the data generated by the method was considered with reference to its use in fatigue analysis.

81-1084

Analysis and Synthesis of Operational Loads (Analyse und Synthese von Betriebsbelastungen)

J.H. Argyris, W. Aicher, and H.J. Ertelt

Stuttgart Univ., Rept. No. ISD-193, Feb. 1976, Rept. No. RAE-Lib-Trans-2108 (5207), 85 pp (May 1979)
N80-33757
Avail: British Library Lending Div., Boston Spa, UK

Key Words: Fatigue life, Fatigue tests

The inadequate estimation of fatigue lives of structures by theoretical methods has led to the development of techniques for simulating service loading histories in the laboratory. The techniques required for the synthesis of a laboratory loading sequence from service loading data are described using the standard fighter loading sequence, FALSTAFF, as an example.

81-1085

Fatigue Testing of Vampire Wings

R.A. Bruton and C.A. Patching
Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC-378, 114 pp (June 1979)
AD-A089 402/2

Key Words: Fatigue tests, Fatigue life, Flight vehicles, Aircraft wings

The fatigue behavior of a total of 21 port and starboard Vampire wings has been investigated for a 12 load level programmed loading sequence, representative of an average Australian flight loading spectrum. An additional two wings were subjected to a randomized sequence of these loads. This report describes the investigation and furnishes information on the following aspects: the fatigue life of major components in the wing; the ineffectiveness of replacing Parker-Kalon self tapping screws in the spar boom with pinned Chobert blind rivets; the increase in fatigue life achieved by replacing the lower spar boom; the residual strength of the cracked structure; the distribution of strain between screwed panels and the spar boom; and the fatigue resistance of glued wooden fuselages.

ELASTICITY AND PLASTICITY

81-1086

Harmonic Wave Propagation in an Infinite Elastic Medium with a Periodic Array of Cylindrical Pores

T.-C. Ma, R.A. Scott, and W.H. Yang
Dept. of Applied Mechanics and Engrg. Science, Univ. of Michigan, Ann Arbor, MI 48109, J. Sound Vib., 71 (4), pp 473-482 (Aug 22, 1980) 6 figs, 12 refs

Key Words: Elastic media, Porous materials, Harmonic waves, Finite element technique, Galerkin method

The propagation of plane harmonic waves in an elastic medium in which there is a periodic distribution of infinitely long, cylindrical pores is analyzed. The waves propagate perpendicular to the pores and the approach used is a finite element method based on Galerkin's technique. Results on dispersion, for several values of porosity, and on strain energy distributions within a typical half-cell are given. Also, as a check on the dynamic results, equivalent elastic moduli are derived by using a static analysis.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

81-1087

The Application of a Transient Testing Method to the Determination of Acoustic Properties of Unknown Systems

C.W.S. To and A.G. Doige
Dept. of Mech. Engrg., Univ. of Calgary, Calgary, Alberta, Canada T2N 1N4, J. Sound Vib., 71 (4), pp 545-554 (Aug 22, 1980) 10 figs, 12 refs

Key Words: Testing techniques, Acoustic impedance, Acoustic reflection, Acoustic properties, Transient excitation, Random excitation

A transient testing technique for the determination of matrix parameters of acoustic systems has been developed and presented in two papers by the authors. This paper deals with the application of this rapid testing method to the determination of several acoustic properties of unknown systems. Theoretical expressions for acoustic impedances and reflection factors are presented as functions of measured pressure ratios and known matrix parameters. Excellent results obtained for simple test cases show that the procedure is fast and accurate over at least a 70 dB range. Moreover, the method lends itself to applications with steady mean flow in the system and with either transient or random input acoustic excitation.

81-1088

The Cepstrum: A Viable Method for the Removal of Ground Reflections

A.A. Syed, J.D. Brown, M.J. Oliver, and S.A. Hills

Rolls-Royce Limited, Aero Division, Derby DE2 8BJ, UK, J. Sound Vib., 71 (2), pp 299-313 (July 22, 1980) 8 figs, 6 refs

Key Words: Cepstrum analysis, Noise measurement, Measurement techniques, Engine noise

Noise data from open air test facilities is contaminated by the effect of ground reflections causing cancellations and augmentations of the sound at certain frequencies. The present empirical method used at Rolls-Royce for the estimation of one third octave band free field spectra involves the use of two microphones, one at ground level for frequencies up to 1 kHz and the other at 1·524 m above the ground for higher frequencies. Corrections are applied to the one third octave spectra from these low and high microphones to take account of intensity increases. In this paper cepstrum analysis is proposed as a satisfactory method to produce both narrow band and one third octave band free field spectra from high level microphones only. A series of tests has been carried out in an anechoic chamber facility in which ground reflections were simulated. The cepstrum technique was applied to this data to deduce the free field spectra. These compared very well with free field spectra obtained under anechoic conditions.

81-1089

Leakage Error in Fast Fourier Analysis

H.J. Thompson and D.R. Tree

Ray W. Herrick Labs., School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 71 (4), pp 531-544 (Aug 22, 1980) 9 figs, 2 tables, 4 refs

Key Words: Fast fourier transform, Error analysis

Leakage, a common phenomenon in digital Fast Fourier Analysis, is discussed. An analytical explanation of leakage is presented with examples used to illustrate the detrimental effects to accurate signal analysis. Through this development, it is shown that signal amplitude errors of more than 36% are possible as a result of leakage. Also, an analytical method to resolve the error introduced by leakage, and hence to obtain accurate signal information, is presented. In conjunction with this methodology examples are provided to demonstrate the improvement in signal amplitude and frequency estimation possible. Finally, charts for quick estimation of signal amplitude and frequency based on this analytical method are presented. For further illustration, examples of use of this method are also given.

81-1090

Holographic Interferometry and Image Analysis for Aerodynamic Testing

J.E. O'Hare and W.T. Strike

Arnold Engrg. Development Ctr., Arnold Air Force Station, TN, Rept. No. AEDC-TR-79-75, 45 pp (Sept 1980)

AD-A089 438/6

Key Words: Holographic techniques, Interferometric techniques, Testing techniques, Wind tunnel tests

This report summarizes the progress achieved in the development of operational techniques and hardware for recording holographic interferograms in the VKF wind tunnels, development of automated image analysis techniques for reducing quantitative flow-field data from holographic interferograms, and investigation and development of software for the application of digital image analysis to other photographic techniques used in wind tunnel testing.

81-1091

Real-Time Response of a Rotating Disk Using Image-Derotated Holographic Interferometry

J.C. MacBain, W.A. Stange, and K.G. Harding

Air Force Aero Propulsion Lab., Turbine Engine Div., Wright-Patterson AFB, OH 45433, Exptl. Mechanics, 21 (1), pp 34-40 (Jan 1981) 11 figs, 4 refs

Key Words: Holographic techniques, Disks (shapes), Rotating structures, Real time spectrum analyzers

A recently developed technique that shows great promise for studying the structural response of rotating objects is that of image-derotated holographic interferometry. This study reports on the extension of the technique to the real-time analysis of rotating objects by replacing the pulsed ruby laser with an acousto-optically modulated argon laser.

81-1092

A Universal Measuring System for the Investigation of Small Motors (Universelles Messystem zur Untersuchung von Kleinmotoren)

H. Buschmann and W. Hickmann

Institut fur Elektromechanische Konstruktionen, Darmstadt, Germany, Feinwerk u. Messtechnik, 88 (8), pp 425-428 (Dec 1980) 6 figs, 1 table, 7 refs (In German)

Key Words: Measuring instruments, Mechanical properties, Velocity measurement, Displacement measurement, Force measurement, Motors

A universal measuring system was developed for the determination of mechanical and electrical quantities in energy transmitting electromechanical instruments. The quantities that can be measured directly are displacement, velocity, current, and voltage. From these measured data, other values may be calculated by means of analog computers.

81-1093

Mobile Parametric Measurement Device. Volume 1: Operation. (Users Manual)

C. Thatcher

Dynamic Science, Inc., Phoenix, AZ, Rept. No. 8309-80-026/1613-VOL-1, DOT-HS-805 477, 60 pp (Jan 1980)

PB80-213689

Key Words: Measuring instruments, Ground vehicles

The objective of this program was to design, construct, and validate a mobile device for measuring vehicle parameters necessary for an accurate prediction of the vehicle's handling characteristics. As a result of this program, a Mobile Parametric Measurement Device (MPMD) was constructed, and test procedures validated. This document is a Users Manual for the operation (including calibration and maintenance), test procedures, and data reduction procedures of the MPMD.

