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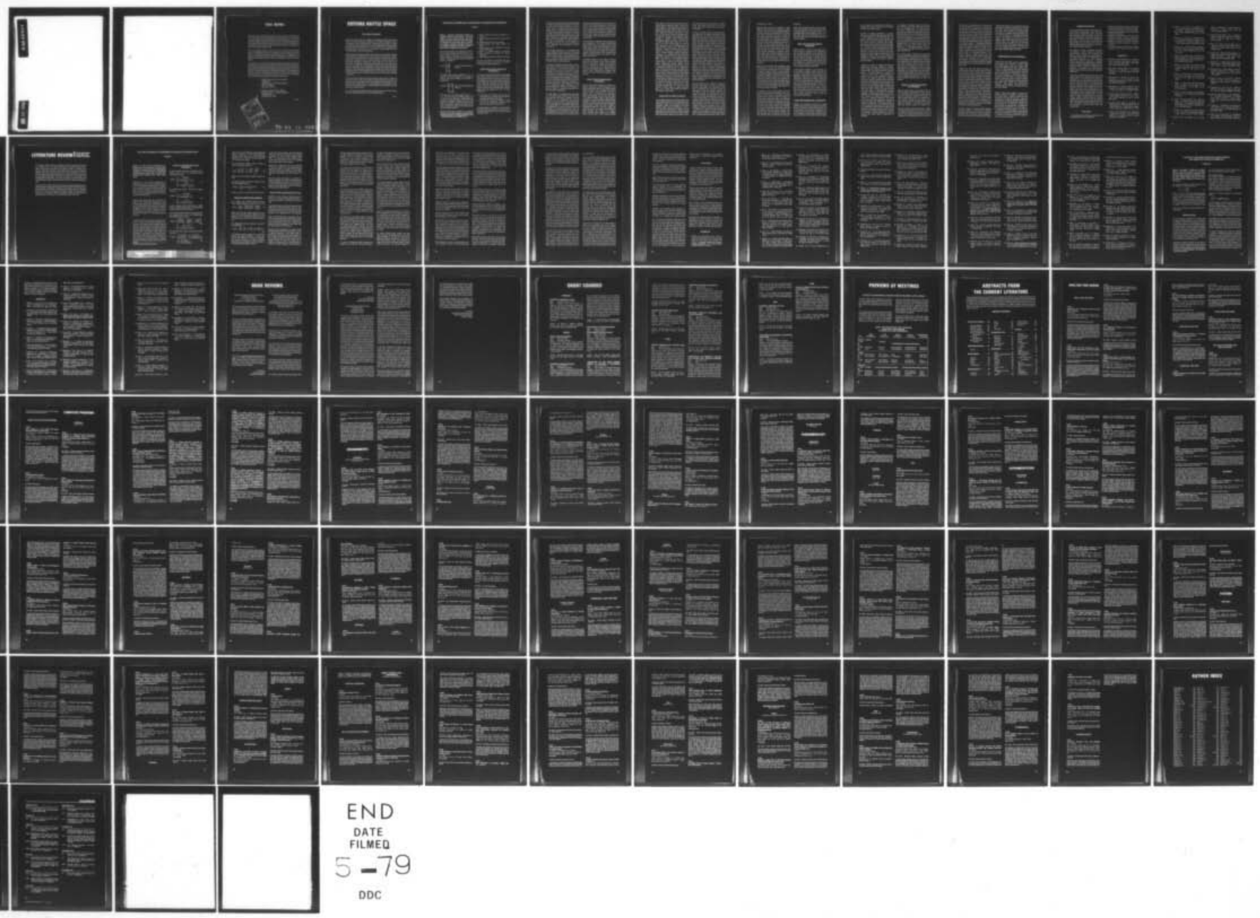

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SVIC NOTES

We were fortunate to have had John Haas who is the Chairman of the Navy Metrication Group describe the International System of Metric Units, or SI units, during the opening session of the 46th Shock and Vibration Symposium. For those who might be interested, his paper is published in Part 2 of the 46th Shock and Vibration Bulletin. Since then the conversion to the use of SI units has proceeded at a slow but steady pace, although I have yet to hear the expression "I wouldn't touch it with a 3.05m pole" become a cliche.

The most noticeable progress in the use of SI units in shock and vibration has been in the publication of papers in technical journals. Starting with the 46th Shock and Vibration Bulletin we have required SI units in our publications. The use of SI units has been required in NASA technical reports since 1964 and more recently they have been required in most of the Department of Defense technical reports.

The conversion to SI units should pose fewer problems for the shock and vibration community than for many of the technical communities because we deal with a limited number of physical quantities and the units of two of the more frequently used quantities, frequency and acceleration, are either unaffected by the type of units or they can be expressed as a dimensionless quantity. In the changeover to SI units, no matter how gradual, there is bound to be some confusion regarding the proper units for many physical quantities or the conversion to the proper units. Fortunately help is available in the following publications:

1. ASME Text Booklet SI Units in Vibration,
   ASME SI-8
   American Society of Mechanical Engineers
   345 E. 47th Street
   New York, NY 10017

2. Standard for Metric Practice, E380-76
   American Society for Testing and Materials
   1916 Race Street
   Philadelphia, PA 19103

R.H.V.

EDITORS RATTLE SPACE

THE LITERATURE REVIEW

One of the major sections of the DIGEST is the Literature Review, the purpose of which is to provide a subjective assessment of the literature published on shock and vibration over a three-year period. These articles are intended to present summaries of the major developments in small well-defined areas -- and to eliminate published material with little utility. A short tutorial on the area is presented in the initial article. The field of shock and vibration has been divided into about 150 subject areas to accomplish this program.

During the past four years this program has met with mixed success. Many excellent articles have been published, but some topic areas have not even been reviewed. In some cases it has been difficult to obtain reviewers. In others authors have not been able to complete the work. Authors often survey the entire literature in an area rather than prepare a critical review. This creates much more work for the writer than is intended by the program. Another pitfall involves the definition of the topic area. Large topic areas necessitate lengthy articles and a discouraging amount of preparation time. Occasionally the author never finishes the review. Typically a topic area should not encompass the breadth of the authors' technical expertise but rather a small well-defined part of it. These factors have contributed to some uneven results in the literature review section -- mostly a lack of material in some areas.

In the near future we shall be examining the literature review program to determine what can be done to make it more effective. New reviewers will be solicited, old reviewers will be encouraged, and some new guidelines will be provided for those who participate in this program. It is hoped that these new guidelines will make it easier for the reviewers to provide a critical assessment of the literature of a small topic area on a triannual basis.

If you are interested in joining the literature review program of the DIGEST, please send a short (50 word) description of your potential topic area.

R.L.E.

STRUCTURAL OPTIMIZATION UNDER SHOCK AND VIBRATION ENVIRONMENT

S.S. Rao*

Abstract - Structural optimization problems are classified according to major constraint -- e.g., natural frequency, flutter, dynamic response, and chatter stability. Each class is discussed. Approximate analysis techniques and some recent work on optimization methods, as applied to the design of structures, are presented. Structural optimization problems in need of further investigation are summarized.

Structural optimization can be defined as the evolution of a structural design that satisfies a set of functional requirements and that, in terms of a predefined criterion, is the best of all such acceptable designs. A standard parameter or static optimization problem can be stated.

$$\text{Find } \vec{X} = \begin{Bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{Bmatrix} \quad \text{which minimizes the objective function}$$

$f(\vec{X})$ subject to the constraints $g_j(\vec{X}) \lesseqgtr 0,\ j = 1, 2,\ldots,m$ where $\vec{X}$ is called the design vector. A trajectory or dynamic optimization problem can be stated in standard form.

$$\text{Find } \vec{X}(t) = \begin{Bmatrix} x_1(t) \\ x_2(t) \\ \cdot \\ \cdot \\ \cdot \\ x_n(t) \end{Bmatrix} \quad \text{which minimizes the objective function}$$

$f(\vec{X})$ subject to the constraints $g_j[\vec{X}(t)] \lesseqgtr 0,\ j = 1, 2,\ldots,m$, where each of the design variables x_i is a function of the parameter t. Mathematical programming techniques are generally used for solving parameter optimization problems; optimal control theory, Pontryagin's maximum principle, and calculus of variations are usually used for solving trajectory optimization problems.

Structural optimization problems can be classified according to the major constraint, as stated below.

- design problems with natural frequency constraints
- design problems with dynamic response restrictions
- design problems with flutter constraints
- design problems with chatter stability constraints
- design problems with probabilistic constraints (under dynamic loads)
- design of vibration isolators and absorbers
- design problems with strength and stability constraints
- design problems with static deflection constraints

The last two problems are concerned with static structural optimization; only the first six problems are discussed in the following sections.

DESIGN WITH NATURAL FREQUENCY CONSTRAINTS

Structural and mechanical systems should be designed with natural frequency restrictions to avoid failure due to resonance under the action of external forces. The problem of minimum mass design of a structural element satisfying a constraint on natural frequency is not a recent one. Although much work has been done in this field, many problems remain. The contradictory nature of the results obtained by different authors has been discussed [12, 41]. Two basic problems are

- minimization of the mass of the structural element subject to a specified natural frequency constraint, called the primal problem
- maximization of the natural frequency of vibration with an isoperimetric constraint on the structural mass, called the dual problem

No definite answer is available for the solution of the dual problem when there is no solution for the primal and vice versa [12]. Hati has tried to answer this problem [41].

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Most work on the optimum design of vibrating beams is concerned with Euler-Bernoulli beams. The effects of rotary inertia and shear deformation on the optimum design of vibrating beams have been considered [10, 17]. It has been found that the inclusion of rotary inertia and shear deformation terms reduces the weight savings available compared to an Euler-Bernoulli beam. Some investigations have been made with a constraint on higher order natural frequency and/or with multiple frequency constraints [13, 14, 17, 18]. The optimization of bars subjected to longitudinal, torsional, and lateral vibrations has been investigated using Pontryagin's maximum principle [7].

The thickness distribution of a rectangular plate whose fundamental natural frequency of transverse vibration attains an optimum value for a given volume has been considered [15]. A similar problem for the case of a simply supported rectangular laminated plate consisting of several layers of equally thick composite material has been solved [2].

Optimization techniques have been used to avoid a given bending frequency band in the design of the cross section of a turbine rotor blade [6]. The centrifugal force of the rotor blade upon the disc, expressed as a functional, to which it is attached was minimized. The blade was modeled as a Timoshenko beam; rotary inertia and the stiffening effect of the centrifugal force were neglected. Unexpectedly, the results showed that a rotor blade of uniformly constant cross section satisfies the conditions imposed and optimizes the centrifugal force. The problem of maximizing a linear combination of the natural frequencies of vibration of an idealized turbine disc subject to weight and fabrication constraints has been considered [5].

The determination of thickness variation with width of a long elastic plate immersed in an ideal fluid that maximizes its minimum frequency has been considered [1]. The optimization for minimum weight of a simple model of a rectangular wing subject to strength and natural frequency constraints has been discussed [11]. The design variables were the dimensions of the chord and semi-span and the thicknesses of the spars and wing skin. The wing was analyzed using a cylindrical tube theory; the Fiacco-McCormick interior penalty function algorithm was used for optimization. The number of wing cells was varied parametrically to find the optimum number of cells. Multiple constraints in the optimization of such structural elements as columns, portal frames, and rectangular plates have been considered [8, 9]. A steepest descent method for boundary value state equations was developed and applied; constraints were imposed on design variables, displacement, buckling, and natural frequencies of the structural element.

The optimization of stiffened structural elements has been considered [3, 16]. Circular cylindrical shells were reinforced with T-ring stiffeners for minimizing weight and for maximizing the separation of two natural frequencies [3]. The optimization of stiffened cylindrical panels with weight as the objective function has been presented [16]; constraints were placed on the frequencies in the presence of initial stresses using SUMT.

Formulations dealing with the design of vibrating structures using optimal control theory have been shown to correspond to singular control problems [4]. For such problems, neither the conditions of maximum principle nor the classical variational theory provide adequate tests for optimality of the solution; hence, supplementary necessary conditions must be used to examine the optimality of the solutions.

DESIGN WITH DYNAMIC RESPONSE CONSTRAINTS

Optimum design with restrictions on dynamic response is important in structures subjected to wind loading, earthquakes, impacts, gusts, and blast waves. Cassis and Schmit [19] considered the optimum design of planar orthogonal frames subjected to dynamic loads. They concluded that the feasible design space associated with structural optimization in the dynamic response regime is usually disjoint. An algorithm for optimum design of elastic structures subjected to dynamic loads has been given [20]. The finite element modal analysis and a generalized steepest descent method were used to develop a computational algorithm. Structural weight was minimized subject to constraints on displacement, stress, frequency, and member size. A uniform tubular cantilever beam subject to a sinusoidal force at the free end, a uniform tubular cantilever beam subject to a shock input at the fixed end, and a seven-member truss-frame subject to shock input were considered as example problems. The minimum weight design of linear elastic structures subject to periodic dynamic loads within the constraint of the given steady-state defelction specified at a given point of the structure has been investigated [21]. The approach was based upon Shield and Prager's principle of stationary mutual potential energy generalized to include the effect of inertial forces. A disjointed feasible space results when the constraint on the first natural frequency is removed during optimization of a thin walled cantilever rod under harmonic loading [22]. McConnell [23] described a method of adjusting the fundamental frequency of a structure to a prescribed minimum level; a modified Rayleigh method simultaneously converged to the fundamental mode while being proportioned according to a fully-stressed optimum design. The problem of finding design parameters that minimize the cost of an idealized multistory framed structure -- subject to the constraint that the relative displacements between adjacent stories do not exceed preassigned limits when the structure is subjected to ground motion of a design earthquake -- has been considered [24]. The design problem was formulated as a state-constrained optimal control problem. Venkayya and Knot [25] designed optimum structures to impulsive type loading. They represented the aperiodic forcing function with a Fourier integral to determine the dynamic response of the structure. Recent developments concerning the optimum reinforcement of nuclear power plant structures for protection against aircraft impact have been discussed [26]. The results of a sample analysis of aircraft impact on a square plate were given, but no details were provided with regard to the materials or method used.

DESIGN WITH FLUTTER CONSTRAINT

Flutter speed and frequency are defined, respectively, as the lowest airspeed and the corresponding circular frequency at which a given structure flying at given atmospheric density and temperature will exhibit sustained simple harmonic oscillations. Flutter is most commonly encountered on bodies -- aircraft wings, tails, and control surfaces -- subjected to large lateral aerodynamic loads of the lift type. Considerable work has been reported in the design of structures with flutter as a major constraint. The reason is that flutter behavior was found to be more important than static strength and other dynamic considerations.

A review of the state of the art of automated structural design with aeroelastic constraints has been published [37]. The treatment of parametric constraints with application to optimization for flutter using a continuous flutter constraint has been discussed [29]. The optimum design of structures with flutter as a major constraint has been considered by several investigators. Haftka [31] developed a computer program for the design of minimum mass wing structures under flutter, strength, and minimum gage constraints. The wing structure was idealized by finite elements; second order piston theory aerodynamics were used for flutter calculations. Mathematical programming methods were used for optimization. Computation times for the design process were reduced by three techniques. Iterative analysis methods significantly reduced re-analysis times compared to the original analysis of the structure. In addition, the number of design variables was kept small by not using a one-to-one correspondence between finite elements and design variables. Finally, a technique for using approximate second derivatives with Newton's method of optimization was used. Such flutter characteristics as flutter speed were found to display discontinuous dependence on the design variables (which are the thicknesses of the structural elements).

Pines and Newman [34] presented a method for structural optimization in which the aeroelastic structural modal shapes were represented as functions of mass distribution, structural stiffness, and aerodynamic forces. The optimality condition was the minimum weight that satisfied given structural strength constraints and precluded the onset of flutter over the airplane speed-altitude domain. The minimum weight design of a delta wing subjected to multiple constraints has been obtained by using an algorithm based on gradient projection [28]. Analytical expressions were used to evaluate constraint gradients, which were calculated only for active constraints. Constraint tolerances were also provided. A triangular wing having ten design variables and subject to stress, supersonic flutter, and minimum gage constraints showed a 44 percent weight reduction in six design steps; a 59 percent weight reduction was obtained in 17 steps.

Weisshaar [38] minimized the weight of a large aspect ratio panel immersed in a high Mach number supersonic flow when a critical aeroelastic parameter for flutter was held within specified limits. A refined finite element technique was used to model the panel flutter equations that acted as constraints on the design search. The optimization mechanism itself was studied to obtain qualitative results. Symodynes [36] presented the gradient optimization of structures to satisfy flutter requirements. An all-movable horizontal tail application was used; the skin alone and then the entire structure were resized. Several methods for sizing finite elements of an aircraft structural idealization to achieve minimum weight design under combined strength and flutter speed requirements have been developed and evaluated [39]. Methods based on a combination of energy principles and optimality criteria and procedures employing numerical search techniques were considered.

Segenreich and McIntosh [35] considered weight minimization of structures for fixed flutter speed via an optimality criterion. Pierson [33] described a gradient projection optimal control algorithm incorporating conjugate gradient directions of search. He applied the algorithm to several minimum weight panel design problems subject to a flutter speed constraint. Numerical solutions were obtained for simply supported and clamped homogeneous panels of infinite span for various levels of in-plane loading and minimum thickness. Pierson [32] used control theory to optimize a rectangular panel subject to a supersonic air stream on one side.