81-1094

Mobile Parametric Measurement Device. Volume II: Test Procedures (Users Manual)

C. Thatcher

Dynamic Science, Inc., Phoenix, AZ, Rept. No. 8309-80-026/1613-VOL-2, DOT-HS-805 478, 97 pp (Jan 1980)

PB80-213697

Key Words: Measuring instruments, Parametric response, Ground vehicles

The objective of this program was to design, construct, and validate a mobile device for measuring vehicle parameters necessary for an accurate prediction of the vehicle's handling characteristics. As a result of the program, a Mobile Parametric Measurement Device (MPMD) was constructed, and test procedures validated.

81-1095

Mobile Parametric Measurement Device. Volume III: Data Reduction Procedures. (Users Manual)

C. Thatcher

Dynamic Science, Inc., Phoenix, AZ, Rept. No. 8309-80-026/1613-VOL-3, DOT-HS-805 479, 42 pp (Jan 1980)

PB80-213705

Key Words: Measuring instruments, Parametric response, Ground vehicles

The objective of this program was to design, construct, and validate a mobile device for measuring vehicle parameters characteristics. As a result of this program, a Mobile Parametric Measurement Device (MPMD) was constructed, and test procedures validated.

81-1096

Studies on Dynamic Measurement Method of Mass and Weight. Part 3: Statistical Characteristics of the Measured Value Obtained via "Dynamic Weighing Method-B"

T. Ono, K. Kameoka, H. Sekiguchi, and K. Nakajima

College of Engrg., Univ. of Osaka Prefecture, Sakai, Japan, Bull. JSME, 23 (185), pp 1899-1904 (Nov 1980) 6 figs, 2 refs

Key Words: Dynamic weighing method

The asymptotic properties of the measured value are theoretically investigated, introducing a noisy mathematical model of the weighing system.

81-1097

Wheel Force Transducer, Calibration Report

C.A. Lysdale

Maritime Dynamics, Inc., Fullerton, CA, Rept. No. MD-R-1166-03, FHWA/RD-80/134, 31 pp (May 1979)

PB80-210131

Key Words: Measuring instruments, Transducers, Wheels, Trucks

A force transducer for measuring the dynamic forces on truck wheels has been designed and a prototype constructed. This report describes the static and low speed calibration of the transducer and gives the calibration results.

81-1098
Wheel Force Transducer, Operation Manual
C.A. Lysdale
Maritime Dynamics Inc., Fullerton, CA, Rept. No. MD-OM-1166-02, FHWA/RD-80/133, 31 pp (May 1979)
PB80-210149

Key Words: Measuring instruments, Transducers, Wheels, Trucks

A force transducer for measuring the dynamic forces on truck wheels has been designed and a prototype constructed. The prototype was calibrated statically and at low driving speeds.

81-1099
Measurements of On-Site Dynamic Parameters for Seismic Evaluations
R.M. Zimmerman and K.R. White
New Mexico State Univ., Las Cruces, NM, Rept. No. NSF/RA-800125, 21 pp (June 1980)
PB80-221799

Key Words: Measuring instruments, Vibration damping, Vibration measurement, Bridges, Seismic response

In an effort to develop a low cost and relatively simple method to determine the sensitivity of existing bridges to earthquakes, this study developed a non-contract electromagnetic induction device to measure bridge vibration and damping properties.

81-1100
Experimental Determination of Structural Modal Densities and Average Loss Factors
B.L. Clarkson and R.J. Pope
Inst. Sound Vib. Res., Univ. of Southampton, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 169-184, 11 figs, 7 refs

Key Words: Vibration measurement, Statistical energy methods, Loss factor, Modal densities, Plates, Cylinders

The statistical energy analysis forms the basis of the computational procedure for estimating high frequency vibration levels in structures. This method requires a knowledge of several parameters which describe the dynamic properties of the structural components and their interconnections. The two most important parameters are the modal density and the loss factor. This paper describes the development of experimental methods of measuring the modal density and loss factor. Results are given for simple components such as plates and cylinders and built up structures.

81-1101
Single-Station Time-Domain (SSTD) Vibration Testing Technique: Theory and Application
S.A. Zaghlool
Dept. of Mech. Engrg., Univ. of California, Berkeley, CA, 94720, J. Sound Vib., 72 (2), pp 205-234 (Sept 22, 1980) 15 figs, 2 tables, 36 refs

Key Words: Testing techniques, Vibration tests, Time domain method, Parameter identification technique

The single-station time-domain (SSTD) technique is proposed as a vibration testing method for the identification of the dynamic characteristics of complex structures. The theoretical part of the study shows that the technique works, in principle, for lumped mass systems and continuous systems when a finite number of modes are included in the response. The idea behind the method is to make use of free vibration time response data -- such as acceleration, velocity, displacement, or strain at a station on the structure – to determine unknown natural frequencies and associated viscous damping ratios.

81-1102
A Simple Method for Converting Frequency Domain Aerodynamics to the Time Domain
E.H. Dowell
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81844; L-13789, 42 pp (Oct 1980)
N80-33358

Key Words: Aerodynamic characteristics, Frequency domain method, Time domain method

A simple, direct procedure was developed for converting frequency domain aerodynamics into indicial aerodynamics. The data required for aerodynamic forces in the frequency domain may be obtained from any available (linear) theory. The method retains flexibility for the analyst and is based upon the particular character of the frequency domain results. An evaluation of the method was made for incompressible, subsonic, and transonic two dimensional flows.

81-1103
Errors in Mechanical Impedance Data Obtained with Impedance Heads
J.M.W. Brownjohn, G.H. Steele, P. Cawley, and R.D. Adams
Dept. of Mech. Engrg., Univ. of Bristol, Bristol B58 1TR, UK, J. Sound Vib., 73 (3), pp 461-468 (Dec 8, 1980) 11 figs, 2 refs

Key Words: Mechanical impedance, Measuring instruments

The use of impedance heads for the measurement of the point mechanical impedance of structures is discussed. It is shown that instruments of this type are subject to an error in the acceleration measurement which is proportional to the force input to the structure through the impedance head and to the square of the frequency, and is inversely proportional to the stiffness between the structure and the point at which the acceleration is measured in the instrument. Methods for minimizing this error are discussed but it is shown that the existence of the error is an inevitable consequence of attempting to measure the force input to the structure and its response at the same point.

DYNAMIC TESTS

81-1104
Utilizing Modal Testing in System Analysis to Affect Design and Predict Structural Performance
S.A. Beck, R.D. Brillhart, D.L. Hunt, and J. Van Benschoten
Structural Dynamics Res. Corp., Western Operations, San Diego, CA, SAE Paper No. 801126, 16 pp, 22 figs, 3 refs

Key Words: Modal tests, Design techniques

Dynamic performance has become a significant criterion in the design and evaluation of structures. In this paper an integrated approach of modal testing and system analysis is described which gives the engineer a useful tool to effect design modifications and to predict structural performance. This approach can be used for redesign of existing systems or the development of new structures.

81-1105
The Effect of Non-Linear Damping Mechanisms in Resonance Testing
G.R. Tomlinson
Simon Engrg. Labs., Univ. of Manchester, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 235-248, 9 figs, 9 refs

Key Words: Resonance tests, Nonlinear damping, Testing techniques

The results described in this paper have outlined the effect that nonlinear damping mechanisms have upon the response of lightly damped linear systems. It has been shown that the normal method of analyzing resonance test results, i.e., the circle fitting of vector plots within the resonant region, could lead to significant errors in the derived parameters since the vector plots are distorted in various ways, the distortions being dependent upon the characteristics of the non-linear damping mechanisms. By presenting the resonance information in the form of complex power plots the effects of the nonlinearities are minimized and realistic estimation of the modal parameters is possible.

81-1106
Digital Control Techniques for a Three-Axis Vibration Test System
S. Smith, R.C. Stroud, G.A. Hamma, and L. Johnson
Synergistic Technology, Inc., SAE Paper No. 801233, 12 pp, 6 figs, 10 refs

Key Words: Vibration tests, Shakers, Test equipment and instrumentation, Digital techniques

A design for a three-axis shaker system and its control system are described. Emphasis is placed on the digital-control techniques planned to implement real time control of multi-axis sine wave and random vibration with cross-axis compensation. The microprocessor-based hardware system is designed to perform closed-loop control algorithms using a low-cost array processor.

81-1107
Pavement Evaluation and Overlay Design Using Vibratory Nondestructive Testing and Layered Elastic Theory. Volume II. Validation of Procedure
R.A. Weiss and J.W. Hall, Jr.
Geotechnical Lab., Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. FAA-RD-77-186-VOL-2, 57 pp (May 1980)
AD-A087 716/7

Key Words: Pavements, Nondestructive testing, Vibratory techniques, Elasticity theory

A method of pavement evaluation and overlay design based on vibratory nondestructive testing and layered elastic theory was validated in this report. This method is compared with the conventional methods of evaluation and overlay design for rigid and flexible pavements. Results of the validation showed good agreement between allowable loads determined from the NDT-elastic theory method and the conventional standard method. However, there was poor agreement between overlay thickness requirements determined from the two methods.

SCALING AND MODELING

(See No. 925)

DIAGNOSTICS

81-1108

SSME Turbopump Bearing Analytical Study

J.W. Kannel and T. Merriman

Battelle Columbus Labs., OH, Rept. No. NASA-CR-161554, 33 pp (Aug 20, 1980)

N80-31794

Key Words: Bearings, Pumps, Computer programs, Diagnostic techniques

Three shuttle pump bearings operating under severe overspeed and shut-down conditions are evaluated. The specific parameters investigated include outer race stresses, cage stresses, cage-race drag, bearing heating, and crush loading. A quasi-dynamic version of a computer code was utilized which involved the calculation of ball-race forces (inner and outer), contact pressures, contact dimensions, and contact angles as a function of axial load, radial load, and centrifugal load on the bearing.

81-1109

Acoustic Emission Analysis. Part 1. Acoustic Emission: Origin, Propagation and Application (Schallemissionsanalyse. Teil 1. Schallemission: Entstehung, Ausbreitung und Anwendung)

J. Kolerus

c/o Reinhard Kuhl KG, Birkenweg 3-5, 2085 Quickborn, Techn. Messen-ATM, 47 (11), pp 389-394 (Nov 1980) 9 figs, 11 refs

Key Words: Acoustic emission, Diagnostic techniques

The fundamentals of the theory of acoustic emission and its most important applications are briefly reviewed.

81-1110

Acoustic Emission Analysis. Part 2. Methods and Instrumentation (Schallemissionsanalyse. Teil 2. Verfahren und Geräte)

J. Kolerus

c/o Reinhard Kuhl KG, Birkenweg 3-5, 2085, Quickborn, Techn. Messen-ATM, 12 (47), pp 427-434 (Dec 1980) 14 figs

(In German)

Key Words: Diagnostic techniques, Diagnostic instrumentation, Acoustic emission

The techniques of acoustic emission analysis are discussed. Their application is demonstrated by practical examples.

81-1111

Testing of Industrial Components by Means of Acoustic Emission Analysis (Prüfung industrieller Bauteile mit Hilfe der Schallemissionsanalyse)

J. Kasser and K.P. Nerz

Gebruder Sulzer Aktiengesellschaft, CH-8401, Winterthur, Techn. Messen-ATM, 12 (47), pp 435-440 (Dec 1980) 7 figs, 7 refs

(In German)

Key Words: Diagnostic techniques, Acoustic emission, Fatigue life

This paper gives examples on acoustic emission investigations.

81-1112

A Synthesizer of Random Signals with Bispectral Characteristics -- A Machine Noise Simulator

K. Sasaki, T. Sato, and M. Kano

The Graduate School at Nagatsuta, Tokyo Inst. of Tech., 4259 Nagatsuta, Midori-ku, Yokohamashi, Japan, J. Acoust. Soc. Amer., 69 (1), pp 286-292 (Jan 1981) 9 figs, 8 refs

Key Words: Machinery noise, Simulation, Bispectral analysis, Diagnostic techniques

Machine noises have been synthesized by randomly modulating the relative phases of multiple sinusoidal oscillators which are harmonically related with one another. Each of the random signals for phase modulation consists of a common random signal and a mutually independent one. The details of the statistical properties of the generated random signals are examined from both theoretical and experimental viewpoints. An application of the system acoustical noises from a gear train are synthesized. The results show the effectiveness of the method as a simulator of rotating-machine noises.

81-1113

Diagnostically Oriented Measures of Vibroacoustical Processes

C. Cempel

Tech. Univ. of Poznan, Piotrowo 3 Street, 60-965 Poznan, Poland, J. Sound Vib., 73 (4), pp 547-561 (Dec 22, 1980) 8 figs, 4 tables, 14 refs

Key Words: Machinery vibration, Diagnostic techniques

In diagnostic applications of machinery vibration or noise data it is convenient to describe the whole process by a set of numbers called discriminants. Five discriminants can be constructed and measured for every vibroacoustical process. Two of them have dimensional natures and give information about process amplitude and frequency. Two others, dimensionless, give information about the amplitude and spectral spread of the process. The last one, also dimensionless, characterizes the time fluctuations of the process, and can be used to detect instability of a running machine. Numerical and experimental examples are presented.

81-1114

Detection of Cavitation in Cylinder Liners by Means of Quartz Pressure Transducers (Nachweis von Kavitation an Zylinderbüchsen mittels Quarzdruckgebern)

J. Affenzeller, E. Schreiber, and H. Janisch

Grazer Strasse 44, A-8045 Graz, MTZ Motortech., Z., 41 (11), pp 499-505 (Nov 1980) 8 figs, 11 refs (In German)

Key Words: Diagnostic techniques, Engines, Linings, Cavitation

A new measuring technique is described which enables measurement of cavitation directly on the engine during the development stage. It uses the quartz pressure transducer which is a sensitive indicator for the detection of any cavitation in the cylinder lining.

BALANCING

81-1115

Balancing Method of Multi-span, Multi-bearings Rotor System (2nd Report: Balancing for a Flexible Rotor Considering Constraint of the Correction Mass)

K. Shiohata and F. Fujisawa

Mech. Engrg. Res. Lab., Hitachi, Ltd., Bull. JSME, 23 (185), pp 1894-1898 (Nov 1980) 7 figs, 2 tables, 3 refs

Key Words: Balancing techniques, Rotors (machine elements), Flexible rotors, Rotor-bearing systems

A method of balancing a flexible rotating shaft is investigated in which the magnitude of correction masses is constrained. Analytically, the least squares method was used, introducing a constraint coefficient into the performance function. Experimentally, the above method was applied to one rotor of a 5-span, 10-bearing rotor system and obtained good balancing results.

81-1116

Active Feedback Control for Stabilization of Vibration in Rotating Machinery (24.034)

B. Bakaysa

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA, Rept. No. DOE/ET-13151/T5, 15 pp (1980)

N80-32725

Key Words: Rotating structures, Machinery vibration, Vibration control, Balancing techniques, Feedback control

Some of the considerations involved in the use of feedback control as a means of reducing the unbalanced response of a rotor or of eliminating or alleviating rotor dynamic instability are discussed. A simple model of a mass on a flexible shaft was used to illustrate the application of feedback control concepts. A description is given of a system which uses feedback control individually adjustable in the vertical and horizontal directions to support the shaft bearings.

MONITORING

81-1117
Monitoring Turbogenerators in the Underfrequency Range
V. Narayan
Brown Boveri Rev., 67, pp 530-534 (Sept 1980) 4 figs, 6 refs

Key Words: Turbomachinery, Monitoring techniques

Operation of a turbogenerator set in the underfrequency range can, under certain circumstances, cause increased stressing of the set, leading to a shorter service life. This article introduces protection equipment which monitors the time during which large turbogenerators operate in the underfrequency range and which accumulates over the total service life. Six different frequency bands were monitored facilitating matching to the tolerance-limit curves recommended by the manufacturers.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see Nos. 924, 1045, 1046)

81-1118
On the Effectiveness of the Lanczos Method for the Solution of Large Eigenvalue Problems
S. Ramaswamy
Orthopaedic Biomechanics Lab., Beth Israel Hospital, Boston, MA 02215, J. Sound Vib., 73 (3), pp 405-418 (Dec 8, 1980) 1 fig, 5 tables, 10 refs

Key Words: Eigenvalue problems, Natural frequencies, Mode shapes

The calculation of the smallest eigenvalues and associated eigenvectors of the generalized eigenproblem is considered. Numerical examples are given to substantiate these theoretical predictions. Also, the computational drawbacks of the method are discussed and an algorithm for implementing the Lanczos method on the computer is presented. Finally, it is proposed that the vectors generated in using the Lanczos method be used as the starting vectors for the subspace iteration, in which case the accuracy of the calculated eigensolution becomes user controllable. Some examples solved by using such a combined scheme are presented and the solution effectiveness is discussed.