A comparison of the results obtained from mathematical programming and optimality criteria procedures for the minimum mass design of typical aircraft wing structures was used to satisfy prescribed flutter requirements [30]. The mathematical programming method was based on the interior penalty function approach. A Lagrangian optimality criterion and an intuitive optimality criterion based on uniform strain energy density were considered. Second order piston theory aerodynamics were used for supersonic conditions; kernel functions aerodynamics were used for subsonic conditions. This study indicated that the optimality criteria were more efficient than the penalty function technique considered.

Claudon [27] considered an elastic cantilever subjected to nonconservative loading consisting of either a tangential load at the tip (Beck's column) or a distributed tangential load (Hauger's column). For a given total mass the mass distribution that maximizes the critical flutter load was determined by an iterative procedure.

DESIGN WITH CHATTER STABILITY CONSTRAINT

Severe vibrations in metal cutting machine tools often give rise to undulations on the machined surface and excessive variations in the cutting forces. Such energetic vibrations are self-excited vibrations commonly known as chatter in machine tools; the source of self-excited energy is the cutting process itself. Because these self-excited vibrations are due to the interaction of cutting forces and the machine tool structural dynamics, the structure of the machine tool should be stable during chatter.

A computational capability for the automated optimum design of complex machine tool structures to satisfy static rigidity, natural frequency, and regenerative chatter stability requirements was first developed by Reddy and Rao [58]. Mathematical programming techniques were applied to determine the minimum weight design of a Warren-type lathe bed and horizontal knee-type milling machine structures using finite element idealization. The Warren-type lathe bed was optimized to satisfy minimum gage, torsional rigidity, and natural frequency requirements; the milling machine structure was optimized with constraints on the static rigidity of the cutter center, natural frequencies, minimum gage, and regenerative chatter stability.

DESIGN WITH PROBABILISTIC CONSTRAINTS

Whenever the parameters affecting such design problems as material properties and external loads are random in nature, the optimum design problem must be formulated within a reliability framework. Each constraint must be satisfied with a prescribed minimum probability, and the stated objective function must be optimized. Alternatively, the overall reliability of the system can be defined by considering all possible failure modes; a lower bound can be placed on reliability during optimization.

Examples of element optimization in concrete structures and highway bridge girder elements subject to fatigue loading have been discussed [50], the complex interrelationship between elements and failure modes in structural systems was also discussed. The optimum design of structures with random parameters has been considered [47]. Rao and Reddy [51] presented a method for evaluating the reliability of machine tool structures using finite element idealization. Specifically the reliability of horizontal knee-type milling machine structures with static rigidity of the cutter center, natural frequencies, and regenerative chatter stability failure modes was considered. A method for optimizing the design of machine tool structures with reliability constraints was also indicated.

A general formulation for weight optimization of indeterminate structures subjected to transient dynamic loads and reliability constraints has been presented [48]. Two distinct methods of structural analysis -- numerical integration of equations of motion and shock spectra -- were examined and compared for use in the optimization algorithm. Details of the essential computation of standard deviation of response quantities were also examined. The formulations were illustrated using a rigid frame subjected to an acceleration impulse applied to its base. The optimum aseismic design of building and equipment has been considered [49]. The structural model was typical of single or multistory buildings with floor, ceiling, or wall-supported equipment assemblies. Attention was focused on the random properties of the earthquake environment and structural response. The method was applied to the protection of industrial equipment in the vicinity of an active fault. When compared to conventional earthquake design and deterministic methods of analysis, the advantages of this method are that the random properties of the ground motion are analyzed at all earthquake intensity levels; the results reflect the location, protection level, and service life of the building; and earthquake damage cost, protection cost, reliability, important design factors, and cost-effective and optimal design configurations are disclosed.

The feasibility of applying modern control theory to the vibration of structures under random loadings has been investigated [52]. It was assumed that such random excitations as wind loads and earthquakes can be modeled by passing either a stationary Gaussian white noise or a nonstationary Gaussian shot noise through a filter. The minimized performance index consisted of the covariances of both the structural responses and the control forces. Under these conditions the optimal control law was a linear feedback control. The optimal control forces were obtained by solving a matrix Riccati equation. Application to a multi-degree-of-freedom structure under stationary wind loads and nonstationary earthquakes was presented.

The optimum design of beam-type and plate-type structures subjected to a constraint on the probability of failure due to combined blast and finite-duration acoustic loading has been considered [57]. This problem has application in the design of structures located near rocket testing or launching facilities where structures may occasionally be exposed not only to blast loads due to explosions but also to rocket noise excitation. The expressions for the first passage probabilities of a linear oscillator were used to determine the damage probability of the given structure. The optimization problem was posed as a constrained nonlinear programming problem. The design of a simply supported rectangular plate was used as an example.

DESIGN OF VIBRATION ISOLATORS AND ABSORBERS

Isolation devices reduce the unwanted effects of shock and vibration disturbances on critical elements of a mechanical system. Optimum design involves selection of isolators or absorbers that optimize an index of performance subject to the satisfaction of the constraints imposed on other aspects of the system repsonse and the parameters describing the isolators or absorbers. A monograph on optimum shock and vibration isolation is available [67].

Hati [41] used the concepts of game theory to design a vibration isolation system as a two-criteria parameter optimization problem subjected to a system of second order coupled differential equations and side constraints on the design variables. The first objective was taken as the integrated value of the square of the relative displacement between the main or top mass (which is to be isolated from the disturbance) and the base (to which excitation is given). The second objective was taken as the square of the force transmitted to the main mass. In order to determine an optimal trade-off between the two criteria, a suitable super-criterion was constructed and the corresponding best Pareto-optimal solution determined. Two different base disturbances were considered in the synthesis problem. A single-degree-of-freedom system was synthesized to examine the worth of the multi-degree-of-freedom system with respect to the objective considered. It has been shown that an indirect synthesis method can be used in the efficient optimal design of multi-degree-of-freedom, multi-element, nonlinear, transient systems [40]. The technique began with a limiting performance analysis requiring linear programming for a kinematically linear system. The system was selected by using system identification methods such that the designed system responded as closely as possible to the limiting performance.

Potemkin and Sinev [46] treated the problem of synthesizing an optimum vibration isolation system for an arbitrary dynamic linear system. Quadratic optimizing criteria involving both motion and transmitted force were used. A combination of stationary random and deterministic excitation was assumed. A new technique has been proposed for the optimum design of linear and nonlinear suspension systems for rotating shafts [45]. First, a generic force was substituted for the suspension system to be designed, and the absolute optimum (or limiting) performance characteristics of the shaft were computed. Second, using a chosen suspension system configuration, parameter identification techniques were used to obtain the design parameters so that the suspension system would respond as closely as possible to the absolute optimal performance. A simple Jeffcott rotor was used to demonstrate this technique. The improvements obtainable by using a quadratic-law damper over the linear type, under optimum damping conditions, have been discussed [42].

The optimum design of a dynamic vibration absorber has been treated by a formulation that enforces performance constraints over a range of excitation frequencies [44]. A harmonic force was applied to the main mass. The goal of the analysis was to choose a damper-mass system so as to reduce the main mass displacement. A generalized steepest descent method was used to obtain the optimum solution. Jacquot and Foster [43] considered a double-ended cantilever beam as a distributed parameter dynamic vibration absorber applied to a single-degree-of-freedom system in the presence of sinusoidal forces. The problem was analyzed exactly and by an energy approach using a single mode approximation for the cantilever beam. The results for both techniques compared favorably. Damping was introduced in the form of a complex beam modulus. Optimal tuning and optimal damping parameters were found for a given ratio of absorber mass to main mass.

APPROXIMATE ANALYSIS TECHNIQUES

Conducting an exact (static, dynamic, or aeroelastic) analysis each time a structure is modified makes any iterative design process costly. Hence, several simple and approximate structural re-analysis techniques have been proposed. Arora [53] presented a survey of available structural re-analysis techniques based on finite element representation of the structure. Several techniques -- initial strain concept of re-analysis, techniques based on Sherman-Morrison identity, general techniques of structural modifications, Taylor's series approach, iterative techniques, and reduced basis methods for computing static response -- were reviewed. Three techniques for predicting frequency response of modified structures were also discussed.

Efficient modal flutter analysis involving many iterations have been investigated for aircraft structural design [55]. A method for determining the magnitude of any particular increment -- mass, stiffness, damping -- necessary to satisfy prescribed flutter constraints has been presented [56]. Application of this procedure to the evaluation of flutter with external stores was presented with a simplified stiffness optimization procedure. Use of the method in an interactive (computer graphics) mode was discussed. Efficient re-analysis techniques using discrete structural and aerodynamic methods have been used in connection with the optimal aeroelastic design of an oblique wing structure [54].

OPTIMIZATION METHODS

A survey of analytical methods in structural optimization has been published [65], as has a basis for a unified theory encompassing modern automated design procedures [63]. In the latter, various methods are reviewed and examples given to indicate the wide range of problems to which the methods have been applied. The economics of automating the design process and the development of modular software packages based on the finite element method for analysis are briefly discussed.

The efficiency of three unconstrained minimization methods -- Powell's, requiring no derivatives; Fletcher-Powell's, requiring first derivatives; and Newton's, requiring first and second derivatives -- was studied using SUMT [61]. Subsequently the computational efficiencies of three constrained nonlinear programming techniques -- sequential linear programming, Zoutendijk's feasible directions method, and SUMT (using Powell, Stewart, Fletcher-Powell and Newton methods of unconstrained optimization) -- as applied to the minimum weight design of plane trusses and plane stress plates were studied [60].

Arora and Govil [59] presented an optimal structural design technique that incorporates the concept of substructures in its formulation. The method was developed using functional analysis techniques and the state space formulation of the optimal design problem. Numerical results for truss structures involving 25 and 200 members showed that the substructure method was up to 60 percent more efficient than results without substructuring. The implementation of the extended penalty function formulation has been considered [62]. The techniques of integer nonlinear programming, complementary geometric programming, and stochastic nonlinear programming, all of which are potential areas for structural optimization, have been presented [64]. The dangers of structural optimization, from the view point of structural stability, have been discussed [66].

CONCLUSION

It can be seen that the following structural optimization problems need further investigation.

- application of geometric, dynamic and stochastic programming techniques for the optimum design of structures subjected to shock and vibration
- reliability-based optimization of structures in the dynamic response regime
- application of decomposition principle in solving large-scale nonlinear structural optimization problems involving dynamic response restrictions
- handling of dynamic parametric constraints efficiently during the optimization of practical structures
- structural optimization in shock and vibration environment with integer or discrete variables

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

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

This issue of the DIGEST contains review articles on analysis techniques for experimental frequency response data and approximate methods for determining the vibrational modes of membranes. M. Radeş of the Polytechnic Institute of Bucharest has written a review of techniques for frequency domain post test analysis of vibration data. J. Mazumdar reviews approximate methods for determining the vibrational modes of membranes. This is the second review in this series.

ANALYSIS TECHNIQUES OF EXPERIMENTAL FREQUENCY RESPONSE DATA

M. Radeş*

Abstract - A review is given of techniques for frequency-domain post test analysis of vibration data. Emphasis is on procedures for curve fitting algebraic expressions of transfer functions to experimentally measured frequency response data for systems with nonproportional damping and/or closely spaced modes.

Measurement of the dynamic characteristics of materials and structures is an increasingly important part of the design and development of air- and spacecrafts, automotive and railroad vehicles, and machine tools and other equipment. Dynamic analyses are made in both the time-domain and the frequency-domain; the latter is sometimes preferred by mechanical and structural engineers.

Generally, the system under test is assumed to be linear; to have constant real parameters; and to be nongyroscopic, deterministic, asymptotically stable and of finite dimension. When attention is restricted to single-input/output measurements, the system is represented by the matrix of transfer functions, whose elements are Laplace transforms of the responses of the system to a unit impulse input at time zero.

A transfer function can be written as a rational fraction or in terms of the modes of vibration of the structure. The transfer function evaluated along the frequency axis is referred to as a frequency response function. Measured frequency response functions are being used to obtain the system's natural frequencies, damping values, mode shapes, modal masses, and stiffnesses or, alternatively, the analytical expressions for the elements of the matrix of transfer functions. Surveys of the methods used in the field of modal analysis and system identification of vibrating structures have been presented [33, 45, 49-51, 54, 59, 64].

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FREQUENCY RESPONSE ANALYTICAL EXPRESSIONS

For lightly damped structures, the transfer function between points j and ℓ, for proportional viscous damping can be written

$$H_{j\ell}(i\omega) = \sum_{r=1}^{N} \frac{\Psi_j^{(r)}\Psi_\ell^{(r)}}{m_r(\omega_r^2 + i2\zeta_r\omega_r\omega - \omega^2)} = \sum_{r=1}^{N} \frac{P_0^{(r)}}{1 + i\omega Q_1^{(r)} - \omega^2 Q_2^{(r)}} \qquad (1)$$

For proportional hysteretic damping the transfer function is

$$H_{j\ell}(i\omega) = \sum_{r=1}^{N} \frac{\Psi_j^{(r)}\Psi_\ell^{(r)}}{m_r(\omega_r^2 + ig_r\omega_r^2 - \omega^2)} = \sum_{r=1}^{N} \frac{P_0^{(r)}}{1 + iQ_1^{(r)} - \omega^2 Q_2^{(r)}} \qquad (2)$$

ω_r are undamped natural frequencies; m_r, modal masses; ζ_r, modal damping ratios; g_r, modal damping factors; and $\{\Psi^{(r)}\}$, real modal vectors.

For moderately damped structures, the transfer function between points j and ℓ, for nonproportional viscous damping can be written

$$H_{j\ell}(i\omega) = \sum_{r=1}^{2N} \frac{q_j^{(r)} q_\ell^{(r)}}{a_r(i\omega - p_r)} = \sum_{r=1}^{N}\left(\frac{\delta_{j\ell}^{(r)}}{i\omega - p_r} + \frac{\delta_{j\ell}^{(r)*}}{i\omega - p_r^*}\right) = \sum_{r=1}^{N} \frac{P_0^{(r)} + i\omega P_1^{(r)}}{1 + i\omega Q_1^{(r)} - \omega^2 Q_2^{(r)}} \qquad (3)$$

For nonproportional hysteretic damping the transfer function is

$$H_{j\ell}(i\omega) = \sum_{r=1}^{N} \frac{w_j^{(r)} w_\ell^{(r)}}{\overline{m}_r(\lambda_r - \omega^2)} = \sum_{r=1}^{N} \frac{w_j^{(r)} w_\ell^{(r)}}{\overline{m}_r(\omega_r^2 + ig_r\omega_r^2 - \omega^2)} = \sum_{r=1}^{N} \frac{P_0^{(r)} + iP_1^{(r)}}{1 + iQ_1^{(r)} - \omega^2 Q_2^{(r)}} \qquad (4)$$

[redacted]

where $P_r = \omega_r(-\zeta_r + i\sqrt{1-\zeta_r^2})$ are complex frequencies; $\{q^{(r)}\}$ and $\{w^{(r)}\}$, complex modal vectors; $\overline{m}_r$, complex modal masses; and a_r, complex quantities depending on the mass and damping distribution. The * denotes the conjugate.

The corresponding transfer function, defined in terms of the Laplace variable s, is

$$H_{j\ell}(s) = \sum_{r=1}^{2N} \frac{\delta_{j\ell}^{(r)}}{s-p_r} = \sum_{r=1}^{N} \frac{\delta_{j\ell}^{(r)}}{s-p_r} + \frac{\delta_{j\ell}^{(r)*}}{s-p_r^*} \qquad (5)$$

where p_r are pole locations and $\delta_{j\ell}^{(r)}$, complex residues.

For heavily-damped structures, the transfer function has a rational fraction form

$$H_{j\ell}(i\omega) = \sum_{n=0}^{N} P_n(i\omega)^n \Big/ \sum_{n=0}^{N} Q_n(i\omega)^n \qquad (6)$$

where p_n and Q_n are real coefficients (with $Q_0=1$).

FREQUENCY RESPONSE MEASUREMENT

For a system with a frequency response function $H(i\omega)$, whose response to excitation $x(t)$ is $y(t)$

$$H(i\omega) = \frac{Y(i\omega)}{X(i\omega)} = \frac{Y(i\omega)\cdot X^*(i\omega)}{X(i\omega)\cdot X^*(i\omega)} = \frac{S_{xy}(i\omega)}{S_{xx}(i\omega)} \qquad (7)$$

$X(i\omega)$ and $Y(i\omega)$ are Fourier transforms of $x(t)$ and $y(t)$, $X^*(i\omega)$ is the complex conjugate of $X(i\omega)$, $S_{xy}(i\omega)$ is the cross-spectral density of $x(t)$ and $y(t)$, and $S_{xx}(\omega)$ is the power spectral density of $x(t)$.