81-1119
A Numerical Study of the Solution of the Partial Eigenvalue Problem
M. Papadrakakis
Inst. of Structural Analysis and Aseismic Res., National Technical Univ., Athens, Greece, J. Sound Vib., 73 (3), pp 353-362 (Dec 8, 1980) 8 tables, 16 refs

Key Words: Eigenvalue problems, Finite element technique, Steepest descent method, Gradient methods, Relaxation method (mathematics)

The partial eigenvalue problem that arises from the application of the finite element method is considered. A number of iterative methods are examined which consist in seeking the stationary points of the Rayleigh quotient and thus avoiding the physical assembling of the matrices involved. The computational efficiencies of the steepest descent, the conjugate gradient and the co-ordinate overrelaxation methods are compared. Several other modifications to the original conjugate gradient algorithm as well as an orthogonalization process are studied. The dependence of the convergence of the methods on the initial estimate of the eigenvectors and on different values of the relaxation parameter, in the case of the co-ordinate overrelaxation, are also examined.

81-1120
Analysis of Systems with Impulsive Parametric Excitation (Analyse von Systemen mit Impuls-Parametererregung)
K. Popp
Institut f. Mechanik, TU München, Germany, Ing. Arch., 50 (1), pp 49-60 (1981) 5 figs, 1 table, 8 refs
(In German)

Key Words: Parametric excitation, Periodic structures

By impulsive parametric excitation we mean those excitations which may be represented in a mathematical model by periodic coefficients consisting of period sequences of Dirac functions. Some examples for this type of excitation are given. The aim of the paper is the analysis of periodic systems with impulsive parametric excitation regarding deterministic and stochastic disturbances. For that the common simulation techniques are used beside the methods based on Floquet's theory, which are extended to the given system type.

81-1121

Analytical Study of a Class of Non-Linear, Stochastic, Autonomous Oscillators with One Degree of Freedom

R. Riganti
Istituto di Meccanica Razionale, Politecnico di Torino, Italy, Meccanica, 14 (4), pp 180-186 (Dec 1979) 6 figs, 12 refs

Key Words: One degree of freedom systems, Oscillators

The behavior of a class of autonomous, one degree of freedom, non-linear oscillators with random coefficients and initial conditions is studied. Analytical approximated results regarding the joint density function and the moments of the state variables are deduced by a suitable application of the classical perturbation methods used in the deterministic cases, and by making use of some constructive theorems. The analytical results are utilized in two simple examples, to study the behavior of an undamped non-linear oscillator and a Van der Pol oscillator with random constant coefficients and initial conditions.

81-1122

Theory of Vibroconductivity

A.K. Beljaev and V.A. Palmov
Polytechnical Inst., Leningrad, USSR, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 157-168, 21 refs

Key Words: Thermal conductivity, Vibration analysis

Theory of vibroconductivity is a way to describe and analyze high-frequency vibrations of complex dynamic systems by methods of thermal conductivity theory. The high-frequency random vibration propagation in polycrystalline structures is investigated. Thermal motion of molecules is a random high-frequency vibration, which can be described by the equation of thermal conductivity. Statistical Energy Analysis (SEA) is the vibroconductivity theory's precursor. Development of SEA has revealed the analogy between vibrational and thermal problems.

81-1123

The Response of Structures to Transient Disturbances by the Normal Mode-Cum-Recursive Digital Filtering Method

C.W.S. To
Inst. Sound Vib. Res., Univ. of Southampton, UK, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 73-88, 4 figs, 3 tables, 30 refs

Key Words: Transient response, Normal modes, Digital filtering, Recursive methods

In this paper direct integration methods, modal superposition methods, and matrix exponential approaches are reviewed and then an alternative numerical method incorporating the normal mode approach and the recursive digital filtering technique is presented. Recursive filter equations of displacement, velocity and acceleration responses are derived. Application of the method is made for the determination of responses of a quarter-scale physical model of a mast antenna structure, idealized by the finite element method, to an exponentially decaying sinusoid applied at the base of the structure. The displacement responses obtained by the method and the commonly used central difference scheme are compared.

81-1124

Some Theory and Applications of the Relationship Between the Real and Imaginary Parts of a Frequency Response Function Provided by Hilbert Transforms

H.G.D. Goyder
United Kingdom Atomic Energy Establishment, Harwell, Oxon, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 89-97, 4 figs, 3 refs

Key Words: Transfer functions, Mobility functions, Hilbert transforms

A relationship between the real and imaginary parts (or the log modulus and phase) of a frequency response function

has been presented. This relationship enables the real part of a frequency response to be deduced from the imaginary part and vice versa. Transform relationship enables an approximation to be made which will have consistent real and imaginary parts.

81-1125

On the Substructure Synthesis Method

L. Meirovitch and A.L. Hale

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 3-22, 3 figs, 2 tables, 21 refs

Key Words: Substructuring method, Structural synthesis

Two examples demonstrating the general substructure synthesis are presented: one for a stucture composed of distributed substructures and the other for one composed of discrete substructures. A small number of simple weighting functions (vectors) is capable of yielding good convergence to the actual distributed (discrete) structures.

81-1126

A Zooming Method for Dynamic Contact Stress Analysis by Finite Element Method

N. Asano

Dept. of Mech. Engrg., Tamagawa Univ., Machida, Tokyo, Japan, Bull. JSME, 23 (184), pp 1575-1580 (Oct 1980) 8 figs, 4 tables, 7 refs

Key Words: Contact stresses, Finite element technique, Gears

A dynamic zooming analysis method (ZAM) is presented, to calculate efficiently dynamic contact stresses and their distributions by the finite element method. The zooming region is determined by the same method as the static ZAM. However, displacements and velocities of nodal points in the region are iteratively computed by use of boundary values until their values approach the correct ones at a specific discrete time. This method is used to evaluate correctly the approximated initial values of the equation of motion.

81-1127

On the Tangent Stiffness Matrix in a Convected Coordinate System

S.C. Tang, K.S. Yeung, and C.T. Chon

Engrg. and Res. Staff, Research, Ford Motor Co., Dearborn, MI 48121, Computers Struc., 12 (6), pp 849-856 (Dec 1980) 12 figs, 14 refs

Key Words: Collision research (automotive), Stiffness methods, Matrix methods, Computer programs

The general purpose nonlinear computer program known as WRECKER-II, which referred to the convected coordinate system, has been modified to WRECKER-F. The modified program has the capability to analyze structures with arbitrarily large rotation. Test examples show excellent agreement with the analytic solutions for rotations larger than 90°.

81-1128

Singular Perturbation Equations for Flexible Satellites

T.C. Huang and A. Das

Dept. of Engrg. Mechanics, Univ. of Wisconsin, Madison, WI, Intl. J. Nonlin. Mechanics, 15 (4/5), pp 355-365 (1980) 1 fig, 17 refs

Key Words: Satellites, Equations of motion, Perturbation theory

Force equations of motion of the *individual flexible elements* of a satellite were obtained in a previous paper. Moment equations of motion of the composite bodies of the same satellite are developed in this paper. These two sets of equations form the basic system for any dynamic model of flexible satellites. The solutions for these angular velocities lead to linear equations in the n-generalized structural position coordinates, which then can be solved by known methods. A method of using continuity conditions has also been shown, which greatly reduces the number of independent coordinates of the set of n-position coordinates.

MODELING TECHNIQUES

81-1129

Applications of Structural Dynamics Modification

M.R. Herbert and D.W. Kientzy

Structural Measurement Systems, Inc., Santa Clara, CA, SAE Paper No. 801125, 12 pp, 5 figs, 6 tables

Key Words: Tuning, Mathematical models, Damping coefficients, Mass coefficients, Stiffness coefficients

The use of Structural Dynamics Modification (SDM) for determining changes in the dynamic characteristics of mechanical structures due to changes in their mass, stiffness, or damping properties, is presented. SDM requires as input the modal properties of the unmodified structure, which can be obtained either from a modal test or from finite element analysis. Structural modifications are then modeled as the addition (or removal) of mass, stiffness, or damping to the structure, and the resulting modal properties of the modified structure are determined. This same procedure can also be used to model the connection of two or more substructures, or the attachment of "tuned" vibration absorbers to a structure, and it predicts the new dynamic properties of the modified structure or coupled substructures.

81-1130

Numerical Modeling of Dynamic Propagation in Finite Bodies, by Moving Singular Elements. Part I. Formulation

T. Nishioka and S.N. Atluri

Ctr. for the Advancement of Computational Mechanics, Georgia Inst. of Tech., Atlanta, GA, Rept. No. GIT-CACM-SNA-24, TR-8, 28 pp (June 1980) AD-A087 395/0

Key Words: Crack propagation, Finite element technique

An efficient numerical (finite element) method is presented for the dynamic analysis of rapidly propagating cracks in finite bodies, of arbitrary shape, wherein linear-elastic material behavior and two-dimensional conditions prevail. Procedures to embed analytical asymptotic solutions for singularities in stresses/strains near the propagating crack-tip, to account for the spatial movement of these singularities along with the crack-tip, and to directly compute the dynamic stress-intensity factor, are presented.

81-1131

Dynamic Fracture Analysis: a Translating-Singularity Finite Element Procedure

S.N. Atluri and T. Nishioka

Ctr. for the Advancement of Computational Mechanics, Georgia Inst. of Tech., Atlanta, GA, Rept. No. GIT-CACM-SNA-22, TR-6, 10 pp (June 1980) AD-A087 226/7

Key Words: Crack propagation, Finite element technique

In this paper an efficient finite element method, which accounts for the translating singularities near the tip of a dynamically propagating crack, is presented. Two aspects of analyses of dynamic fracture, namely, determination of dynamic stress-intensity factors from given crack velocity history; and determination of crack-velocity history (and arrest) from given dynamic-fracture-toughness versus crack-velocity data are considered. Results are presented and discussed for wedge-loaded rectangular, as well as tapered, double-cantilever beam specimens.

81-1132

Numerical Modeling of Dynamic Crack Propagation in Finite Bodies, by Moving Singular Elements. Part II. Results

T. Nishioka and S.N. Atluri

Ctr. for the Advancement of Computational Mechanics, Georgia Inst. of Tech., Atlanta, GA, Rept. No. GIT-CACM-SNA-25, TR-9, 29 pp (June 1980) AD-A087 228/3

Key Words: Crack propagation, Finite element technique

Using the moving-singularity finite element method, several problems of dynamic crack propagation in finite bodies have been analyzed. Discussions of the effects of wave interactions on the dynamic stress-intensity factors are presented. The obtained numerical results are compared with the corresponding infinite domain solutions and other available numerical solutions for finite domains.

81-1133

Optimization of the Mathematical Model of a Structure

H. Zimmerman

Vereinigte Flugtechnische Werke G.m.b.H., Bremen, W. Germany, AGARD Math. Modeling of Linear and Non-Linear Aircraft Struct., pp 1-14 (July 1980) N80-31327

Key Words: Mathematical models, Flexibility coefficients, Stiffness coefficients, Mass coefficients, Algorithms, Optimization

Adjustment algorithms are presented for improving the theoretically obtained flexibility or stiffness and mass distribution of such a structure by dynamic test or ground resonance test results. The necessary assumptions for the adjustment and the mathematical formalism for the adjustment procedure are given. Experiences gained and adjustment results obtained with these algorithms are reported on concentrating especially on one which uses only the measured and calculated eigenfrequencies. Proposals for improvements on the procedures and in the algorithms are also given.

NONLINEAR ANALYSIS

81-1134

Convergence of Implicit-Explicit Algorithms in Nonlinear Transient Analysis

T.J.R. Hughes and R.A. Stephenson
Div. of Engrg. and Appl. Science, California Inst. of Tech., Pasadena, CA 91125, Intl. J. Engrg. Sci., 19 (2), pp 295-302 (1981) 1 fig, 13 refs

Key Words: Nonlinear theories, Transient response

Recently introduced implicit-explicit algorithms in transient analysis are not covered by the standard convergence theorems. Convergence is established herein for the methods introduced by Hughes et al. The techniques employed are general and may be easily extended to encompass related formulations.

NUMERICAL METHODS

(Also see No. 971)

81-1135

Experience with Implicit-Explicit Time Integration for Nonlinear Transient Dynamic Analysis

D.K. Paul and E. Hinton
Dept. of Civil Engrg., Univ. College of Swansea, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. II, pp 587-596, 4 figs, 3 tables, 5 refs

Key Words: Dynamic structural analysis, Integral equations, Newmark method

Explicit and implicit predictor-corrector versions of the Newmark method for solving nonlinear transient dynamic problems are presented. An axisymmetric elasto-plastic, geometrically nonlinear problem is modeled using 8-node isoparametric elements and the influence of the choice of predictor value on the response accuracy is investigated. Solutions are obtained using explicit, implicit and implicit-explicit algorithms.

81-1136

Accelerated Converging Methods in Structural Response Analysis

Y.T. Leung
Dept. of Civil Engrg., Univ. of Hong Kong, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 101-108, 2 tables, 6 refs

Key Words: Modal analysis, Random response, Periodic response, Stiffness methods, Mass matrices, Matrix methods

The convergence property of the conventional modal method in structural response analysis may be improved by using the condensed stiffness and mass matrices of the system to avoid the difficulties of computing high natural modes. Undamped and damped system responses due to deterministic and random excitations are discussed. Simple numerical examples are given to illustrate the convergence property.

PARAMETER IDENTIFICATION

(Also see No. 1101)

81-1137

Mathematical Modeling of Linear and Non-Linear Aircraft Structures

AGARD, Neuilly-sur-Seine, France, Rept. No. AGARD-R-687, 41 pp (July 1980)
AD-A089 439/4

Key Words: Aircraft, Mathematical models, Parameter identification techniques, Flexibility coefficients, Mass coefficients, Wing stores, Flutter

In this paper, adjustment algorithms for improving the theoretically obtained flexibility and mass distributions of a structure by dynamic or ground resonance tests is proposed.

81-1138

Covariance Sequence Approximation for Parametric Spectrum Modelling

L.L. Scharf and A.A.L. Beex
Dept. of Electrical Engrg., Colorado State Univ., Fort Collins, CO, Rept. No. CSU-TR-AUG80-1, 35 pp (Aug 1980)
AD-A089 680/3

Key Words: Spectrum analysis, Parameter identification technique

In this paper a wide variety of spectrum types are submitted to modal analysis wherein the modes are characterized by amplitudes, frequencies, and damping factors. The associated modal decomposition is applied to both continuous and discrete components of the spectrum.

81-1139
An Application of System Identification to Flutter Testing
D.R. Gaukroger, C.W. Skingle, and K.H. Heron
Royal Aircraft Establishment, Farnborough GU14 6TD, UK, J. Sound Vib., 72 (2), pp 141-150 (Sept 22, 1980) 3 figs, 1 table, 2 refs

Key Words: System identification techniques, Flutter

It is shown that the equations of motion of an aeroelastic system may be derived from measured response data. The structural and aerodynamic terms are separated by analyzing response measurements at two values of kinetic pressure; the derived equations can then be used to calculate dynamic characteristics of the system at any chosen values of kinetic pressure. Two examples of the application of the analysis to the prediction of flutter characteristics are given.

MOBILITY/IMPEDANCE METHODS

81-1140
Mobility Measurements on a Beam and Dynamic Absorber
S.M. Damms
Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TM-AERO-1842, DRIC-BR-74521, 27 pp (May 1980)
AD-A088 845/3

Key Words: Beams, Dynamic vibration absorption (equipment), Mobility method

This memorandum describes the measurement of the responses of two structures to certain input forces. The main object of the experiment was to use the measurements performed on the two separate structures to predict the results for a structure formed by connecting them together. One of the structures chosen was a beam and the other was designed to behave as a dynamic absorber when attached to the beam. Confidence was given to the measurements by comparing the results with theory as far as possible.