For steady-state harmonic excitation, $x(t)=x_0 e^{i\omega t}$, $y(t)=y_0 e^{i(\omega t-\varphi)}$,

$$H(i\omega) = \frac{y(t)}{x(t)} = \frac{y_0}{x_0} e^{-i\varphi} = \frac{y_0}{x_0}\cos\varphi - i\frac{y_0}{x_0}\sin\varphi \qquad (8)$$

For transient excitation, equation (7) is used either off-line, with digital computers or on-line, with real-time FFT analyzers. For random or pseudorandom excitation, equation (7) is used; the spectral densities can be calculated as Fourier transforms of the corresponding correlation functions.

If the input forcing function cannot be measured under some restrictive conditions, transfer functions calculated from minimum phase response spectra [36], from random decrement signatures [58], or from the autocorrelation function of the response [24] are used, mainly in flutter testing.

Measurement considerations have been published [3, 22, 34, 41, 65, 72]. Data manipulation techniques are available to overcome the noise problem [24, 27] and truncation effects [36, 75]. Multidirectional measurements have been reported [13, 14].

Multi-point (*either simultaneous or successive*) excitation techniques and related data analysis techniques are available [2, 5, 6, 15, 16, 25, 44, 56, 69, 73, 74, 80, 81].This problem will be discussed in detail in a future review paper. Single-point excitation techniques are considered below.

CURVE FITTING IN THE FREQUENCY PLANE

Depending on the closeness of resonances and the amount of damping, single-degree-of-freedom or multi-degree-of-freedom curve analysis techniques are used.

One-degree-of-freedom analysis techniques are applicable when the overlap between modes is small. A general assumption is that the off-resonance vibration has a (zero or) constant contribution to the total response in the neighborhood of any resonance.

Most of the techniques used in connection with systems having proportional damping have been presented in a previous review article [61]. Graphical techniques for analyzing systems with nonproportional damping have been developed for both viscous [64, 82] and hysteretic [31, 84] damping.

Woodcock [82] demonstrated the validity of the frequency spacing method and described the rotation of resonance diameters in the Argand plane for systems with viscous nonproportional damping. He also proposed a method that avoids the need to locate the resonance points on vector plots; the forcing frequency values for which the in-phase and in-quadrature components of the response reach an extremum are used. Klosterman [31] extended the findings to systems with hysteretic damping. Zimmerman [84] established formulas for viscous damping evaluation based on the diagrams of the vector components of the response. Richardson [67] proposed new equations for both residues and pole locations of transfer functions derived for systems with relatively separated complex modes.

It has been shown [8, 19] that, if the modes are uncoupled and well separated in frequency, the diameters of the circles fitted in the Argand plane to the near-resonance points of the displacement response are normal to the force reference direction. If the modes are uncoupled, but close in frequency, the diameters have a phase offset relative to the force reference direction due to the variation with frequency of the off-resonance modes. If the modes are coupled, the resonance diameters have additional phase offsets.

The amount and type of nonlinearities can be determined by plotting a family of vector diagrams for different force amplitudes and the isochrones drawn through the points of equal frequency. These are straight lines only in the range of amplitudes where the system is linear. Their deviation to the left or to the right is the best indication of whether the elastic characteristic is softening or hardening [62]. For relatively separated modes, the deviation from the circular shape of the vector diagrams indicates the type of damping nonlinearity [1]. Application of the excitation with forces in quadrature to the analysis of a class of nonlinear systems has been considered [63].

The limitations of the classical method of Kennedy and Pancu are generally known [19]. It has again been proved [29] that plots of the derivative of the Nyquist plot arc length with respect to frequency, locate maxima with increased accuracy. The limits of single-degree-of freedom methods have been evaluated by considering ways in which the response of one mode of vibration might interfere with the response of an adjacent mode. A simplified interference boundary has been determined [40] that relates modal damping ratios and the ratio of neighboring natural frequencies (only for proportional damping).

In general, multi-degree-of-freedom analysis techniques must be used when the modal overlap is sufficient to cause significant errors by single-degree-of-freedom techniques. Elimination from the frequency-response equation of the relatively isolated and/or highly damped modes could be done after inspection of response curves.

Curve fitting methods for highly resonant structures can be divided in direct methods and parameter estimation methods. Direct methods (nonstatistical parameter determination methods) suppose zero error between measured and calculated values of the response. Techniques have been derived to consider viscous [78] and hysteretic [46, 76] proportional damping, as well as viscous [35, 84] and hysteretic [48] nonproportional damping.

In the phase separation method, Stahle [76] used single-degree-of-freedom graphical methods to determine the undamped natural frequencies and the hysteretic damping factors from the diagram of the in-quadrature component of the acceleration response. The modal matrix is then extracted from the response matrix evaluated at the resonance frequencies. A similar method used [78] for viscously damped systems is based on the response displacement magnitude curve and on the matrix of the in-quadrature part of the response. No improvement of the initial estimates of ω_r and g_r or ζ_r is carried out. Modes whose natural frequencies are not visible in the response plots cannot be determined by this method.

Natke [46] proposed and applied [47] a method in which measurements of both in-phase and in-quadrature components are used at forcing frequencies in the neighborhood of system resonances. After elimination of the modal matrix, a set of N quadratic equations of order N is obtained. From these equations the natural frequencies and damping factors are obtained after a mean-value calculation; thus no graphical technique is used to obtain prior estimates of ω_r and g_r. The modal matrix is then obtained as in [76].

An iterative mode-by-mode approach has been used [17]. When the dominant mode in each measured bandwidth is removed from the mobility eigenvalue equations, the iterations converge on the next most dominant mode. The procedure can reveal modes that are completely masked if, at each measured frequency, the dominant eigenvalue is greater than the eigenvalues of the other modes. But, if two modes are nearly coincident, the convergence is very slow; the approximation of the dominant mode might then be inadequate for a suitable estimate of the following modes. Neglecting the influence of the modes outside the frequency range of measurements is common to all these techniques.

The phase separation method preceded by the modal matrix elimination has been extended [35, 84] to systems with viscous and to systems with hysteretic nonproportional damping [48]. One method [35] requires prior knowledge of the system mass matrix for a complete identification and leads to a large system of nonlinear equations. Another method [48] leads to determination of zeroes of N polynomials of N-th degree and solution of two systems of linear equations. Again some averaging is necessary as for proportional damping.

Cottin and Dellinger [4] developed one method [48] for flight flutter testing, using the Fourier transform of the truncated response to an impulse excitation. Elimination of the matrix of residues leads to a system of nonlinear equations that is solved by an iterative method.

Parameter estimation methods can be classified as one-step methods and iterative methods, most minimize the deviations between measured and calculated values of the frequency response and use a least-squares error procedure.

One-step least-squares curve fitting methods have been reported for systems with viscous nonproportional damping [7, 8, 9, 42, 77].

One approach is to multiply out the series in equation (3) to obtain a rational fraction of two frequency-dependent polynomials. If the considered error is simply the difference between the absolute magnitudes of the actual frequency response function and the polynomial ratio, minimizing the sum of the so defined errors at the experimental points leads to a nonlinear least squares problem. In order to linearize the minimization problem, the above defined error is multiplied by a weighting function, usually the denominator polynomial.

Dat and Meurzec [7] used a formulation which leads to an eigenvalue problem. Positive experience has been reported [8, 9] for systems with a small number of modes and measurements with small resolution between data points. When the order of polynomials is large, information is lost by truncation because each polynomial is dominated by its highest degree term. The method seems unsuitable if some modes are very near resonance frequencies and relatively important damping ratos. A similar method has been used by Mannetje [39].

A different approach involved reducing the problem so as to minimize a quadratic functional and then to a simple system solved by Cholesky's method. After the coefficients of the response function, written as a rational fraction are identified, the poles are determined by factoring the denominator; the function is then resolved into simple components, and the modal parameters and complex modal vectors calculated.

An experimental technique [4] has been extended [77] to the case in which there are more forcing frequencies than measuring points. An overdetermined system of equations was solved by the method of least squares. Good results were reported for application of the method to a real system with natural frequencies close to each other.

Iterative estimation methods are available for systems with proportional viscous [10, 30] and hysteretic [18] damping, as well as for nonproportional viscous [19, 20, 27, 36, 67] and hysteretic [21] damping.

Klosterman and Lemon [30] used the peaks in the imaginary portion of the response to estimate the undamped natural frequencies; they are not improved afterward. A graphical curve fitting method was used to determine initial estimates for the damping ratios. A least squares technique was used to set up an iterative procedure between the in-phase and in-quadrature components of the response. The procedure converges onto the modal vectors and effective damping ratios. Residual complicances are added to equation (1).

Davis [10] described a technique in which starting estimates of natural frequencies and damping ratios are used. The mode shape coefficients are determined by a least-squares fit of a modal model to the measured in-phase and in-quadrature components of the acceleration response. Residual compliances and rigid body inertias are added to the frequency equation. In order to decrease the rms error between model and response data, a computer program was written; it used an iterative procedure to obtain the best values for the resonance frequencies and damping ratios.

Estimates of the natural frequencies and initial zero damping factors have been used [18]. The in-quadrature component of the displacement mobility was measured at a number of forcing frequencies and measurement points greater than the number of modes assumed. The method of the pseudoinverse matrix was used to develop a double iteration procedure that converges to the best solution for the modal matrix. Modal mobilities were calculated from the matrix of the measured response and the modal matrix, from which the modal parameters were obtained.

The coefficients of the partial fractions have been determined from equation (3) for a maximum of five modes of vibration [19]. A least squares technique was used in which the nonlinear problem was obviated by a Taylor series expansion. The coefficients of the denominators were stage one estimates, obtained from circles fitted to loops of vector plots in the vicinity of the resonances. The coefficients of the numerators were stage two estimates obtained by a least squares procedure in which stage one estimates are kept constant. All are then used as initial estimates in an iterative process in which the entire vector plot is again fitted to equation (3), and new values of the coefficients are obtained. The method is limited to systems with modes that could be recognized from vector plots. In a further application of the method [20], the resonance frequencies and damping ratios were determined from the Fourier transform of the one-sided auto-correlation function of the response to impulsive or random excitation.

Richardson [67] noted that the transfer function shown in equation (5) is a linear function of the residues. Hence, a simultaneous linear equation solution algorithm -- using a least squared error technique -- for identification of residues in combination with a search procedure that iterates toward an optimum estimate of the pole locations, is a reasonable approach to determining modal parameters for highly resonant systems with moderate nonproportional damping.

Lenz and McKeever [36] reported results obtained using a Modal Analysis Package software in connection with the Time/Date 1923/50 Time Series Analyzer. It is an algorithm used to transfer mathematically from the Fourier representation of a system to the Laplace plane. The Laplace software contains procedures that attempt to identify the modes with the highest spectral energy and the lowest damping. The procedures involve calculating a modal energy value for each pole as a percentage of the total energy in the frequency band being analyzed and considering only those modes whose energy is greater than a preselected cutoff value. Checks performed on digitally generated transfer functions and on analog model responses have shown errors in the estimation of closely spaced modes with damping ratios higher than $\zeta = 0.035$. The accuracy was improved if two interfering modes were both highly damped.

The modal analysis and system identification methods developed by Richardson and Potter [60, 66, 67] have led to the implementation of the program entitled "Modal Analysis System" on the FFT Dynamic Analyzer HP-5451B [23]; it transforms the measured frequency response functions into a Laplace description via an iterative least squared error technique. The modes are identified from their resonance peaks on the frequency response magnitude curve; initial estimates of their pole locations and residues are given as starting values. With each iteration of the algorithm new values of the four unknowns for each mode are simultaneously estimated, thereby reducing the error between the measured and analytical responses. Experience with this program has been described [27, 55].

Goyder [21] has shown that if a large number of modes is to be considered, term by term fitting of the series in equation (4) would seem to be preferable. In his method the frequency response curve is divided into intervals, each containing one resonance frequency and therefore corresponding to one term in equation (4). Initial approximations to all terms are first obtained; best estimates for the complex mode shapes and resonance frequencies are calculated for each interval, minimizing a linear error function with respect to each of the four unknowns from equation (4). Each time an estimate for a term is obtained, a better approximation is done for the off-resonance contribution from adjacent frequency intervals; thus, a better estimate is obtained of the complex mode shapes and resonance frequencies. Effects of residual compliances and inertias were also considered.

From the viewpoint of parameter identification, all the methods presented are response-error modeling techniques. If differences occur between analytical results and the corresponding test results, the mathematical model can be improved by analytical methods [52].

Special methods like those proposed for base excited systems [11, 38] and for gyroscopic systems [83] are not discussed herein.

For heavily-damped systems, for which individual modes of vibration are not distinguishable, the frequency response is curve fitted by a transfer function expressed as a rational fraction of the form shown as equation (6).

Methods for evaluation of the polynomial coefficients have been reviewed [26, 32, 71]. A general discussion from the viewpoint of interpolation theory has been given [68]. Techniques used by control system engineers can be used to identify such rational fractions.

Kardashov and Karnyushin [28] determined approximate values of the polynomial coefficients by direct interpolation of a finite set of transfer data measured at discrete frequencies. Corrections were calculated via a weighted least squares method.

Levy [37] solved the linearized interpolation problem; he used as the weighting function the polynomial of the denominator. Similar approaches have been used [43, 53]. Sanathanan and Koerner [70] improved Levy's method by an iteration procedure that effectively eliminated the weighting; this leads to large errors for systems with moderate damping. In order to improve the accuracy of fit to the experimental data and to get stable transfer functions (without right half-plane poles), Payne [57] used additional data from the system time-domain response to different simple inputs. Other approaches to the linearized problem can be found [7, 42, 79]. The only method in which the degree of polynomials has not been established a priori was proposed by Dudnikov [12]. Unfortunately, this is a graphical method based on limited data measured at low frequencies.

CONCLUSIONS

Frequency response data analysis methods based on the theory of nonproportionally damped systems have the best capability to accurately describe the dynamics of actual structural systems with both real or complex modes of vibration. Use of hysteretically damped models leads to simpler equations. Unfortunately for broad excitation methods -- which are presently receiving widespread use due to evident advantages -- these models are inappropriate, being postulated for harmonic motion only.

Promising results have been reported in obtaining Laplace descriptions of the dynamic response from measured frequency domain functions by rational interpolation. Because the rational interpolation problem can be numerically ill-conditioned, a topic for further research is that of approximate identification and partial realization.

There is need for more comparative studies to evaluate the limits and merits of existing frequency domain analysis techniques and to establish the best methodology to be followed in specific applications. A reconsideration of the existing analytical techniques that could provide a nonlinear analysis capability is necessary.

Data reduction techniques should be developed in association with data collection procedures and accomplished with as much operator interaction as desired. More advantage should be taken of the availability of highly automated data acquisition systems and advances in optimal estimation theory.

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A REVIEW OF APPROXIMATE METHODS FOR DETERMINING THE VIBRATIONAL MODES OF MEMBRANES

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Abstract - ***This review is a follow-up of an earlier review of approximate methods for determining vibrational modes of membranes published in 1975. The earlier review described the world literature from the time of Chladni (1802) until the end of 1974. The present review is restricted to the period from 1975 to date.***

The classical differential equation governing the free vibration of a membrane is given by

$$\nabla^2 w = \frac{1}{c^2}\frac{\partial^2 w}{\partial t^2} \qquad (1)$$

where $c^2 = T/\rho$; c is the wave propagation speed, T is the tension of the membrane, ρ is the superficial density, and ∇^2 is the Laplacian operator in two dimensions. It is well known that this simple equation does not have simple solutions if the geometry of the membrane boundary is other than a circle or a rectangle. Hence approximate methods are used.

This review is divided into linear analysis and nonlinear analysis.

LINEAR ANALYSIS

Vibration problems of membranes are often discussed by using the results obtained in such problems as the oscillatory motion of an enclosed body of water, the axial shear vibration of a long elastic bar, and the propagating modes of certain acoustical waveguides. The reason is that all of these problems are classed as one type of boundary value problem. It has recently been shown [18] that the human eardrum also behaves like a thin membrane; in addition, a mathematical model based on membrane hypothesis has been developed to analyze the modus operandi of the mitral valve of the human heart [19].

Approximate analytical methods for the study of problems involving complicated cross sections include Rayleigh's method, Rayleigh-Ritz method, Galerkin's method, conformal mapping, point matching, collocation, finite differences, the finite element method, and the constant deflection contour method.

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Free Vibration Analysis

Free vibration problems for membranes of general shape can be described by the methods mentioned above. However, because approximate solutions for the equation of motion or approximate boundary conditions are used, it is difficult to obtain good results for higher mode vibration. Hence the above-named methods cannot be expected to yield good results for the transient response case.

Jones [11] recently presented an approximate formula

$$\left(\frac{\omega}{c}\right)^2 = (2.4048)^2/4\,W'_{max} \qquad (2)$$

for the frequency of vibration ω of several dynamic systems, including that of a membrane. He showed that, with a reasonable degree of accuracy, the fundamental frequencies of a vibrating membrane can be obtained if the static deflection mode W', corresponding to the unit load of the membrane, is known. This is an interesting piece of work despite the lack of a formal derivation of this simple relationship.

Sundararajan [32] also formulated a similar approximate relationship between the frequency and the static response of undamped, linearly elastic systems. This relationship was used to calculate the fundamental frequencies of membranes and plates having different geometries and boundary conditions.