OPTIMIZATION TECHNIQUES

(Also see No. 1145)

81-1141
Improved Methods for Large Scale Structural Synthesis
M. Pappas
Southeastern Ctr. for Electrical Engrg. Education, Inc., St. Cloud, FL, Rept. No. AFOSR-TR-80-0921, 25 pp (Sept 21, 1979)
AD-A089 366/9

Key Words: Structural synthesis, Oscillation, Vibration control, Optimization

This report describes two potential improvements in techniques for large scale structural synthesis. One involves a method for control of oscillation found to occur in many optimization procedures. The other is a new primal mathematical programming algorithm. The central idea for oscillation control is the use of the gradients of a potentially active constraint set to prevent serious violation of one of the set when a move is made considering only the active constraints.

DESIGN TECHNIQUES

81-1142
Shock Spectra Design Methods for Equipment in Impulsively Loaded Structures
J.M. Kelly and J.L. Sackman
Weidlinger Associates, Menlo Park, CA, Rept. No. R-7958, DNA-5267F, AD-E300 870, 34 pp (Nov 1, 1979)
AD-A088 509/5

Key Words: Shock response spectra, Equipment response, Ground motion, Design techniques

An analytical method is developed whereby a simple estimate can be obtained of the maximum dynamic response of light equipment attached to a structure subjected to ground motion. The results obtained are simple estimates of the maximum acceleration and displacement of the equipment. The method can also be used to treat closely-spaced modes in structural systems, where the square root of the sum of the squares procedure is known to be invalid. It is also applied to nontuned equipment-structure systems for which the conventional floor spectrum method is mathematically valid. A closed-form solution is obtained which permits an estimate of the maximum response of the equipment to be determined without the necessity to compute time histories as required by the floor spectrum method.

81-1143

New Criteria for Selecting Modal Combination Rules

M. Grigoriu

Univ. of Waterloo, Ontario, Canada, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 109-121, 5 figs, 2 tables, 6 refs

Key Words: Seismic design

The new method is applied to design asymmetric space structures subjected to an earthquake with random ground acceleration. The same structures are also designed by the response spectrum method and a risk consistent design method. These designs are compared for selected values of structural damping.

81-1144

Critical Excitations of Structures

R.F. Drenick and F. Novomestky

Polytechnic Inst. of New York, Brooklyn, NY, Recent Advances in Structural Dynamics, Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., Inst. Sound Vib., Univ. of Southampton, Vol. I, pp 123-130, 2 figs, 6 refs

Key Words: Seismic excitation, Seismic design, Reliability

A critical excitation method is described which is used for the assessment of structural reliability under dynamic loads due to strong ground motion.

81-1145

Shape Determination Problems of Structures by the Inverse Variational Principle (2nd Report, Buckling and Vibration Problems)

M. Hamada, Y. Seguchi, and Y. Tada

Faculty of Engrg., Osaka Univ., Suita, Japan, Bull. JSME, 23 (184), pp 1581-1588 (Oct 1980) 8 figs, 11 refs

Key Words: Design techniques, Optimum design, Vibration control, Fundamental frequency, Inverse variational principle

The purpose of this research is to study the problem of determining optimal shapes of structures from a unified point of view by using the inverse variational principle. In this report, optimal structural designs for the buckling and vibration problems are treated by this principle. In the former problem a change in the potential energy during the buckling is considered as an energy functional to be made stationary, and in the latter the sum of the strain and kinetic energies is so considered. It is shown that consideration of the variations of these functionals with respect to shape and displacement leads to the conventional method which maximizes Rayleigh's quotients. As examples, this principle is applied to bars discretized into finite elements to obtain their optimal shapes for which the buckling loads or the fundamental frequencies are maximum among all shapes with the same volume.

COMPUTER PROGRAMS

(Also see No. 1069)

81-1146

Steam Line Dynamics: A Computer Program

W. Wulff

Brookhaven National Lab., Upton, NY, Rept. No. BNL-NUREG-51186, 90 pp (Apr 1980)
NUREG/CR-1438

Key Words: Computer programs, Electric power plants, Transient response

A computer program has been developed for the prediction of transients in the main steam supply lines of power plants. The program is specifically suited for acoustic transients, induced by sudden value actions. The program has been assessed as a stand-alone program by comparing computer results with both analytical and experimental results. The agreement is good.

81-1147

Aircraft Hydraulic Systems Dynamic Analysis. Vol-

ume VI. Steady State Flow Analysis (SSFAN) Computer Program Technical Description
R. Levek and B. Young
McDonnell Aircraft Co., St. Louis, MO, Rept. No. AFAPL-TR-76-43-VOL-6, 344 pp (Apr 1980) (Supersedes Rept. No. AFAPL-TR-76-43-VOL-6, Feb 1977)
AD-A089 240/6

Key Words: Computer programs, Hydraulic systems, Aircraft equipment

SSFAN is a steady state hydraulic flow and pressure analysis computer program. Its primary purpose is to analyze nonlinear resistance aircraft hydraulic systems. The program handles complex flow networks containing flow and/or pressure discontinuities such as unbalanced area actuators and check valves. Solutions for a combination of simultaneously operating subsystems are easily obtained. The program is designed using a building block approach so that new component or element models may be added with minimum change to the main program.

81-1148
The TRAPS Sonic Boom Program
A.D. Taylor
Air Resources Labs., National Oceanic and Atmospheric Admn., Silver Spring, MD, Rept. No. NOAA-TM-ERL-ARL-87, NOAA-80090903, 62 pp (July 1980)
PB81-108177

Key Words: Computer programs, Sonic boom, Aircraft noise

A new program called TRAPS has been written having the capability of modeling an aircraft-created sonic boom. Like an earlier program, ARAP, this program allows the aircraft to perform an arbitrary sequence of maneuvers, accelerations and deaccelerations, and it uses a stratified atmospheric model of either a standard or user-specified composition. The new program introduces the new feature of accounting for sonic booms which travel upward initially, but are subsequently refracted from the stratopause (approx. 50,000 meters) or the thermosphere (approx. 100,000 meters). Overpressures and shocks are computed from an initial aircraft F-function on the basis of Aging and Hilbert Transforms applied according to the travel paths (rays) of the acoustic energy. In addition, input procedures are simplified and information is made available as to what proportion of the aircraft sonic boom can intercept the ground.

81-1149
Piping Benchmark Problems. Dynamic Analysis Uniform Support Motion Response Method. Volume 1
P. Bezler, M. Hartzman, and M. Reich
Brookhaven National Lab., Upton, NY, Rept. No. BNL-NUREG-51267, 412 pp (Aug 1980)
NUREG/CR-1677-V-1

Key Words: Computer programs, Nuclear reactor components, Pipelines, Response spectra

A set of benchmark problems and solutions have been developed for verifying the adequacy of computer programs used for dynamic analysis and design of nuclear piping systems by the Response Spectrum Method. The problems range from simple to complex configurations which are assumed to experience linear elastic behavior. The dynamic loading is represented by uniform support motion, assumed to be induced by seismic excitation in three spatial directions. The solutions consist of frequencies, participation factors, nodal displacement components and internal force and moment components. Solutions to associated anchor point motion static problems are not included.

81-1150
Solution Sensitivity and Accuracy Study of NASTRAN for Large Dynamic Problems Involving Structural Damping
A.J. Kalinowski
Naval Underwater Systems Ctr., New London, CT, NASA John F. Kennedy Space Ctr., 9th NASTRAN Users' Colloq., pp 49-62 (Oct 1980)
N80-33785

Key Words: Computer programs, NASTRAN (computer program), Finite element technique, Plates, Steel, Viscoelastic damping

Large dynamic problems involving NASTRAN SOLUTION 8 are considered. Using a submerged steel plate with a viscoelastic layer layer as the bench mark sample, the solution sensitivity and solution accuracy are checked. The solution sensitivity is examined by running the same finite element model on different computers, different versions of NASTRAN, and different precision levels. The solution accuracy is evaluated for these same runs by comparing the NASTRAN results with the exact solution of the same problem.

81-1151
Ring Element Dynamic Stresses
N. Lambert and M. Tuccnio

Naval Underwater Systems Ctr., New London, CT, NASA John F. Kennedy Space Ctr., 9th NASTRAN Users' Colloq., pp 63-78 (Oct 1980)
N80-33786

Key Words: NASTRAN (computer program), Computer programs, Rings, Dynamic response

The stresses in the CTRAPRG and CTRIARG ring elements are not calculated for any of the dynamic solutions in the current COSMIC version of NASTRAN. A DMAP alter sequence for Solution 8 and post-processing program, NASTPOST, are presented to calculate these stresses. Test cases are used which describe the method. The stiffness and the consistent versus concentrated mass problems ascribed to this element are reviewed.