In another interesting study Eastep [5] proposed a method for obtaining approximate fundamental frequencies for noncircular, doubly-connected membranes. The method considers both inner and outer boundaries as perturbations from concentric circles; the perturbation shape is expressed as a Fourier series. The resulting natural mode expression is in terms of a series of Bessel functions of the first and second kind. Approximate frequencies of the fundamental mode of ring membranes in the shape of an elliptical ring, a circular-eccentric ring, and a square ring were obtained; a comparison to an exact solution for the elliptical case was given. Ring membranes having other boundary curves can be treated in a similar manner, as it is necessary only to obtain the representation of the boundaries in the form of a Fourier series.

Sato [27, 28, 30] discussed the free vibration of both composite elliptical membranes consisting of confocal elliptical strips and composite rectangular membranes consisting of linear strips. Solutions for the former were developed in terms of Mathieu and modified Mathieu functions; solutions for the latter were in terms of simple trigonometric functions. Equations for frequency and eigenfunctions were obtained.

The free vibration of an elliptical membrane has also been discussed by Osmoloskii [24], who used an asymptotic power series to obtain the frequency equation. Formal solutions to the same elliptical membrane problems (together with elliptical plate problems) were also obtained in terms of Mathieu functions and modified Mathieu functions [25, 26]. Consideration was given to the symmetric modes. Transition to the corresponding circular case was obtained with degenerate forms of Mathieu functions.

The vibration of skew membranes has been studied using the perturbation theory [34]. Simple analytical expressions for the frequencies were functions of skew angle. Such formulas are useful for design purposes.

In an integral equation approach [3, 4] the Helmholtz equation was first converted to an integral equation of the Fredholm type using Green's functions. The approximate solution of the integral equation was then obtained numerically.

Holovchan [7] discussed the problem of free vibration of a rectangular membrane with a semicircular cut out at one edge. Natural frequencies and modes were determined from a truncated infinite system of homogeneous linear algebraic equations. Unfortunately, no numerical calculations were carried out.

In a finite element study using trigonometric terms, the accuracy of the solutions obtained with the trigonometric element was very good when compared to solutions using the polynomial elements [20]. Laura and Maurizi [12] subsequently compared numerical results of values obtained in the case of domains of octagonal shape. Because the boundary value problem is analogous to the buckling of a polygonal plate under in-plane hydrostatic pressure or free flexural vibration of the simply supported polygonal plate, numerical results are applicable.

Nagaya [21, 22] proposed a method of solving vibration problems for a membrane having a circular outer boundary and an eccentric circular inner boundary. The frequency equation for the membrane is given, and the dependence of the natural frequency on the eccentricity is obtained.

An interesting method for determining eigenvalues in polygonal domains with concentric circular perforations involves constructing appropriate coordinate functions that identically satisfy the boundary conditons [14]. A vibrational principle is used to generate a simple frequency equation. Various approximate methods for the solutions of membrane problems have been summarized [13].

Forced Vibration

When a membrane is driven by a force distributed over its surface, forced vibration results. The literature dealing with such problems is very limited because of the mathematical complexity of the forcing function.

The usual procedure for analyzing forced vibration is to express the forcing function in terms of the eigenfunctions of the corresponding free vibration and to obtain the amplitude and time response of each mode. Leissa [15] recently proposed an interesting method for the study of forced vibration of continuous systems including membranes. The merit of this method is that the response of the forced vibration can be obtained without the free vibration eigenfunctions. Hutter and Olunloyo [9] used matched asymptotic expansions to study membrane deflection under static and dynamic loading. This work constitutes the first attempt in the literature of membranes to use this technique for constructing the response either to steady forced vibrations (as opposed to the eigenvalue problem) or to impact loading. In general, whenever the forcing function is sinusoidal, both spatially and in time, the character of the solution changes from exponential to sinusoidal, depending on whether the frequency is higher or lower than its spatial mode.

Sato [29] discussed the problem of forced vibration of a composite elliptical membrane consisting of any number of confocal elliptical layers of different materials. Recently Mazumdar and Hearn [19] applied the theory of forced vibrations of membranes to the study of human mitral valve leaflets and obtained results for clinical utilization of a prosthetic valve leaflet.

NONLINEAR ANALYSIS

During the last ten years or so, there have appeared a number of research papers on nonlinear vibrations; however, a number of unanswered questions remain for future study.

The differential equations governing the large amplitude nonlinear vibrations of membranes follow directly from Von Karman's corresponding flat plate equation in which the plate stiffness is zero. Except in rare instances, however, no direct methods are available for solving nonlinear boundary value problems. Consequently, a great deal of effort has been directed toward obtaining approximate solutions.

Many axisymmetric nonlinear membrane problems have been solved in recent years; relatively few non-axisymmetric membrane problems have been investigated. Tielking and Feng [32] studied problems usually encountered in rubber technology. Their method involves minimizing the potential energy by means of the Ritz procedure. The resulting nonlinear equations are solved by the Newton-Raphson method. Their formulation and solution techniques were extended to the non-axisymmetric problems [6].

Another interesting study on axisymmetric deflection of an annular membrane with the outer edge attached to an immovable ring support and the inner edge connected to a weightless rigid circular disk has been reported [2, 31]. Approximate solutions of the nonlinear differential equations were obtained for the deflection and radial displacement using the perturbation method.

Hutter and Olunloyo [8] investigated the dynamic response of a rectangular membrane. Solutions were constructed by using the singular perturbation technique (method of matched asymptotic expansions); results for eigenvalues and eigenmodes were listed for various boundary conditions.

The nonlinear vibration of a circular membrane has been studied with a perturbation scheme [35]. The parameter is the amplitude of transverse displacement; periodic solutions were obtained. The exact solution has been obtained in closed form for the dynamic response of an infinite elastic membrane to a suddenly applied, radially expanding ring load [36].

A relatively simple method for obtaining accurate approximate solutions to the nonlinear deflection of membranes has been suggested [10, 17]. Jones [10] obtained the general solution to the large amplitude deformation of membranes. Membranes of various shapes were considered; the results were shown to be in excellent agreement with other solutions. This work gives the solution for all membrane shapes in a simple form without involved mathematical analysis. Mazumdar and Jones [17] obtained the general solution of the large amplitude nonlinear vibration of membranes of arbitrary shape using the Berger approximation, in which the second strain invariant in the total strain energy of the membrane is neglected. It has been shown that the mode shape is the same as that for the small amplitude vibration. Some comparisons for the circular and rectangular membranes were given.

The nonlinear dynamic equation for membranes has been formulated using constant strain triangular finite elements in conjunction with the central difference time integrator [23]. The nonlinear dynamic response of membranes has also been studied using the finite element technique [1]. This technique was applied to the vibration of a square membrane to demonstrate the accuracy of the formulation.

FUTURE RESEARCH DIRECTIONS

Since the last review [16], the author had hoped to find some reports of experimental work on membrane vibration; unfortunately none were found. Since the introduction of time-averaged holography, however, it is anticipated that the results of membrane vibration studies will be more accurate. The author [18] recently used this technique to study vibration frequency of the tympanic membrane. There still exists the need for extensive experimental work to validate theoretical results and to provide direction for further investigation.

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BOOK REVIEWS

FRACTURE AND FATIGUE CONTROL IN STRUCTURES

S.T. Rolfe and J.M. Barsom
Prentice-Hall, Inc., Englewood Cliffs, New Jersey

This book is a welcome addition to the few published texts in the field of fracture mechanics. It can well serve as an introductory textbook fór senior or beginning graduate students, as well as a valuable reference for the practicing engineer.

The first six chapters address the fundamentals of the field of linear elastic fracture mechanics. These chapters clearly cover the theoretical development of stress intensity factors; test methods for obtaining critical stress intensity factors; the effect of temperature, loading rate, and plate thickness on fracture toughness; and the relationship between stress, flaw size, and material toughness. Specific design examples are also given.

Subcritical crack growth by fatigue, stress corrosion, or corrosion fatigue are treated in chapters seven through eleven. These sections also contain a wealth of plotted experimental data. The final chapters treat fracture criteria, notch toughness criteria, fracture control plans, and an introduction to elastic-plastic fracture mechanics.

In summary, Fracture and Fatigue Control in Structures is an excellent textbook. Both authors are highly respected experts in applications of fracture mechanics. Several excellent example problems in the body of the book demonstrate the practicality of linear elastic fracture mechanics.

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FINITE ELEMENT APPLICATIONS IN VIBRATIONS PROBLEMS

M.M. Kamal and J.A. Wolf, Jr., editors
American Society of Mechanical Engineers, NY, 1977
(papers presented at the Design Engineering Technical Conference, Chicago, Illinois
September 26-28, 1977)

In one paper in this volume J.K. Vandiver discusses the dynamic analysis of offshore structures; 39 references are given. Analysis methods are standard, but offshore structures present special problems, including limited knowledge of marine foundations, and how structural response is changed by foundation settlement and structural degradation. There is little field data with which to compare analyses.

Application of the finite element method to mechanisms is discussed by R.C. Winfrey. The simple presentation is intended to describe the essentials to a reader who has modest familiarity with analytical methods and finite elements.

H.A. Kamel and D. Liu survey structural dynamic problems in ships and list 168 references. Greatest attention is given to the source and nature of dynamic loadings. Some attention is given to problems of such vessels as tankers, container ships, and hydrofoils. Greater use of finite elements in the calculation of hydrodynamic forces is advocated.

Finite element models for automotive vehicle vibrations are surveyed by M.M. Kamal and J.A. Wolf, Jr., in a paper with 102 references. They discuss discretization of the structure, data preparation, and comparison with test results. Attention is given to vehicle vibration, impact dynamics, and vehicle acoustics.

N.F. Rieger discusses finite element analysis of turbomachinery blade problems. He discusses the nature of the problems, surveys applicable finite elements, and outlines analysis procedures for steady state, vibration modes, dynamic stress, and fatigue stress problems. There are also recommendations for research.

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FLOW-INDUCED STRUCTURAL VIBRATIONS

E. Naudascher, Editor
Springer-Verlag, 1974

This book contains papers, general lectures, and workshop reports presented at the 1972 IUTAM-IAHR Symposium in Karlsruhe. The expressed purpose of the symposium was to provide an opportunity for the exchange of ideas and information among representatives of fields as diverse as aerodynamics, theoretical and experimental fluid mechanics, structural mechanics, hydraulics, and hydraulic machinery. Seven sessions and five workshops were held. The topics of the technical sessions were as follows: generation of oscillatory flows; mathematical models of flow-induced vibrations; and flow-induced vibrations of hydraulic structures, beams and bridge-decks, bluff bodies, marine structures, and shells and pipes; and flow-induced vibrations relating to construction. The purpose of the five workshops was to define the research priorities in flow-induced vibrations. The topics of discussion were new theoretical and experimental approaches; air and water craft; buildings, towers, and bridges; hydraulic structures and machinery; and marine structures. In all, 49 papers, five general lectures, and the summaries of five workshops are included in the book. A separate volume containing all discussions during the sessions, not included in the book, is available from the Institute of Hydromechanics, University of Karlsruhe, Karlsruhe, Germany.

Throughout the book a gap exists between research scientists and design engineers. In most of the work presented by research scientists the models are too idealized and too far from reality to be of much use to design engineers. On the other hand, the systems presented by designers are so complicated that research scientists cannot offer simple design expressions.

Damages resulting from flow-induced structural vibration were discussed. These problems have resulted in structural damage to several types of valves and gates, concrete erosion of tunnels and stilling basins, and destruction of steel liners. Field experience indicates that serious damage results whenever excessive cavitation or vibration occurs during operation. The damage resulting from flow-induced vibrations also occur in aircraft, watercraft, buildings, marine structures, heat-exchanger tubes, nuclear fuel rods, and piping systems.

Many authors contributed to flow-induced vibrations of such bluff bodies as circular cylinders and prismatic bodies having equilateral triangular and square cross sections. All studies were experimental investigations and had one or several of the following objectives: (1) to measure the lift force and its dependence on system parameters; (2) to find the correlation length of flow field along the flow stream and along the structural member; (3) to find the phase relationship between lift force and structural motion; (4) to find the effect of the vibration amplitude of the structure on the lift coefficient; (5) to find the damping factor; (6) to find the instability parameters and their stability limit; (7) to find the response induced by drag force; and (8) to find methods for suppressing flow-induced vibrations. These studies have supplied additional insight to the constituent parts of fluid/structure interactions.

In the area of mathematical modeling, most of the studies were confined to the response of a single structural member to cross-flow. The quasistatic model has successfully predicted galloping phenomena; no urgent need exists to improve the model. However, in vortex-excited motion, none of the mathematical models considered includes any analysis of the flow field. Much research is needed in this area. Very little discussion concerned breathing oscillations, or ovalling of the top of a cylindrical stack in a cross-flow, and the important problem of tube vibration in cross-flow through tube banks.

Other flow-induced structural vibration problems included the responses of buildings to wind excitation, of tall chimney structures to vortex shedding, of hydraulic gates to water flow, of vane bends to von Karman vortex trail, of check valves to water flow, of bridge decks to wind load, of bluff bodies to turbulence-boundary-layer pressure fluctuation, and of pipes conveying fluid. All these problems are discussed in the book. But the subject of flow-induced structural vibration is still in a relatively early stage of development. More intensive study is needed.

On the whole, this book is very informative. The reader will find an interesting discussion dealing with a broad spectrum of fluid/structure interaction problems. This beautifully produced volume should be of interest to researchers and engineers working in the general area of fluid/solid interaction.

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SHORT COURSES

FEBRUARY

MACHINERY VIBRATIONS COURSE

Dates: February 26 - March 1, 1979
Place: Shamrock Hilton Hotel, Houston, TX
Objective: This course of machinery vibrations will cover physical/mathematical descriptions, calculations, modeling, measuring, and analysis. Machinery vibrations control techniques, balancing, isolation, and damping, will be discussed. Techniques for machine fault diagnosis and correction will be reviewed along with examples and case histories. Torsional vibration measurement and calculation will be covered.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 - (312) 654-2254/654-2053.

MARCH

DIGITAL SIGNAL PROCESSING

Dates: March 6-8, 1979
Place: San Diego, California
Objective: This seminar covers theory, operation and applications -- plus additional capabilities such as transient capture, amplitude probability, cross spectrum, cross correlation, convolution coherence, coherent output power, signal averaging and plenty of demonstrations.

Contact: Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112 - (714) 268-7100.

MACHINERY VIBRATION SEMINAR

Dates: March 6-8, 1979
Place: New Orleans, Louisiana
Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. Frank Ralbovsky, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2349.

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 12-16, 1979
Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 19-23, 1979
Place: Phoenix, Arizona
Objective: Program emphasis is on how to increase productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists, and managers in industrial, governmental, and educational organizations. Electrical measurements of mechanical and thermal quantities are the major topics.

Contact: Peter K. Stein, 5602 E. Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

APPLICATIONS OF THE FINITE ELEMENT METHOD TO PROBLEMS IN ENGINEERING

Dates: March 12-16, 1979
Place: The University of Tennessee Space Inst.
Objective: This course will concentrate on material developed recently and provide a solid foundation for those relatively new to the field. Topics to be covered are the treatment of mixed type equations

which occur in transonic flow and wave motion in nonlinear solids, mixed type elements which are of importance in systems such as the Navier-Stokes equations, the interrelationship between the equation formation and the iterative scheme needed to solve any of the nonlinear equations, the advantages of hybrid elements, and the use of interactive graphics as an aid to problem solution.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631, Ext. 276 or 277.

DYNAMIC ANALYSIS OF STRUCTURES

Dates: March 19-22, 1979
Place: Detroit, Michigan
Objective: This seminar provides practical laboratory experience on getting good data and recognizing bad; diagnosing machinery with Vibration Spectrum Analyzers; solving structural problems with Transfer Function Analyzers; and demonstrations using state of the art FFT processors.

Contact: Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112 - (714) 268-7100.

APRIL

RANDOM VIBRATION AND ACOUSTIC NOISE

Dates: April 2-4, 1979
Place: The Open University, Milton Keynes, UK
Objective: The course will cover the following topics: descriptions of vibration and acoustic data; response properties of mechanical systems; probability and amplitude functions; correlation and spectral density functions; data collection, processing and analysis; applications to vibration prediction problems; applications to frequency response estimation problems; applications to multipath propagation problems; applications to source localization problems; and applications to structural and equipment failure prediction problems.

Contact: Dr. M.A. Dorgham, Faculty of Technology, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK - (0908) 63945.

VIBRATION AND SHOCK SURVIVABILITY

Dates: April 2-6, 1979
Place: Wilmington, Massachusetts
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 E. Olivos St., Santa Barbara, CA 93105 - (805) 963-1124.

MACHINERY VIBRATION MONITORING AND ANALYSIS SEMINAR

Dates: April 10-12, 1979
Place: New Orleans, Louisiana
Objective: This seminar will be devoted to the understanding and application of vibration technology to machinery vibration monitoring and analysis. Basic and advanced techniques with illustrative case histories and demonstrations will be discussed by industrial experts and consultants. Topics to be covered in the seminar include preventive maintenance, measurements, analysis, data recording and reduction, computer monitoring, acoustic techniques, misalignment effects, balancing, mechanical impedance and mobility, turbomachinery blading, bearing fault diagnosis, torsional vibration problems and corrections, and trend analysis. An instrumentation show will be held in conjunction with this seminar.

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

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: April 16-20, 1979
Place: UCLA
Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions;

evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct dynamics test programs.

Contact: P.O. Box 24902, Continuing Education in Engineering and Mathematics, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

MAY

MACHINERY VIBRATION ANALYSIS

Dates: May 8-10, 1979
Place: San Diego, California
Objective: The topics to be covered during this course are: fundamentals of vibration; transducer concepts; machine protection systems; analyzing vibration to predict failures; balancing; alignment; case histories; improving your analysis capability; managing vibration data by computer; and dynamic analysis.

Contact: Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112 - (714) 268-7100.

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: May 21-25, 1979
Place: The George Washington University
Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

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

JUNE

ACOUSTIC EMISSION STRUCTURAL MONITORING TECHNOLOGY

Dates: June 18-19, 1979
Place: Los Angeles, California
Objective: A theory and practice course covering each of the various facets of acoustic emission structural monitoring technology; basic phenomena, state-of-the-art applications, field testing experience, applicable codes and standards and instrumentation design and calibration. Includes "hands-on" operation of minicomputer and microcomputer acoustic emission systems. This course is designed for potential users of acoustic emission structural monitoring systems.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

PREVIEWS OF MEETINGS

INSTITUTE OF ENVIRONMENTAL SCIENCES TO HOLD SILVER JUBILEE ANNUAL MEETING

The Silver Jubilee Annual Meeting of the Institute of Environmental Sciences will be held at the Olympic Hotel, Seattle, Washington on April 30 through May 2, 1979. The Technical Program is shown on this page.

The Technical Program will be preceeded by a special Awards Presentation Breakfast and Keynote Address on Monday, April 30th. The Technical Program has been completed. The matrix of the program shows the "Learning To Use Our Environment" sessions as they are now scheduled. Some of the highlights within the major session topics of The Earth, The Space, The Induced, The Pollution and The DOD Reliability Environments are: CLIMATICS presentation by the Army Test & Evaluation Command; SPACE APPLICATIONS selected NASA Tech. Briefs; ENERGY sessions related to Earth and Space; ENVIRONMENTAL SCIENCE COLLEGE curriculum and student participation.

The Annual Banquet will be a Gala Silver Jubilee Celebration at Jack McGovern's Music Hall located several blocks from the Olympic Hotel meeting headquarters.

Institute of Environmental Sciences - 25th Annual Meeting
Olympic Hotel - Seattle, Washington
"LEARNING TO USE OUR ENVIRONMENTS"

Date		Space Environment	Earth Environment	Induced Environment	Pollution Environment	DOD Reliability Environment
Monday		• *Keynote*				
APRIL 30	A.M.		• *Exhibits*			
				• *Students Speak on Environmental Sciences*		
	P.M.	Space Power	Climatics	Electromagnetics	Waste Management	Management
		Energy	Acoustics	Electromagnetics	Pollution Control	Management
Tuesday						
MAY 1	A.M.	Remote Sensing	DOE Activities	Shock	Urban Air	DOD Specs
		Remote Sensing	Energy Resources	Transportation	Visibility	DOD Specs
	P.M.	Space Simulation	Solar-Standards	Screening	Air Resources	Design
		Cyrogenics	Solar-Collectors	Screening	Water Resources	Qualification
Wednesday						
MAY 2	A.M.	• *Exhibits*	• *Environmental Sciences Curriculum*		• *Environmental Stress Testing Handbook*	
	P.M.	Applications	Climatics	Solar-Materials	Effect Assessment	Growth
		Applications	Climatics	Solar-Coatings	Energy Alternates	Quality
		Applications	Climatics	Env. Litigation	Economics	Screening

ABSTRACTS FROM THE CURRENT LITERATURE

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

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ANALYSIS AND DESIGN

ANALYTICAL METHODS

79-199

Conservation Laws of Dynamical Systems Via D'Alembert's Principle

B. Vujanovic
Inst. of Information Sciences and Electronics, Univ. of Tsukuba, 300-31, Japan, Intl. J. Nonlin. Mech., 13 (3), pp 185-197 (1978) 18 refs

Key Words: Numerical analysis, Dynamic systems

In this note a method is studied for finding the conserved quantities of nonconservative holonomic dynamical systems. In contrast to the classical Noetherian approach, which is based upon the variational principle of Hamilton, the starting point in this note is based on the differential principle of D'Alembert which is equally valid for conservative and nonconservative systems. In the second part of this note, an attempt is made to employ symmetry properties as a vehicle for obtaining approximate solutions of linear and non-linear dynamical systems.

79-200

Element Spaces and Their Separation for Determining Bounds to Eigenvalues in Vibration Problems

E. Dokumaci
Faculty of Mech. Engrg., Ege Univ., Izmir, Turkey, J. Sound Vib., 59 (4), pp 557-566 (Aug 22, 1978) 2 figs, 3 tables, 10 refs

Key Words: Boundary value problems, Eigenvalue problems, Finite element technique

In this paper the concept of convergent eigenvalue trnasformations is introduced. The use of the finite element method for obtaining close upper and lower bounds to the eigenvalues of continuous systems in free vibration is discussed. Criteria are derived for the determination of the elements which give upper and lower bounds to the eigenvalues and their applicability is discussed with reference to some vibration problems of beams.

79-201

An Application of the Calculus of Variations to the Existence and Bifurcation of Periodic Motions in a Class of Nonlinear Dynamical Systems

T.L. Johnson
Ph.D. Thesis, Cornell Univ., 183 pp (1978)
UM 7817762

Key Words: Normal modes, Nonlinear systems

The calculus of variations is applied to study particular periodic motions in a class of two degree-of-freedom nonlinear conservative dynamical systems. Motions which pass through points of maximum potential energy (zero kinetic energy) and maximum kinetic energy (zero potential energy) have been called nonlinear normal modes. Among all such normal modes for a given system, the class of modes which provide Jacobi's Principle of Least Action with a true minimum are considered in this work. All of the results presented in this work are independent of the value of system total energy. Thus, large nonlinear effects may be considered. Illustrative examples are included throughout.

79-202

On a Stationarity Principle for Non-Conservative Dynamical Systems

T.M. Atanackovic
Faculty of Technical Sciences, Univ. of Novi Sad, 21000 Novi Sad, Yugoslavia, Intl. J. Nonlin. Mech., 13 (3), pp 139-143 (1978) 8 refs

Key Words: Equations of motion, Variational methods

A stationarity principle for non-conservative, holonomic dynamical systems is formulated. It is based on the notion of Gâteaux directional derivative. Its relation to the classical and variational principle with non-commutative variational rules is discussed.

79-203

Computational Aspects of Time Integration Procedures in Structural Dynamics. Part 2: Error Propagation

K.C. Park and C.A. Felippa
Structures Lab., Lockheed Palo Alto Res. Lab., Palo Alto, CA, J. Appl. Mech., Trans. ASME, 45 (3), pp 603-611 (Sept 1978) 9 figs, 10 refs

Key Words: Dynamic structural analysis, Error analysis

The propagation of computational error in the direct time integration of the equations of structural dynamics is inves-

tigated. Asymptotic error propagation equations corresponding to the computational paths are derived and verified by means of numerical experiments.

79-204

The Inertial-Damping Collocation Approximation (IDCA) for Uncoupling Fluid-Structure Interaction Problems

F. DiMaggio, D. Ranlet, H. Bleich, and M. Baron
Dept. of Civil Engrg. and Engrg., Mechanics, Columbia Univ., New York, NY 10027, Mech. Res. Comm., 5 (4), pp 207-210 (1978) 4 refs

Key Words: Interaction: structure-fluid

The doubly asymptotic approximation is presented and applied in modal form. In this paper, an uncoupling scheme is exhibited which, in addition to approaching exact steady state solutions at zero and infinite frequencies, as the DAA does, permits matching exact solutions at two intermediate frequencies.

NONLINEAR ANALYSIS

79-205

Analytical Experimental Correlation of a Nonlinear System Subjected to a Dynamic Load

J.C. Anderson and S.F. Masri
Univ. of Southern California, Los Angeles, CA, ASME Paper No. 78-PVP-37

Key Words: Beams, Pipes (tubes), Nonlinear systems

Analytical and experimental studies of the dynamic response of a system with geometric and material nonlinearity are described. Dynamic excitation consists of sinusoidal and impulsive base acceleration. The dynamic system, which is representative of many practical cases involving mechanical equipment and piping systems, consists of a cantilever beam with a gapped support at the free end. The material nonlinearity considers both the effect of yielding and the effect of strain rate on the initial yield level.

NUMERICAL ANALYSIS

79-206

Numerical Investigation of Nonlinear Mode Coupling of Elastic Waves

N. Sugimoto
Dept. of Mech. Engrg., Faculty of Engrg. Science, Osaka Univ., Toyonaka, Osaka 560, Japan, J. Acoust. Soc. Amer., 64 (4), pp 1190-1195 (Oct 1978) 4 figs, 8 refs

Key Words: Numerical analysis, Elastic waves, Initial value problems, Mode coupling

Initial value problems are solved numerically for the equations proposed in a previous paper for describing the nonlinear mode coupling of elastic waves. Mode coupling arising as a result of nonlinear interactions between the main pulse and disturbance is investigated.

VARIATIONAL METHODS

79-207

Computational Aspects of Time Integration Procedures in Structural Dynamics. Part 1: Implementation

C.A. Felippa and K.C. Park
Structures Lab., Lockheed Palo Alto Res. Lab., Palo Alto, CA, J. Appl. Mech., Trans. ASME, 45 (3), pp 595-602 (Sept 1978) 1 fig, 4 tables, 12 refs

Key Words: Dynamic structural analysis, Error analysis

A unified approach for the implementation of direct time integration procedures in structural dynamics is presented. Two key performance assessment factors are considered, viz., computational effort and error propagation.

CRITERIA, STANDARDS, AND SPECIFICATIONS

79-208

Noise in Ships

J.C. Johnson
Applied Res. Lab., The Pennsylvania State Univ., University Park, PA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 39-44, 4 figs, 3 tables

Key Words: Standards and codes, Ships, Noise reduction, Vibration control

The matter of setting specific standards for allowable noise levels in commercial ships must necessarily be a cooperative venture between the state of ship registration, the shipbuilder, and the shipowner. While this is obviously a delicate and cumbersome background in which to work, there have been impressive advances in the development of realistic goals for maximum permissible noise levels and practical techniques for noise and vibration control during the past fifteen years. This paper presents a summary of such goals and techniques as agreed upon for the protection of ship safety, and the health and comfort of ship occupants.

79-209

Aircraft Noise

R.E. Russell

Noise Technology, Boeing Commercial Airplane Co., Seattle, WA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27 - Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 29-38, 23 figs

Key Words: Regulations, Aircraft noise

An overview of current and proposed commercial airplane noise regulations is presented. Noise contributions from the individual components of a typical airplane powered by high bypass ratio engines are described followed by a discussion of the constituent elements of the airplane noise reduction engineering process. A brief status report is provided on the state of technology of each of the major airplane noise components. The scope of a required national research effort is indicated, as implied in recently proposed aircraft noise regulatory requirements.

79-210

Regulation and Control of Ground Vehicle Noise

R. Hickling

Fluid Dynamics Res. Dept., General Motors Res. Labs., Warren, MI, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27- Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 19-28, 7 figs, 57 refs

Key Words: Regulations, Ground vehicles, Noise generation

During the past decade, regulations were enacted in the USA that are beginning to have a significant effect on the noise of newly-manufactured transportation and construction vehicles. At the same time user preferences are continuing to play a role in the control of vehicle noise. The development of the regulations is reviewed here and possible future trends are discussed. To meet the regulatory standards and to satisfy user needs, it is necessary to develop an increased understanding of the mechanisms of noise generation in vehicles. Current knowledge of individual noise mechanisms is reviewed.

SURVEYS AND BIBLIOGRAPHIES

79-211

Automobile Impact Tests. Volume 2. 1973-August-1978 (A Bibliography with Abstracts)

E. Kenton

National Tech. Information Service, Springfield, VA, 163 pp (Aug 1978)

NTIS/PS-78/0892/6GA

Key Words: Bibliographies, Collision research (automotive)

This bibliography covers impact tests for car design, for studying passenger safety, and for design and safety of highway structures and barriers. Impact tests for car deisgn include areas such as collision research, research on standard vehicles and their crashworthiness, damage susceptibility, and automobile-body-structural studies for design of bumpers, doors, and front end. Passenger safety studies include accident research, injury severity, biomechanics, kinematics and modeling; anthropomorphic test dummy usage; design of safety devices for occupant protection, such as belts and air bags; and pedestrian safety studies. Impact tests of highway structures and barriers include design and safety studies on median and traffic barriers, crash cushions, breakaway signs and luminaire supports, guardrails, bridge rails, and like structures. This updated bibliography contains 157 abstracts, 28 of which are new entries to the previous edition.

79-212

Improved Passenger Equipment Evaluation Program Technology Review

A.L. DeVilliers, A.L. Dow, R.B. Watson, and R. Uher

Unified Industries, Inc., Alexandria, VA., Rept. No. FRA/ORD-78/38, 89 pp (May 1978)

PB-283 659/1GA

Key Words: Rail transportation, Vibration isolation, Suspension systems (vehicles), Reviews

The status of two foreign rail technologies is analyzed in this second of four semiannual reports. The two technologies are Trucks and Carbody Construction. Trucks are discussed from the viewpoint of their function in the rail vehicle suspension system. This function consists of vehicle guidance, vibration isolation, vehicle support, and traction and braking. Several current trucks are reviewed, followed by a discussion of radial-axle trucks. Carbody construction is reviewed from 1965 forward. French technology, 1965 to 1975, is covered, followed by discussion of two modern trains, the TGV

(France) and the ET 403 (Germany). Advanced technologies are then discussed, principally construction with aluminum extrusions followed by a short discussion of composite materials.

79-213

Literature Review-Elastic Constants for Airport Pavement Materials

J.L. Green
Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. FAA-RD-76-138, 141 pp (Mar 1978)
AD-A056 195/1GA

Key Words: Reviews, Airports, Aircraft landing areas, Pavements, Vibratory techniques

A literature review was made to support an ongoing study to develop a method for evaluating airport pavements based on the layered elastic theory and using constants as determined from vibratory test results. The review covered the definitions and relations between elastic constants, methods used by various researchers for measuring elastic constants, and values of elastic constants found (or used) by various researchers. The review also included a study to determine the sensitivity of pavement responses to arbitrarily assigned values of elastic constants and an examination of the relationships between vibrator test results and elastic constants.

79-214

A Review of Dynamic Response of Composites

T.C. Lee and T.C.T. Ting
Dept. of Materials Engrg., Illinois Univ. at Chicago Circle, Chicago, IL, Rept. No. AMMRC-TR-78-20, 141 pp (Apr 1978)
AD-A055 739/7GA

Key Words: Reviews, Composite structures, Transient response, Harmonic waves

The purpose of this project was to review the state of the art on the dynamic response of composites and to suggest possible future research directions. More than three hundred papers are reviewed and compiled at the end of this report. The existing theories of the dynamic repsonse of composites are summarized. The harmonic waves and transient waves in, and the experiments on, composites are discussed. The differences between various theories and possible future research directions are presented.

79-215

Balancing Machines Reviewed

D.G. Stadelbauer
Schenck Trebel Corp., Deer Park, Long Island, NY 11729, Shock Vib. Dig., 10 (9), pp 3-9 (Sept 1978) 6 figs, 4 refs

Key Words: Reviews, Balancing machines

This article reviews the history of balancing machines and compares various types currently in use.

79-216

Transonic Blade Flutter: A Survey of New Developments

M.F. Platzer
Naval Postgraduate School, Monterey, CA 93940, Shock Vib. Dig., 10 (9), pp 11-20 (Sept 1978) 1 fig, 77 refs

Key Words: Reviews, Blades, Flutter

This paper is a review of current work in transonic blade flutter research. Aerodynamic theory and flow models are summarized. Analyses of supersonic and transonic flow past oscillating cascades, blade row interactions, and three-dimensional unsteady flow through rotating annular cascades are given. Experimental studies are described.

79-217

Recent Progress in the Dynamic Plastic Behavior of Structures. Part I

N. Jones
Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Shock Vib. Dig., 10 (9), pp 21-33 (Sept 1978) 71 refs

Key Words: Reviews, Dynamic plasticity, Beams, Fiber composites, Modal analysis, Transverse shear deformation effects, Rotatory inertia effects, Interaction: structure-fluid

This two-part article reviews the literature on the dynamic plastic response of structures published since 1975. The review focuses on the behavior of such simple structural components as beams, plates, and shells subjected to dynamic loads that cause extensive plastic flow of material. Part 1 deals with recent work on the behavior of ideal fiber-reinforced beams, higher modal response of beams, and influence of transverse shear and rotatory inertia, approximate methods of analysis, rapidly heated structures, fluid-structure interaction, and dynamic plastic buckling. Part II contains a discussion of a few numerical studies on the

dynamic plastic response of structures and some miscellaneous comments and concluding remarks.