81-1152

A Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics. Part 2: User's Manual

W. Johnson

National Aeronautics and Space Admn., Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-81183, AVRADCOM-TR-80-A-6-PT-2, 97 pp (July 1980)
N80-28297

Key Words: Computer programs, Rotors, Helicopters, Rotary wings, Wind-induced excitation, Flutter

The use of a computer program for a comprehensive analytical model of rotorcraft aerodynamics and dynamics is described. The program calculates the loads and motion of helicopter rotors and airframe.

81-1153

A Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics. Part 3: Program Manual

W. Johnson

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-81184, AVRADCOM-TR-80-A-7, 155 pp (June 1980)
N80-28298

Key Words: Computer programs, Rotors, Helicopters, Rotary wings, Wind-induced excitation, Flutter

The computer program for a comprehensive analytical model of rotorcraft aerodynamics and dynamics is described. This analysis is designed to calculate rotor performance, loads, and noise; the helicopter vibration and gust response; the flight dynamics and handling qualities; and the system aeroelastic stability. The analysis is a combination of structural, inertial, and aerodynamic models that is applicable to a wide range of problems and a wide class of vehicles. The analysis is intended for use in the design, testing, and evaluation of rotors and rotorcraft and to be a basis for further development of rotary wing theories.

81-1154

An Evaluation of a Computer Code Based on Linear Acoustic Theory for Predicting Helicopter Main Rotor Noise

S.J. Davis and T.A. Egolf

Sikorsky Aircraft, Stratford, CT, Rept. No. NASA-CR-159339; SER-510038, 290 pp (July 1980)
N80-34217

Key Words: Computer programs, Rotors, Helicopters, Helicopter noise, Noise prediction

Acoustic characteristics predicted using a recently developed computer code were correlated with measured acoustic data for two helicopter rotors. The analysis is based on a solution of the Ffowcs-Williams-Hawkings equation and includes terms accounting for both the thickness and loading components of the rotational noise. Computations are carried out in the time domain and assume free field conditions.

81-1155

Aircraft Noise Prediction Program Validation

B.N. Shivashankara

Boeing Commercial Airplane Co., Seattle, WA, Rept. No. NASA-CR-159333; D6-48727, 163 pp (Oct 1980)
N80-34219

Key Words: Computer programs, Aircraft noise, Noise prediction

A modular computer program (ANOPP) for predicting aircraft flyover and sideline noise was developed. A high quality flyover noise data base for aircraft that are representative of the U.S. commercial fleet was assembled. The accuracy of ANOPP with respect to the data base was determined. The data for source and propagation effects were analyzed and suggestions for improvements to the prediction methodology are given.

81-1156
TRBASIS: A Program Module for Transient Modal Analysis of Linear Structures, Part 1
P. Stehlin
Structures Dept., Aeronautical Res. Inst. of Sweden, Stockholm, Sweden, Rept. No. FFA-HU-2125-PT-1, 56 pp (Oct 1979)
N80-28762

Key Words: Computer programs, Modal analysis, Linear systems

An integrated program module of the BASIS 3 structural analysis code which performs transient analyses of linear structures is described. A summary of the theoretical relations on which the code is based is given. The operation of the program module is explained and illustrated by examples. The program is written for CDC computers. As far as the use of the program is concerned it is assumed that the reader is already familiar with the data card input to the BASIS 3 code and that he has some working knowledge of the CDC SCOPE or NOS operating systems.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

81-1157
Recent Advances in Structural Dynamics
Intl. Conf., July 7-11, 1980, Univ. of Southampton, UK, M. Petyt, ed., published by Inst. of Sound and Vibration, Univ. of Southampton, 2 vols., 1980

Key Words: Structural elements, Vibration analysis, Vibration testing, Proceedings

At this conference twenty-seven papers were presented on the theoretical and experimental advances in structural dynamics. The contributions are based towards theoretical studies, however, ample time was allowed for practical applications. Several relatively new approaches were presented together with developments of established techniques by authors from fourteen different countries. Individual papers are abstracted in the appropriate sections of this issue of the DIGEST.

81-1158
Wind and Seismic Effects
H.S. Lew
National Engrg. Lab., National Bureau of Standards, Washington, D.C., Proc. Joint Panel Conf. of U.S.-Japan Cooperative Program in Natural Resources (10th), Gaithersburg, MD, May 23-26, 1978, Rept. No. NBS-SP-560, 649 pp (Oct 1980)
PB81-107393

Key Words: Proceedings, Wind-induced excitation, Seismic waves, Seismic excitation, Seismic design

This volume includes thirty-eight technical papers presented at the Tenth Joint Meeting of the U.S.-Japan Panel's eight task committees. The subjects covered in the Joint Meeting include: natural wind characterization and extreme wind records, characterization of earthquake ground motions and strong-motion earthquake data, engineering seismology, response of hydraulic and earth structures to seismic forces, structural responses to wind loading, recent developments in seismic design criteria, design and analysis of special structures, damage evaluation, repair and retrofit, earthquake hazard mitigation, and storm surge.

81-1159
Special Course on Unsteady Aerodynamics
Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine, France. Course held in Rhode-Saint-Genese, Belgium, Mar 10-14, 1980, sponsored by Fluid Dyn. Panel, von Karman Inst., and the Consultant and Exchange Program of AGARD, Rept. No. AGARD-R-679; ISBN-92-835-1364-9, 236 pp (June 1980)
N80-33363

Key Words: Aircraft, Aerodynamic loads, Vibration response, Proceedings

A wide range of related unsteady flow phenomena relevant to aeronautical applications are addressed. Aircraft response, aircraft loads, vibration environments, and flight systems analysis are emphasized.

TUTORIALS AND REVIEWS

81-1160
Free Vibration Analysis of Cooling Towers
R.L. Nelson

Engrg. Sciences Div., Central Electricity Res. Labs. (of the C.E.G.B.), Kelvin Ave., Leatherhead, Surrey KT22 7SE, UK, Shock Vib. Dig., 12 (12), pp 15-24 (Dec 1980) 3 tables, 39 refs

Key Words: Reviews, Cooling towers, Free vibration

A critical review of many of the theoretical techniques used since 1965 to analyze the free vibration of cooling towers is presented. Comparison of theoretical methods and experimental results shows that most theoretical methods have not yielded accurate results, primarily because the column-supports of the tower have not been accurately modeled. Explicit definition of column-supports and use of the property of rotational periodicity lead to accurate predictions of the free vibration of cooling towers and allow efficient use of computer facilities.

81-1161

Vibration of Overhead Transmission Lines III

R.N. Dubey and C. Sahay

Univ. of Waterloo, Waterloo, Ontario, Canada, Shock Vib. Dig., 12 (12), pp 11-14 (Dec 1980) 29 refs

Key Words: Reviews, Transmission lines, Vibration reduction

This article describes investigations in which theoretical results are combined with experimental data in attempts to assess the efficiency of design mechanisms for reducing vibration amplitude of power transmission lines.

81-1162

Torsional Vibration of Ship Engine Shafts

D.K. Rao and A. Sanyal

Indian Inst. of Tech., Kharagpur, India, Shock Vib. Dig., 12 (12), pp 3-8 (Dec 1980) 2 figs, 56 refs

Key Words: Reviews, Ships, Engines, Shafts, Torsional vibration

Ship engine shafting can fail when the operating speed range contains torsional critical speeds. Such failures can be avoided if torsional vibration response characteristics of the shafting are analyzed during the design stage. This paper reviews the current literature dealing with determination of these characteristics using simple formulas, design charts, and complex computer programs.

CRITERIA, STANDARDS, AND SPECIFICATIONS

81-1163

Fatigue Research

J.T. Fong

National Bureau of Standards, Washington, D.C., 4 pp (Feb 1980)

PB80-212319

Key Words: Fatigue life, Structural elements, Standards and codes

Following an introduction of the goals and the organization of the subcommittee, a detailed description of the recent international symposium on fatigue mechanisms (Kansas City, May 1978) is given. A summary of three special activities and some future plans of the subcommittee involving not only members of E9 but also of other ASTM committees is presented.

81-1164

Motor Vehicle Noise Test Procedures in Australia – A Critical Review

R. Law

Noise Control Branch, Environment Protection Authority, Australia, SAE Paper No. 801433, 12 pp, 1 fig, 5 tables, 9 refs

Key Words: Motor vehicle noise, Testing techniques, Standards and codes, Reviews

A review is presented of the motor vehicle noise test procedures currently used in Australia by regulatory authorities for both new and in-use vehicles. Problems associated with the test procedures are discussed and criteria for assessing the suitability of new test procedures are suggested.