MODAL ANALYSIS AND SYNTHESIS

79-218

Mode Coupling in a Sound Channel with Range-Dependent Parabolic Velocity Profile

F.S. Chwieroth, A. Nagl, H. Uberall, R.D. Graves, and G.L. Zarur
Dept. of Physics, Catholic Univ., Washington, D.C. 20064, J. Acoust. Soc. Amer., 64 (4), pp 1105-1112 (Oct 1978) 7 figs, 27 refs

Key Words: Mode coupling

Pierce and Milder have developed a normal-mode theory with adiabatic separability for sound propagation in a channel whose environmental parameters depend not only on depth, but in a gradual fashion also on range. If range dependence is less gradual, the range equations become coupled and energy transfer between modes takes place. We have investigated this coupling phenomenon for a parabolic profile model with linear range dependence, using a method of approximate diagonalization for uncoupling the range equations, and have shown the energy transfer between modes to become significant for sufficiently large range variations of the profile.

79-219

Understanding Modal Analysis

S.C. Walgrave and J.M. Ehlbeck
Freightliner Corp., SAE No. 780695, 16 pp, 19 figs, 6 refs

Key Words: Modal analysis

This article reviews the fundamentals of vibration theory and discusses how the concepts used in describing the motion of single mass-spring-damper system can be extended to describe the motion of structures and systems via modal analysis. The material presented progresses from a discussion of a single mass-spring-damper system to modal properties of multidegree of freedom systems to frequency response and mode superposition methods. Although these techniques are not new, the intent is to present the fundamentals of modal analysis for those not already well acquainted with the theory and techniques involved.

COMPUTER PROGRAMS

GENERAL

(Also see No. 243)

79-220

Description of a Computer Program and Numerical Techniques for Developing Linear Perturbation Models from Nonlinear Systems Simulations

J.E. Dieudonne
Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-78710; L12114, 41 pp (July 1978)
N78-28865

Key Words: Computer programs, Mathematical models, Perturbation theory, Nonlinear systems

A numerical technique was developed which generates linear perturbation models from nonlinear aircraft vehicle simulations. The technique is very general and can be applied to simulations of any system that is described by nonlinear differential equations. The computer program used to generate these models is discussed, with emphasis placed on generation of the Jacobian matrices, calculation of the coefficients needed for solving the perturbation model, and generation of the solution of the linear differential equations. An example application of the technique to a nonlinear model of the NASA terminal configured vehicle is included.

79-221

SRS: A Program for Computing and Matching Shock Response Spectra

M.R. Posehn
Lawrence Livermore Lab., California Univ., Livermore, CA, Rept. No. UCID-17735, 32 pp (Feb 10, 1978)
N78-28382

Key Words: Shock response spectra, Computer programs

A program named SRS is available on the T-DAC computer, at B836, and at B854/858 for the calculation of shock response spectra of pulse waveforms used in environmental testing. The capabilities of the program are described and its use is illustrated by an example.

79-222

Dynamic Finite Element Analysis of Two Compact Specimens

A.S. Kobayashi, Y. Urabe, S. Mall, A.F. Emery, and W.J. Love

Univ. of Washington, Seattle, WA, ASME Paper No. 78-Mat-17

Key Words: Computer programs, Crack propagation, Steels, Finite element technique

A dynamic finite element code was used to compute the dynamic stress intensity factors and crack arrest stress intensity factors which are related to the crack run-arrest responses in longitudinal and transverse wedge-loaded compact specimens machined from A533B and 1018 steels, respectively. Measured crack velocities were used to prescribe crack motions in the longitudinal and transverse wedge-loaded compact specimens under fixed wedge displacements.

79-223

Shake Testing of Vehicles Through Recorded Simulation Control Scheme. Volume 1

A.B. Boghani, K.M. Captain, and R.B. Fish

Foster-Miller Assoc., Inc., Waltham, MA, Rept. No. TAC-7622-VOL-1, TARADCOM-TR-12347-VOL-1, 113 pp (Jan 1978)

AD-A056 543/2GA

Key Words: Computerized simulation, Trucks, Interaction: vehicle-terrain, Computer programs

Recorded simulation control scheme described in this report is a method of providing realistic inputs to a vehicle shaker. The scheme involves generating axle displacement records by simulating motion of the vehicle operation on the specified terrain, storing the records in memory of a control system and using them to provide input signals to the vehicle shaker. A terrain-tire-vehicle model needed to simulate vehicle motion is developed. The vehicle selected for the model is a typical three axle military truck. The tires are represented by any of these independently developed models: point contact model, rigid tread band model, fixed footprint model and adaptive footprint model.

79-224

Recorded Simulation Control Scheme. User's Manual. Volume II

A.B. Boghani and R.B. Fish

Foster-Miller Assoc., Inc., Waltham, MA, Rept. No. TAC-7622-VOL-2, TARADCOM-TR-12347-VOL-2, 186 pp (Jan 1978)

AD-A056 544/0GA

Key Words: Computerized simulation, Trucks, Interaction: vehicle-terrain, Computer programs, Manuals and handbooks

Recorded simulation control scheme is a method of generating realistic inputs for vehicle shake tests. The scheme involves generating axle displacement records by simulating vehicle operation over the specified terrain, storing the records in memory of a control system and using them to provide input signals to the vehicle shaker. This user's manual provides instructions on implementing the scheme.

79-225

Prediction of Satellite Substructure Response to Acoustic Excitation. Volume 1: Application of the Dynamic Statistical Approach to the Prediction Study of the Dynamic Characteristics of Satellite Substructure Assemblies and of their Vibratory Behavior in a Random Diffuse Acoustic Environment. Final Report (Application De L'Approche Dynamique Statistique A L'Etude Previsionelle Des Characteristiques Dynamiques D'Assemblages de Sous-Structures de Satellites et de Leur Comportement Vibratoire Dans Une Ambiance Acoustique Aleatoire Diffuse)

A. Bourgine, R. Tretout, P. Monteil, and J.P. Bobichon

Direction Scientifique de la Resistance des Structures, Office National d'Etudes et de Recherches Aerospatiales, Paris, France, Rept. No. RTS-5/3277; ESA-CR(P)-1048, 240 pp (Dec 1977)

(In French)

N78-28497

Key Words: Spacecraft, Acoustic response, Statistical analysis, Vibration response, Acoustic excitation

The possibility of predicting the vibratory behavior, in a vast spectral domain, of satellite structures consisting of assemblies of various substructures in a random diffuse acoustic environment was studied. In the theoretical part, in which the dynamic statistical approach is used, the problem of solving assembly problems also with respect to forecasting structural characteristics is treated. The calculation of vibration transfer between structure and equipment is dealt with. Experiments performed with a satellite substructure consisting of three elements are described. The software used in the study is presented.

79-226

Prediction of Satellite Substructure Response to Acoustic Excitation. Volume 2: User and Programming Manual of the PRA Software for the Cascade Assembly of Substructures and for the Calculation of the Response of a Structure to an Acoustic Environment. Final Report (Manuels D'Utilisation et De Programmation du Logiciel Pra D'Assemblage en Cascade de Sous-Structures et de Calcul de la Response D'une Structure a Un Environnement Acoustique)

P. Monteil and G. LeDeunff

Direction Scientifique de la Resistance des Structures, Office National d'Etudes et de Recherches Aerospatiales, Paris, France, Rept. No. RTS-6/3277; ESA-CR(P)-1048, 191 pp (Jan 1978)

(In French)

N78-28498

Key Words: Computer programs, Spacecraft, Acoustic response

The PRA program permits the semi-automatic calculation of the acoustic response of a structure from its dynamic characteristics: it takes into account the prinicpal arithmetic operations of the spectra, the trajectories, and also the calculation of certain predictive functions. It provides a link with the programs SET and ASS. A complete description of the PRA computer program, including input file, output file, user commands, necessary fields, possible values, error messages and meanings, and memory requirement is given. All subroutines of the program are listed.

79-227

Prediction of Satellite Substructure Response to Acoustic Excitation. Volume 3: User and Programming Manual of the ASS Program for the Calculation of Dynamic Characteristics of an Assembly of Two Substructures from the Dynamic Characteristics of the Two Separate Substructures. Final Report (Manuels D'Utilisation et de Programmation Du Logiciel ASS De Calcul Des Caracteristiques Dynamiques D'un Assemblage de Deux Sous-Structures Connaissant les Caracteristiques Dynamiques de Ces Dernieres Prises Isolement)

P. Monteil

Direction Scientifique de la Resistance des Structures, Office National d'Etudes et de Recherches Aerospatiales, Paris, France, Rept. No. RTS-7/3277; ESA-CR(P)-1048, 85 pp (Jan 1978)

(In French)

N78-28499

Key Words: Spacecraft, Acoustic response, Computer programs

The ASS program permits the calculation of the dynamic characteristics of a structure consisting of an assembly of two substructures. The calculation is performed (IRIS 80) with machine readable data (spectra and frequencies) obtained from tests. The number of data is optimized using nymetric and hermicity properties of certain matrices. One calculation is performed in one run of the data processing routines, but several calculations can be performed during the same job. A complete description of the program, including files used, memory requirement, command cards, error messages, and meanings, is given. All subroutines of the program are listed.

79-228

Prediction of Satellite Substructure Response to Acoustic Excitation. Volume 4: User and Programming Manual of the SET Program for the Calculation of Structure-Equipment Transfer. Final Report (Manuels D'Utilisation et de Programmation du Logiciel SET de Calcul de Transfert Structure-Equipment)

P. Monteil

Direction Scientifique de la Resistance des Structures, Office National d'Etudes et de Recherches Aerospatiales, Paris, France, Rept. No. RTS-8/3277; ESA-CR(P)-1048, 50 pp (Jan 1978)

(In French)

N78-28500

Key Words: Computer programs, Spacecraft equipment repsonse, Acoustic excitation

The SET program permits the calculation of the acoustic response of equipment mounted on a structure from machine readable data, in random order, obtained from tests. The calculation is performed (IRIS 80) in one run and it is up to the user to define and to collect on input cards the test data to be used for data processing. A complete description of the program, including files used, memory requirements, on input cards the test data to be used for data processing. A complete description of the program, including files used, memory requirements, command cards, error messages, and meanings, is given.

79-229

User's Guide for a Modular Flutter Analysis Software System (Fast Version 1.0)

R.N. Desmarais and R.M. Bennett

Langley Res. Center, NASA, Langley Station, VA,

Rept. No. NASA-TM-78720, 147 pp (May 1978)
N78-28101

Key Words: Computer programs, Flutter, FAST (computer program)

The use and operation of a group of computer programs to perform a flutter analysis of a single planar wing are described. This system of programs is called FAST for Flutter Analysis System, and consists of five programs. Each program performs certain portions of a flutter analysis and can be run sequentially as a job step or individually. FAST uses natural vibration modes as input data and performs a conventional V-g type of solution. The unsteady aerodynamics programs in FAST are based on the subsonic kernel function lifting-surface theory although other aerodynamic programs can be used. Application of the programs is illustrated by a sample case of a complete flutter calculation that exercises each program.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 208, 209, 210, 274, 276, 330, 344, 357, 373, 374)

79-230

Preliminary Study of the Effect of the Turbulent Flow Field Around Complex Surfaces on Their Acoustic Characteristics

W.A. Olsen and D. Boldman
Lewis Res. Center, NASA, C'eveland, OH, Rept. No. NASA-TM-78944; E-9691, 32 pp (1978)
N78-28886

Key Words: Noise generation, Turbulence, Fluid-induced excitation

Fundamental theories for noise generated by flow over surfaces exist for only a few simple configurations. The role of turbulence in noise generation by complex surfaces should be essentially the same as for simple configurations. Examination of simple-surface theories indicates that the spatial distributions of the mean velocity and turbulence properties are sufficient to define the noise emission. Measurements of these flow properties were made for a number of simple and complex surfaces. The configurations were selected because of their acoustic characteristics are quite different.

79-231

Basic Mechanisms of Noise Generation by Fluids

R.C. Chanaud
Dyna-Systems, Inc., Denver, CO, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 45-50, 4 figs

Key Words: Noise generation, Fluid-induced excitation

The basic equations for the production of sound by fluid motion are related. Model techniques that result from these equations help to clearly define the nature of a noise problem on a complex machine and the dynamic variables that determine its magnitude. Noise control at the source, accomplished by lessening the magnitude of these variables, is discussed.

79-232

Noise Calculation on the Basis of Vortex Flow Models

J.C. Hardin
Langley Res. Center, NASA, Hampton, VA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 59-68, 9 figs, 21 refs

Key Words: Sound waves, Wave propagation

A technique for noise calculation on the basis of vortex flow models is described. The "reflection principle" was extended to the whole class of potential flows which may be solved by the method of images. Several examples of such noise calculations are included.

79-233

Revised Simplified Formulae for Calculating the Speed of Sound in Sea Water

D. Ross
Saclant ASW Research Centre, La Spezia, Italy, Rept. No. SACLANTCEN-SM-107, 15 pp (Mar 15, 1978)
AD-A056 556/4GA

Key Words: Underwater sound, Sound propagation

Recently-published data on the speed of sound in water as a function of temperature, salinity, and pressure reveal significant differences from former data. In the present memorandum a number of simple equations are developed from the new data. Sound speeds calculated using these

equations are shown to be in agreement with the new data to within 0.1 m/s over a wide range of temperatures and salinities at atmospheric pressure, and to within 0.5 m/s at great depths. It is shown that the disagreement between experiments is of such magnitude as not to merit equations any more precise than those developed herein.

79-234

Evaluation of the Annoyance Due to Helicopter Rotor Noise

H. Sternfeld, Jr. and L.B. Doyle

Boeing Vertol Co., Philadelphia, PA, Rept. No. NASA-CR-3001, 74 pp (June 1978)

N78-24903

Key Words: Helicopter rotors, Noise, Human response, Noise tolerance

A program was conducted in which 25 test subjects adjusted the levels of various helicopter rotor spectra until the combination of the harmonic noise and a broadband background noise was judged equally annoying as a higher level of the same broadband noise spectrum. The subjective measure of added harmonic noise was equated to the difference in the two levels of broadband noise. The test participants also made subjective evaluations of the rotor noise signatures which they created. The test stimuli consisted of three degrees of rotor impulsiveness, each presented at four blade passage rates. Each of these 12 harmonic sounds was combined with three broadband spectra and was adjusted to match the annoyance of three different sound pressure levels of broadband noise.

79-235

Factory Noise: Its Generation and Control

T.A. Dear

Acoustics & Noise Control, E.I. du Pont de Nemours & Company, Wilmington, DE, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 7-18, 7 figs, 2 tables, 11 refs

Key Words: Machinery noise, Noise reduction, Industrial facilities

Case histories and new tools for the control of machinery noise are presented.

79-236

Air-Abrasive Blast Noise

J.E. Sneckenberger

Mech. Engrg. and Mechanics, West Virginia Univ., Morgantown, WV, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 131-136, 13 figs, 2 tables

Key Words: Nozzles, Noise generation, Noise reduction

The objective of the research reported in this paper was to reduce the noise level produced by the air-abrasive discharge through the nozzle of an industrial blast system without appreciably affecting the existing surface improvement performance. Experimental development using noise reduction techniques extrapolated from aerodynamic jet noise abatement methods led to several improved nozzle and add-on silencer designs. The experimental facilities developed for measurement of sound pressure level, abrasive flow rate and abrasive velocity are described.

79-237

Diffraction Effects of Baffles on Acoustic Directivity Patterns

W.J. Hughes

Applied Res. Lab., Pennsylvania State Univ., University Park, PA, Rept. No. TM-77-304, 171 pp (Nov 12, 1977)

AD-A056 292/6GA

Key Words: Baffles, Acoustic diffraction

The acoustic diffraction phenomena which occur at the edges of a baffle is investigated both experimentally and theoretically. Various sharp-edged and cylindrical-edged baffles were constructed in which geometry, impedance, and structural resonances were controlled. Data were obtained as a function of incident pressure, angle of incidence, and frequency, using two transducers, one in the far field and one on the baffle surface. Also investigated is the effect of placing small scattering barriers at the edge of rigid baffle surfaces.

RANDOM

(Also see No. 288)

79-238

The Energy Envelope of a Randomly Excited Non-Linear Oscillator

J.B. Roberts

School of Engrg. and Appl. Sciences, Univ. of Sussex, Brighton BN1 9QT, UK, J. Sound Vib., 60 (2), pp 177-185 (Sept 22, 1978) 10 refs

Key Words: Random excitation, Oscillators, Non-linear theories

The exact differential equation for the energy envelope of a randomly excited non-linear oscillator is approximated by a time-averaging procedure. The resulting equation shows that, if the damping is sufficiently light and the correlation time scale of the excitation process is sufficiently small, the energy envelope can be approximated as a one-dimensional Markov process, governed by an appropriate Fokker-Planck equation. The physical significance of the various terms in this latter equation is emphasized.

79-239

The Effect of a Feedback Operation on the Probability Distribution of a Non-Stationary Non-Linear Vibratory System with an Arbitrary Random Input

M. Ohta, M. Nishimura, and S. Hiromitsu
Dept. of Electrical Engrg., Hiroshima Univ., Hiroshima, Japan, J. Sound Vib., 59 (4), pp 533-555 (Aug 22, 1978) 4 figs, 1 table, 13 refs

Key Words: Random excitation, Statistical analysis

This paper provides a new method for the unified statistical treatment of the output probability expressions, when an arbitrarily distributed and correlated random signal is passed through a class of time-variant vibratory system having a non-linear element in the forward path and a linear element of finite memory type in the feedback path. The statistical expressions derived can reflect various effects of the feedback operation due to the linear element into the second and higher expansion terms of series solutions. The method essentially depends on an introduction of the multivariate statistical Laplace expansion method which includes the statistical Lagrange expansion method reported previously. The experimental results obtained by means of digital simulation are in good agreement with theory.

79-240

Response of a Multidegree-of-Freedom System to Nonstationary Random Excitation

S.F. Masri
Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, J. Appl. Mech., Trans. ASME, 45 (3), pp 649-656 (Sept 1978) 10 figs, 1 table, 15 refs

Key Words: Multidegree of freedom systems, Random excitation

This paper presents an analytical study of the covariance kernels of a damped linear two-degree-of-freedom system that is subjected to spatially correlated nonstationary stochastic excitation consisting of modulated white noise. A unit-step intensity function and an exponential function, resembling the envelope of a typical earthquake, are considered in conjunction with a propagating disturbance. Results of the analysis are used to determine the dependence of the peak transient mean-square response of the system on the uncoupled frequency ratios, mass ratios, wave propagation speed, shape of the intensity function, and system damping.

SEISMIC

(Also see Nos. 256, 355, 377)

79-241

Structural Walls in Earthquake-Resistant Buildings. Dynamic Analysis of Isolated Structural Walls - Parametric Studies

A.T. Derecho, S.K. Ghosh, M. Iqbal, G.N. Freskakis, and M. Fintel
Construction Tech. Labs., Portland Cement Assoc., Skokie, IL, Rept. No. PCA-SER-1587, NSF/RA-78005, 233 pp (Mar 1978)
PB-283 705/2GA

Key Words: Earthquake resistant structures, Walls, Parameter identification technique

The results of a parametric study to identify the most significant structural and ground motions parameters, as these affect the dynamic inelastic response of isolated structural walls, are presented. The parameters examined include intensity, duration and frequency content of the ground motion and the following variables relating to the structure: fundamental period, yield level in flexure, yield stiffness ratio, unloading and reloading parameters characterizing the decreasing stiffness hysteretic loop assumed for the model, damping, stiffness, and strength taper along height of structure, and base fixity condition.

79-242

Architectural Design of Building Components for Earthquakes

G.M. McCue, A. Skaff, and J.W. Boyce
MBT Associates, San Francisco, CA, Rept. No. TX-11-601, NSF/RA-780159, 233 pp (1978)
PB-283 571/8GA

Key Words: Earthquake resistant structures, Structural members, Seismic response

Review of the dynamic principles governing site and building response provides the basis for a conceptual model of building and component interaction during earthquakes. This conceptual model consists of: a four-part Dynamic Model, which describes the various elements of a building, their interactive relationships during earthquakes, and the effect of their interaction on overall building response; and, the dynamic environment, which describes the nature of the seismic motions that a component will be subjected to in a particular location of a building. Any given component will have its own particular dynamic environment. The conceptual model is then applied to architectural design procedures: two studies illustrate the design of building components according to the principals of the model: - in a case study of an enclosure wall system, design objectives are defined, alternative design concepts studied, and the wall designed to meet the given seismic design criteria; - a study of selected ceiling and partition systems defines generic ceiling systems and partitions, discusses their possible responses to input motions, identifies potentially damaging responses, and suggests means of achieving compatibility between systems.

79-243

Dynamic Response of Reinforced Concrete Structures

S.K. Sharma

Construction Engrg. Res. Lab. (Army), Champaign, IL, Rept. No. CERL-SR-M-243, 28 pp (July 1978)
AD-A056 627/3GA

Key Words: Earthquake resistant structures, Reinforced concrete, Finite element technique, Beam-columns, Computer programs

Beam-column and plane stress finite elements were described for an inelastic analysis of plane RC structures under earthquake-type ground motion. Material nonlinearities in the beam-column finite element were taken into account by considering cyclic inelastic deformations throughout the element. The plane stress finite element allowed for cracking of the element in tension. These elements were incorporated in the DRAIN-2D computer program, which was determined to be flexible and efficient. Preliminary results for simple structures showed that, with the addition of new finite elements described in this report, this program would be very useful for practical investigations of RC structures.

SHOCK

(Also see Nos. 221, 302, 316, 333, 351)

79-244

Explosion Effects and Properties. Part II. Explosion Effects in Water

M.M. Swisdak, Jr.

White Oak Lab., Naval Surface Weapons Center, Silver Spring, MD, Rept. No. NSWC/WOL/TR-76-116, 112 pp (Feb 22, 1978)
AD-A056 694/3GA

Key Words: Underwater explosions, Explosion effects

This report updates an earlier report. The tables, charts, and graphs contained herein show the effects of explosives detonated underwater.

79-245

Response of Shallow-Buried Structures to Blast Loads

S.A. Kiger and J.P. Balsara

Army Engineer Waterways Experiment Station, Vicksburg, MS, 14 pp (June 1978)
AD-A056 455/9GA

Key Words: Underground structures, Hardened installations, Blast response, Vulnerability, Nuclear explosions

Hardness levels of shallow-buried structures for vulnerability studies are primarily obtained from calculations using an undamped single-degree-of-freedom (SDOF) elastic-plastic model. Recent and past tests on buried structures are discussed.

79-246

A Study of the Flow Field Induced by an Explosion Near the Ground

J.H.B. Anderson

Defence Research Establishment, Suffield Ralston, Alberta, Canada, Rept. No. DRES-TN-424, 27 pp (Apr 1978)
AD-A056 665/3GA

Key Words: Explosions, Shock waves

An experiment is described in which an attempt was made to investigate the phenomenology of an airburst explosion, in particular those phenomena related to the interaction of the blast wave with the ground beneath the charge. The experiment conducted under free-field conditions is described.

79-247

Crash Testing of Nuclear Fuel Shipping Containers

R.M. Jefferson and H.R. Yoshimura

Sandia Labs., Albuquerque, NM, Rept. No. SAND-77-1462, 50 pp (Dec 1977)
N78-28467

Key Words: Shipping containers, Transportation effects, Collision research (automotive)

In an attempt to understand the dynamics of extra severe transportation accidents and to evaluate state-of-the-art computational techniques for predicting the dynamic response of shipping casks involved in vehicular system crashes, a program was initiated to investigate these areas. Computational methods for predicting the effects of the accident environment were utilized and the damage incurred by a container as the result of such an accident was calculated. The second phase involves the testing of 1/8 scale models of transportation systems. Through the use of instrumentation and high-speed motion photography, the accident environments and physical damage mechanisms were studied in detail. After correlating the results of these first two phases, a full scale event involving representative hardware was conducted. Results indicate that both computational techniques and scale modeling are viable engineering approaches to studying accident environments and physical damage to shipping casks.

79-248
Performance of Advanced Passive Restraints
R.W. Carr
Dynamic Science, Inc., SAE Paper No. 780679, 8 pp, 2 figs, 2 tables

Key Words: Collision research (automotive), Safety restraint systems

A program to integrate advanced restraint systems into a small production vehicle and to evaluate their performance over a variety of impact conditions is described. The vehicle selected for this program was the 1976 Volvo 244 and the restraint systems used were those developed for the Minicars RSV.

79-249
Frontal-Crash-Testing Techniques (Beitrag zur Problematik des Frontal-Crash-Tests)
J. Fischer
Friedenstrasse 76, 7542 Schomberg 4, Automobiltech. Z., 80 (9), pp 407-413 (Sept 1978) 11 figs, 10 refs
(In German)

Key Words: Collision research (automotive), Automobiles, Testing techniques

Frontal crash testing techniques for automobiles are investigated. A comparison of the 0°-crash (vertical against a fixed barrier) at 30 mph and a 30°-angled crash against a fixed barrier shows that the 30° crash is preferable.

TRANSPORTATION

(See No. 247)

PHENOMENOLOGY

COMPOSITE

(Also see No. 214)

79-250
A Comparative Study on Transverse Elastic Wave Propagation in Laminates: Subsonic Case
R.J. Alfrey and R.A. Scott
Dept. of Appl. Mech. and Engrg. Science, The Univ. of Michigan, Ann Arbor, MI 48109, J. Sound Vib., 60 (2), pp 239-250 (Sept 22, 1978) 8 figs, 31 refs

Key Words: Layered materials, Composite structures, Periodic response, Moving loads

Many approximate theories have been advanced for the analysis of elastic wave propagation in layered composites. Most comparisons between these theories and the linear theory of elasticity have been restricted to cases of harmonic wave propagation. In this paper, such comparisons are made in a somewhat more demanding context: namely, the steady-state response of an unbounded periodically layered medium to a moving subsonic load, simulated by a self-equilibrating body force. Both the load speed and load thickness are adjustable, lending a valuable flexibility to the study.

79-251
The Resonance-Impedance Method as a Means for Quality Control of Advanced Fibre Reinforced Plastic Structures
R.J. Schliekelmann
Technological Centre, Royal Netherlands Aircraft Factories, Fokker, Schiphol-Oost, In: AGARD, Non-destructive Inspection Relationships to Aircraft Design and Material, 16 pp (Mar 1978)
N78-26475

Key Words: Fiber composites, Laminates, Resonant frequencies, Impedance

The principles of the resonance frequency/impedance method are discussed. Detection of laminate thickness variations, matrix density variations, and delaminations is considered along with application of the method to inspection of advanced composite structures.

DAMPING

79-252

Equivalent Viscous Damping of Elasto-Plastic Systems Under Sinusoidal Loading

R.G. Merritt

Construction Engrg. Res. Lab. (Army), Champaign, IL, Rept. No. CERL-SR-M-242, 27 pp (July 1978) AD-A057 225/5GA

Key Words: Viscous damping

This report addresses the possibility of establishing a simple algorithm applicable to structural design that would provide information on a nonlinear structural system based on information on a linear damped structural system. Two variables were considered -- geometric stiffness and resonant amplitude.

ELASTIC

(See No. 311)

FATIGUE

(See No. 269)

FLUID

(Also see Nos. 230, 290, 294)

79-253

Analysis of Preflutter and Postflutter Characteristics with Motion-Matched Aerodynamic Forces

H.J. Cunningham

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TP-1232; L-12109, 33 pp (July 1978)
N78-28481

Key Words: Flutter, Aerodynamic loads

The development of the equations of dynamic equilibrium for a lifting surface from Lagrange's equation is reviewed and restated for general exponential growing and decaying oscillatory motion. Aerodynamic forces for this motion are obtained from the three-dimensional supersonic kernel function that is newly generalized to complex reduced frequencies. Illustrative calculations were made for two flutter models at supersonic Mach numbers. Preflutter and postflutter motion isodecrement curves were obtained.

79-254

Noise Radiated from Hydraulic Circuits

H.R. Martin

Univ. of Waterloo, Waterloo, Ontario, Canada, ASME Paper No. 78-DE-23

Key Words: Hydraulic equipment, Noise generation

This paper presents experimental data showing the distribution of vibration and radiated noise from a typical hydraulic circuit. Relationships between component surface movement and the resultant Lp levels can be seen, together with the excitation of component casing modes. The effect of increase of hydraulic load is also demonstrated.

SOIL

79-255

Torsional Soil-Structure Interaction Effects

P.C.-K. Lam

Ph.D. Thesis, The Univ. of Akron, 204 pp (1978)
UM 7819074

Key Words: Interaction: soil-structure, Torsional response

Closed-form solutions expressing the torsional soil-structure interaction effects are developed by a semi-inverse method with the aid of Laplace and Hankel transforms. Numerical results are obtained by iteration of a structural model subject to the El-Centro, California earthquake of May 18, 1940 and an ideal ramp-sinusoidal ground acceleration. Interaction effects are evaluated by comparing the free-field response spectrum with the output acceleration response spectrum. For the soil-structure mechanism investigated, interaction effects evaluated by an existing equivalent spring-dashpot solution are found to be in good agreement with those determined from the closed-form continuum formulations of the torsional interaction problem. In addition, numerical results indicated that the torsional soil-structure interaction effects are significant in the seismic analysis of structural buildings.

79-256
Soil Structure Interaction in an Arbitrary Seismic Environment
A.J. Gomez-Masso
Ph.D. Thesis, The Univ. of Texas at Austin, 311 pp (1978)
UM 7817641

Key Words: Interaction: soil-structure, Seismic excitation

A plane strain method for soil-structure interaction analysis valid for a completely general seismic excitation with an approximation for 3-dimensional geometry has been developed. This method consists of the superposition of the free field motions and the interaction motions, and it is carried out by the computer program CREAM developed for the CDC 7600 System.

79-257
Propagation and Decay of Waves in Porous Media
Y. Mengi and H.D. McNiven
The Middle East Tech. Univ., Ankara, Turkey, J. Acoust. Soc. Amer., 64 (4), pp 1125-1131 (Oct 1978) 1 fig, 7 refs

Key Words: Wave propagation, Porous materials, Fluid-filled media

A study is made of the propagation of wave fronts in two types of fluid-filled porous media, anisotropic and isotropic. The characteristic equation governing wave propagation velocities in anisotropic media is obtained by using the motion of surfaces of discontinuity.

79-258
Comparison of Soil Moduli Obtained from Non-Destructive Dynamic Testing and Constitutive Equations
W.H. Highter
Dept. of Civil and Environmental Engrg., Clarkson College of Tech., Potsdam, NY, Rept. No. AFOSR-TR-78-1056, 42 pp (1978)
AD-A055 670/4GA

Key Words: Aircraft landing areas, Pavements, Nondestructive testing, Constitutive equations

This report describes an effort to determine the degree of agreement between moduli of airfield granular base materials as measured by a nondestructive (vibratory) pavement evaluation procedure and as predicted from constitutive equations that relate moduli to states of stress induced in the granular material by aircraft loading.

VISCOELASTIC

79-259
Uniaxial Pulse Propagation in a Viscoelastic Medium Governed by a Boltzmann Superposition Integral
J.E. Cole, III and R. Barakat
Dept. of Mech. Engrg., Tufts Univ., Medford, MA 02155, J. Sound Vib., 59 (4), pp 567-576 (Aug 22, 1978) 5 figs, 11 refs

Key Words: Wave propagation, Viscoelastic media

The problem of pulse propagation through a linear viscoelastic medium is formulated by using the Boltzmann superposition integral. The relaxation times and coefficients which describe the modulus of a real material are therefore used directly in the formulation. The basic equation governing the wave motion is a partial integro-differential equation. The resulting initial value problem is solved via Laplace transforms and the asymptotic behavior of the solution is discussed. Pulse shapes for a real material (monodispersive polystrene) are calculated by using the numerical procedure of Dubner and Abate to evaluate the inverse Laplace transforms.

EXPERIMENTATION

BALANCING
(See No. 215)

DIAGNOSTICS

79-260
Acoustic Emission Monitoring During Rupture Test of Pressure Vessel and Laboratory Fracture Test
N. Ohtsuka, M. Nakano, and H. Ueyama
Chiyoda Chemical Engrg. and Construction Co., Ltd., Kanagawa, Japan, ASME Paper No. 78-PVP-18

Key Words: Diagnostic techniques, Acoustic techniques, Pressure vessels

The purpose of this paper is to try to make clear the correlation between acoustic emission (AE) monitoring during a hydropressurizing rupture test of a model vessel and during its simulating laboratory tests, discussing the relationship between AE and fracture mechanics.

79-261
Testing the Behavior of Structures
R.W. Lally
PCB Piezotronics, Inc., Buffalo, NY, TEST, 40 (1/2), pp 10-15 (Aug/Sept 1978) 8 figs

Key Words: Diagnostic techniques

Technology for monitoring mechanical, hydraulic, pneumatic and acoustic structures is summarized. It involves the nature and behavior of models, exciters, sensors, and computers.

79-262
Non-Destructive Inspection of Composite Materials for Aircraft Structural Applications
D.E.W. Stone
Structures Dept., Royal Aircraft Establishment, Farnborough, UK, In: AGARD, Non-destructive Inspection Relationships to Aircraft Design and Material, 18 pp (Mar 1978)
N78-26474

Key Words: Nondestructive tests, Fiber composites

The capabilities and limitations of various nondestructive inspection techniques to detect defects in fiber reinforced plastics are reviewed. Emphasis is placed on carbon fiber reinforced plastics. Difficulties in transferring laboratory techniques to prototype and production structural components are discussed along with problem areas. The role of acoustic emission in nondestructive inspection is considered.

79-263
Dynamic Nondestructive Testing of Materials
E.M. Uygur
Dept. of Metallurgical Engrg., Middle East Technical Univ., Ankara, Turkey, In: AGARD, Non-destructive Inspection Relationships to Aircraft Design and Materials, 43 pp (Mar 1978)
N78-26470

Key Words: Nondestructive tests

It is shown that damping or internal friction and frequency measurements can be used for flaw detection and quality control as well as measurements of physical properties. Application areas and instrumentation used are discussed.