81-1165

Light Vehicle Noise – Origins, Characteristics and Standard Test Procedures

P.E. Waters

Vehicle Standards and Engrg. Div., Dept. of Transport, UK, SAE Paper No. 801431, 24 pp, 10 figs, 28 refs

Key Words: Motor vehicle noise, Testing techniques, Standards and codes

This paper sets out the origins and characteristics of light vehicle noise and reviews the data available on light vehicle operation. An appendix gives details of many test procedures that have been used or proposed for light vehicle noise since the original German and proposed United Kingdom legislation of 1935. Six of these procedures have been chosen for detailed evaluation, three maximum noise and three representative driving tests. Data from these tests are used to illustrate the practical as opposed to the theoretical effects of the two philosophies. This paper also reports the United Kingdom Government's policy on light vehicle noise.

BIBLIOGRAPHIES

81-1166

Earthquake Engineering: Buildings, Bridges, Dams, and Related Structures. September 1978 - August 1979 (Citations from the NTIS Data Base)

G.E. Habercom, Jr.

National Technical Information Service, Springfield, VA, 209 pp (Sept 1980)

PB80-815434

Key Words: Bibliographies, Seismic design, Bridges, Dams, Buildings, Nuclear power plants

Seismic phenomena relative to buildings, bridges, dams, and other structures are investigated. Damage assessment is made and design inadequacies are revealed. Suggestions for structural improvements for dynamic response are presented. Abstracts on site selection and earthquake-proofing for atomic power plants are included. This updated bibliography contains 204 abstracts, all of which are new entries to the previous edition.

81-1167

Earthquake Engineering: Buildings, Bridges, Dams, and Related Structures. September 1979 - August 1980 (Citations from the NTIS Data Base)

G.E. Habercom, Jr.

National Technical Information Service, Springfield, VA, 193 pp (Sept 1980) (Supersedes NTIS/PS-79/1051 and NTIS/PS-78/0942)

PN80-815442

Key Words: Bibliographies, Seismic design, Bridges, Dams, Buildings, Nuclear power plants

Seismic phenomena relative to buildings, bridges, dams, and other structures are investigated. Damage assessment is made and design inadequacies are revealed. Suggestions for structural improvements for dynamic response are presented. Abstracts on site selection and earthquake-proofing for atomic power plants are included. This updated bibliography contains 204 abstracts, all of which are new entries to the previous edition.

USEFUL APPLICATIONS

(See No. 1020)

AUTHOR INDEX

CALENDAR

MAY 1981

4-7 Institute of Environmental Sciences' 27th Annual Technical Meeting [IES] Los Angeles, CA *(IES, 940 East Northwest Highway, Mt. Prospect, IL 60056)*

31 - June 5 Spring Meeting and Exhibition of the Society for Experimental Stress Analysis [SESA] Hyatt Regency, Dearborn, MI *(SESA, P.O. Box 277, Saugatuck Station, Westport, CT 06880)*

JUNE 1981

1-4 Design Engineering Conference and Show [ASME] Chicago, IL *(ASME Hq.)*

8-10 NOISE-CON 81 [Institute of Noise Control Engineering and the School of Engineering, North Carolina State University] Raleigh, North Carolina *(Dr. Larry Royster, Program Chairman, Center for Acoustical Studies, Dept. of Mechanical & Aerospace Engr., North Carolina State University, Raleigh, NC 27650)*

22-24 Applied Mechanics Conference [ASME] Boulder, CO *(ASME Hq.)*

SEPTEMBER 1981

1-4 Joint Meeting of the British Society for Strain Measurement and the Society for Experimental Stress Analysis [B.S.S.M. and SESA] Edinburgh University, Scotland *(C. McCalvey, Administration Officer, B.S.S.M., 281 Heaton Road, Newcastle upon Tyne, NE6 5QB, UK)*

7-11 Applied Modelling and Simulation Conference and Exhibition [I.A.S.T.E.D. and A.M.S.E.] Lyon, France *(A.M.S.E., 16, Avenue de Grande Blanche, 69160 Tassin-La-Demi-Lune, France)*

20-23 Design Engineering Technical Conference [ASME] Hartford, CT *(ASME Hq.)*

28-30 Specialists Meeting on "Dynamic Environmental Qualification Techniques" [AGARD Structures and Materials Panel] Noordwijkerhout, The Netherlands *(Dr. James J. Olsen, Structures and Dynamics Division, Air Force Wright Aeronautical Laboratories/FIB, Wright Patterson Air Force Base, OH 45433)*

30-Oct 2 International Congress on Recent Developments in Acoustic Intensity Measurement [CETIM] Senlis, France *(Dr. M. Bockhoff, Centre Technique des Industries Mecaniques, Boite Postale 67, F-60304, Senlis, France)*

OCTOBER 1981

4-7 International Lubrication Conference [ASME - ASLE] New Orleans, LA *(ASME Hq.)*

11-15 Fall Meeting of the Society for Experimental Stress Analysis [SESA] Keystone Reseort, Keystone, CO *(SESA, P.O. Box 277, Saugatuck Station, Westport, CT 06880)*

19-22 Intl. Optimum Structural Design Symp. [U.S. Office of Naval Research and Univ. of Arizona] Tucson, AZ *(Dr. Erdal Atrek, Dept. of Civil Engr., Bldg. No. 72, Univ. of Arizona, Tucson AZ 85721)*

21-23 34th Mechanical Failures Prevention Group Symp. [National Bureau of Standards] Gaithersburg, MD *(J.E. Stern, Trident Engineering Associates, 1507 Amherst Rd., Hyattsville, MD 20783 - (301) 422-9506)*

27-29 52nd Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, D.C.] New Orleans, Louisiana *(Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375)*

Eastern Design Engineering Show [ASME] New York, New York *(ASME Hq.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173

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SUMMARY COVER SHEET
52nd SHOCK AND VIBRATION SYMPOSIUM
New Orleans, LA, 27-29 October 1981
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GENERAL INFORMATION AND REQUIREMENTS

The Shock and Vibration Bulletin is a refereed journal which contains the proceedings of the symposium and an additional number of papers not presented at the symposium.

THOSE WHO DO NOT WISH TO PREPARE A FORMAL PAPER may choose the PRESENT ONLY category. No written paper will be required.

THOSE WHO WISH TO PUBLISH BUT NOT PRESENT a paper at the symposium may choose the PUBLISH ONLY category. This will enable them to submit their papers for the refereeing procedure and publication if accepted.

ALL PAPERS offered for presentation or publication or both must have:

1. Title
2. Summary (600 words) (no figures) - Summaries will be published.
3. Any additional information, including figures or a complete paper which may help the program committee.

NOTE:
1. Six copies of each summary with title, author, and affiliation are to be attached.
2. Submission deadline is 7 July 1981. Earlier submissions will be appreciated.
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   Shock and Vibration Information Center
   Code 5804
   Naval Research Laboratory
   Washington, DC 20375.
4. Receipt of summary will not normally be acknowledged. Notification of Program Committee action will be given promptly.

It is the author's responsibility to obtain all necessary clearances and releases regarding the material he intends to present. Non-government organizations wishing to present classified papers must process the clearance through the cognizant contracting activity. Unclassified papers must also be cleared for public release by appropriate authority. This must be accomplished before the date on which the program becomes firm (Aug. 1, 1981). A written release for oral presentation and publication must accompany the complete paper. This is due in the office of the Shock and Vibration Information Center on September 15, 1981.

SUMMARY OF SHORT DISCUSSION TOPIC
52nd SHOCK AND VIBRATION SYMPOSIUM
NEW ORLEANS, LA, 27-29 OCTOBER 1981

SUBMISSION DEADLINE: 18 August 1981 Mail to: Shock and Vibration Information Center Naval Research Laboratory Code 5804 Washington, D.C. 20375

Discussions offered should cover a short progress report on a current effort or a useful idea or other information too short for a full-length paper. These are for oral presentation only and will not be published so that publication at a later date is not precluded.

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Affiliation: ______________________________

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Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a funtional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinant to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in June and December issues)
- volume, number or issue, and pages in journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7, pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (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., 27 (3), pp 220-231 (1948).
5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

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