79-264
Torsional Vibration Measurements in Preventive Maintenance of Rotating Machinery
H. Hershkowitz
New Jersey Div., Scientific-Atlanta, Inc., Randolph Park West, Route 10, Randolph Township, NJ 07801, 5th Natl. Conf. on Power Transmission, Proc., Chicago, IL, pp 161-169 (Nov 7-9, 1978) 12 figs, 3 tables, 5 refs

Key Words: Diagnostic techniques, Torsional vibration, Rotating structures, Machinery

This paper covers several aspects in the application of torsional vibration measurements to preventive maintenance of rotating machinery. The purpose of making such measurements is to verify that the system is performing to the criteria established by the manufacturer and that various components of the system are in proper working order.

79-265
Monitoring and Diagnosing Process Deviations in Marine Diesel Engines
H. Fagerland, K. Rothaug, and P. Tokle
Ship Research Institute of Norway, Inst. of Marine Engrs., Tech. Repts., Trans., Vol. 90, Ser. A, Pt. 7, pp 321-349 (1978) 13 figs, 14 refs

Key Words: Diagnostic techniques, Marine engines, Diesel engines

This paper describes the basic principles and recent experience with condition monitoring and fault diagnosis in marine diesel engines. A condition monitoring system forms the basis of a condition-based maintenance system. Three different condition monitoring systems are described. A survey of monitoring objectives as well as system layout and service experiences is given. A computer based diagnostic system is described. Both the theory behind the system and service experiences are given.

79-266
Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) - Test Cell Data Collection and Technical Support
J.V. Hickey
Bell Helicopter Textron, Fort Worth, TX, Rept. No.

USAAVRADCOM-TR-78-4, 469 pp (Aug 1977)
AD-A055 385/9GA

Key Words: Aircraft, Diagnostic techniques

This report covers the work accomplished in direct support to the AIDAPS *prototype development.* Work covered includes: test cell data for the AIDAPS developer to use in determining diagnostic and prognostic logic: collection of engineering data and technical support for AIDAPS integration into the UH-1 and AH-1 aircraft; and providing technical representation at AIDAPS development sites. AIDAPS was intended for use in Army aircraft and was intended to be used to reduce maintenance cost and improve flight safety by continuous in-flight monitoring of aircraft subsystems.

79-267

Potential Applications of Acoustic Emission Technology as a Nondestructive Evaluation Method for Naval Aviation Ground Support

W.F. Hartman
Knoxville, TN, Rept. No. NAEC-92-127, 19 pp (July 5, 1978)
AD-A056 650/5GA

Key Words: Aircraft, Aircraft equipment, Nondestructive tests, Diagnostic techniques, Acoustic techniques

This report presents the results of a survey of the potential use of acoustic emission monitoring for specific inspection and maintenance tasks in performance of ground support of Naval aircraft. One potential application, detecting corrosion in composites, is identified as worthy of an implementation study, since the U.S. Air Force has already proven feasibility. Feasibility studies are recommended for AE detection of defects in landing gear, cockpit canopies, fuel tanks, helicopter rotor blades, retreaded tires and fan blades. Research and development programs are suggested for bearing noise analysis, weld inspection, and damage assessment in composites.

79-268

JT9D Engine Diagnostics. Task 2: Feasibility Study of Measuring In-Service Flight Loads

P.G. Kafka, M.A. Skibo, and J.L. White
Boeing Commercial Airplane Co., Seattle, WA, Rept. No. NASA-CR-135395; D6-44664, 68 pp (Oct 15, 1977)
N78-27124

Key Words: Aircraft engines, Diagnostic techniques

The feasibility of measuring JT9D propulsion system flight inertia loads on a 747 airplane is studied. Flight loads background is discussed including the current status of 747/JT9D loads knowledge. An instrumentation and test plan is formulated for an airline-owned in-service airplane and the Boeing-owned RA001 test airplane. Technical and cost comparisons are made between these two options. An overall technical feasibility evaluation is made and a cost summary presented. Conclusions and recommendations are presented in regard to using existing inertia loads data versus conducting a flight test to measure inertia loads.

79-269

An Ultrasonic Nondestructive Test Procedure for the Early Detection of Fatigue Damage and the Prediction of Remaining Life

J.M. Carson
Ph.D. Thesis, Drexel Univ., 94 pp (1978)
UM 7817991

Key Words: Nondestructive tests, Ultrasonic techniques, Fatigue (materials)

The goal of nondestructive testing may be simply expressed as the detection and complete specification (size, shape, orientation, etc.) of flaws. This is seldom possible, however. The most dangerous flaw is one that is crack-like or that serves as a crack initiation site. A procedure to detect and estimate fatigue damage occurring as such a site is reported.

EQUIPMENT

79-270

Frequency Axis Normalization Techniques for Rotating Machinery Analysis

J. Flink
Rockland Systems Corp., West Nyack, NY, S/V, Sound Vib., 12 (9), pp 4-6 (Sept 1978) 6 figs

Key Words: Spectrum analyzers

A spectrum analyzer is described by means of which the user can zoom and frequency normalize at the same time. This occurs because the frequency translator uses an all-digital architecture and an algorithm that makes the center frequency and bandwidth of the translator proportional to the sampling rate clock. (Not every all-digital translator possesses these properties). Another advantage of all-digital implementation is that it is drift-free, and, of course, preserves high accuracy and dynamic range regardless of the frequency magnification employed.

FACILITIES

79-271

Dynamic Analysis of Electrohydraulic Shaking Tables

D. Rea, S. Abedi-Hayati, and Y. Takahashi

Earthquake Engrg. Res. Center, California Univ., Richmond, CA, Rept. No. UCB/EERC-77/29, NSF/RA-770529, 66 pp (Dec 1977)

PB-282 569/3GA

Key Words: Electrohydraulic shakers, Mathematical models, Earthquakes, Simulation

The frequency response characteristics of two shaking tables have been determined experimentally. The lighter table, weighing 2,000 lb (900 kg), was used primarily to determine the effects of a resonant structure on a shaking table's frequency response. The heavier table, weighing 100,000 lb (45,300 kg), was used primarily to determine the effects of foundation compliance on a shaking table's frequency response. Mathematical models were formulated for both tables, and the models were refined by adjusting parameters to obtain the best correspondence between the computed and experimental frequency responses. The mathematical models were then used to study the effects of a resonant structure and of foundation compliance on the frequency responses of shaking tables and on the ability of shaking tables to reproduce earthquake-type motions.

INSTRUMENTATION

(Also see No. 275)

79-272

Quality Control of Thermosets

R.L. Hassel

Instrument Products Div., DuPont Co., Wilmington, DE, Indus. Res., pp 160-163 (Oct 1978) 4 figs, 7 refs

Key Words: Vibration analyzers

Dynamic mechanical analyzer (DuPont 981) is described which provides information on the degree of cures of thermosets and permits assessment of their ultimate properties. Its operation is based on the relationship between oscillation frequency and elastic modulus. Driving force applied to overcome amplitude decay is used to calculate energy absorption term, tan δ.

TECHNIQUES

(Also see Nos. 249, 288, 380)

79-273

Modal Confidence Factor in Vibration Testing

S.R. Ibrahim

Old Dominion Univ., Norfolk, VA, J. Spacecraft Rockets, 15 (5), p 313 (Sept/Oct 1978) 3 figs, 4 tables, 4 refs

Key Words: Vibration tests, Modal tests

The modal confidence factor (MCF) is a number calculated for every identified mode for a structure under test. The MCF varies from 0.00 for a distorted nonlinear, or noise mode to 100.0 for a pure structural mode. The theory of the MCF is based on the correlation that exists between the modal deflection at a certain station and the modal deflection at the same station delayed in time. The theory and application of the MCF are illustrated by two experiments. The first experiment deals with simulated responses from a two-degree-of-freedom system with 20%, 40%, and 100% noise added. The second experiment was run on a generalized payload model. The free decay response from the payload model contained 22% noise.

79-274

Acoustic Impedance Measurement Using Sine Sweep Excitation and Known Volume Velocity Technique

R. Singh and M. Schary

Carlyle Compressor Co., Carrier Corp., Syracuse, NY 13221, J. Acoust. Soc. Amer., 64 (4), pp 995-1003 (Oct 1978) 8 figs, 2 tables, 14 refs

Key Words: Acoustic impedance, Measurement techniques

The direct determination of acoustic impedance requires the measurements of both pressure and volume velocity, but the latter in general cannot be measured directly. Thus, other means must be adopted to bypass this measurement problem. This paper presents two methods which utilize excitation of a system with known volume velocity. This, along with measured pressure response, provides both magnitude and phase of impedance as continuous functions of frequency. The first method uses a convertible acoustic horn driver for excitation. The second method uses for excitation an electrodynamic shaker driven piston which carries an accelerometer.

79-275

Investigation of Torsional Vibrations on Commercial Vehicles - Part 2 (Torsionsschwingungsuntersuchungen bei Nutzfahrzeugen)

E. Lauster and W. Maier
Spiegelberg 5, 7759 Immenstaad, Automobiltech. Z., 80 (9), pp 417-421 (Sept 1978) 23 figs
(In German)

Key Words: Measurement techniques, Measuring equipment, Torsional vibrations, Trucks, Gearboxes

Measurement techniques and equipment used for measurement of vibrations by gearbox manufacturers are presented. Most critical vibrations originate outside the gearbox and the authors discuss which vibrations influence the gearbox. The input shaft and connections to the output flange are preferred measuring points, however, measurements can also be taken at other points of the drive line, e.g., engine, the drive shaft, or the axle drive. The method is illustrated in an example measuring and analyzing truck vibrations.

79-276
Measurements of the Frequency Dependence of Normal Modes
C.T. Tindle, K.M. Guthrie, G.E.J. Bold, M.D. Johns, D. Jones, K.O. Dixon, and T.G. Birdsall
Physics Dept., Univ. of Auckland, Auckland, New Zealand, J. Acoust. Soc. Amer., 64 (4), pp 1178-1185 (Oct 1978) 8 figs, 9 refs

Key Words: Underwater sound, Normal modes, Measurement techniques

An experiment using a vertical array to detect acoustic normal modes in shallow water is described. A high signal-to-noise ratio was achieved by the use of pseudorandom pulse sequences to modulate the projector. Wide bandwidth signals and a tunable acoustic source enabled the frequency dependence of normal modes to be measured and results are in good agreement with the theory. An improved method of extracting the signal present in a single mode is described and used to examine pulse shapes and frequency spectra of individual modes.

COMPONENTS

SHAFTS

79-277
Proposed Design Procedure for Transmission Shafting Under Fatigue Loading
S.H. Loewenthal
Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-78927; E-9667, 10 pp (1978)
N78-26444

Key Words: Shafts, Power transmission systems, Design techniques, Fatigue life

A new standard for the design of transmission shafting is reported. Computed was the diameter of rotating solid steel shafts under combined cyclic bending and steady torsion is presented. The formula is based on an elliptical variation of endurance strength with torque exhibited by combined stress fatigue data. Fatigue factors are cited to correct specimen bending endurance strength data for use in the shaft formula. A design example illustrates how the method is to be applied.

79-278
Demonstration of a Supercritical Power Transmission Shaft
M.S. Darlow, A.J. Smalley, and D.P. Fleming
Mechanical Technology, Inc., 968 Albany-Shaker Rd., Latham, NY 12110, 5th Natl. Conf. on Power Transmission, Proc., Chicago, IL, pp 207-212 (Nov 7-9, 1978) 11 figs, 4 refs

Key Words: Shafts, Power transmission systems, Aircraft engines, Critical speeds

Operation of a very flexible power transmission shaft has been demonstrated in a laboratory environment through four bending critical speeds. Supercritical shafting has long been considered for use in transmitting power, particularly in aircraft applications where component size and weight is a principal design factor.

BEAMS, STRINGS, RODS, BARS

79-279
Bond Graphs, Normal Modes and Vehicular Structures
D.L. Margolis
Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, Vehicle Syst. Dyn., 7 (1), pp 49-63 (Jan 1978) 8 figs, 7 refs

Key Words: Ground vehicles, Beams, Bond graph techniques, Normal modes

Bond graph modeling techniques are used to represent the normal mode dynamic behavior of uniform Bernoulli-Euler beams. The independent beam models are then coupled together to form a distributed system structure of arbitrary complexity. The resulting overall system bond graph is shown to yield the governing state equations in a straightforward manner. Then, through proper ordering of the equations, the normal modes and frequencies of the coupled system are easily obtained. This procedure is demonstrated for a vehicle A-frame structure. In addition, the bond graph model is modified to include primary and secondary suspension dynamics.

79-280

Optimal Design of Uniform Non-Homogeneous Vibrating Beams

V.K. Gupta and P.N. Murthy
Dept. of Aeronautical Engrg., Indian Inst. of Tech., Kanpur 208016, India, J. Sound Vib., 59 (4), pp 521-531 (Aug 22, 1978) 5 figs, 10 refs

Key Words: Flexural vibration, Beams, Optimization

The problem of optimal design of uniform non-homogeneous beams undergoing transverse vibrations is investigated. The optimal longitudinal modulus distribution is sought to produce the maximum value of fundamental frequency for a beam of given mass and geometry. Governing equations are obtained by using an optimal control theory approach. Solutions are presented for hinged-hinged, free-clamped, clamped-clamped and clamped-hinged end-conditions.

79-281

A Simplified Method for Calculating the Natural Frequency of Valve Superstructures

L.I. Ezekoye
Westinghouse Nuclear Energy Systems, Pittsburgh, PA, ASME Paper No. 78-PVP-4

Key Words: Cantilever beams, Beams, Natural frequencies

An approximate and simplified method for calculating the maximum static deflection and the natural frequency of cantilevered beam type designs such as valve operators under earthquake excitation is presented. This method was developed in response to the need to evaluate the pertinent parameters during the design phase so as to assure that the final assembly meets the minimum natural frequency requirement for the equipment specification.

79-282

Dynamic Fracture Testing Using Shear Force Measurements on Double Cantilever Beam Specimens

C. Chow
Ph.D. Thesis, The Univ. of Rochester, 179 pp (1978)
UM 7818251

Key Words: Cantilever beams, Dynamic tests, Fracture properties

Investigating the dynamic critical stress intensity factor versus the crack propagation velocity of Ti-6A1-4V alloy and AISI 1018 cold rolled steel is the main purpose of this work. The dynamic critical stress intensity factor K_{ID}, can only be measured experimentally and the rapidly wedged double cantilever beam model is a unique method for K_{ID} measurements. A new experimental technique was introduced for achieving the dynamic fracture testing.

79-283

Vibration of Cantilever Sandwich Beams

N.A. Rubayi and S. Suresh
Southern Illinois Univ., Carbondale, IL, ASME Paper No. 78-DE-20

Key Words: Cantilever beams, Sandwich structures, Natural frequencies

In this paper, the authors develop theoretical analysis for obtaining the natural frequencies of vibration of cantilever sandwich beams subjected to gravity forces only. The method of minimizing the total energy of the system was used for determining the frequencies. In addition, experimental work was carried out on various types of cantilever sandwich beams to correlate these theoretical analyses.

79-284

High Frequency Flexural Vibration of Thick Rectangular Bars and Plates

H.M. Nelson
Dept. of Mech. Engrg., Univ. of Sydney, Sydney 2006, Australia, J. Sound Vib., 60 (1), pp 101-118 (Sept 8, 1978) 3 figs, 12 tables, 24 refs

Key Words: Flexural vibration, Rectangular plates, Bars, Rotatory inertia effects, Transverse shear deformation effects

With the Timoshenko equation for the bar and the Mindlin equation for the plate Bolotin's solution fitting technique is employed to provide estimates of natural frequencies and approximate modal shapes for finite bars and plates. Unlike Bolotin's boundary region solutions, which satisfy only the Euler-Bernoulli equation in the case of the beam and the Lagrange equation in the case of the plate, the solutions adopted here satisfy the Timoshonko equation for the bar

and the Mindlin equation for the plate.

79-285

Equivalent Linearization Modeling Applied to Nonlinear Distributed, Discrete Parameter Dynamic Cable Systems

R.A. McLauchlan
Ph.D. Thesis, The Univ. of Texas at Austin, 333 pp (1978)
UM 7817679

Key Words: Cables, Equivalent linearization method

Two equal linearization models are developed to describe the one-dimensional, vertical motion of hybrid nonlinear dynamical systems which consist of distributed parameter cable segments and discrete payload bodies. These models assume taut cable systems of moored or free floating configuration. Single frequency and random surface excitation cases are considered in the two models. The constitutive relation for the fluid drag involves a drag coefficient, and the sign and the square of the relative velocity between the cable or the payload and the surrounding fluid. The models are the first to consider the depth or the length variation of the tangential drag coefficient of the cable segments. The cable drag coefficient is calculated as a function of the local cable Reynolds number. The payload drag and inertia coefficients are calculated as functions of the local payload Strouhal number. The effects of local variation with velocity of the Reynolds number upon the cable drag and of the Strouhal number upon the payload drag are included in the single frequency and stochastic equivalent linearizations.

79-286

Superharmonic Vibrations of Order 3 in Stretched Strings

C.R. Raghunandan and G.V. Anand
Dept. of Electrical Communication Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Acoust. Soc. Amer., 64 (4), pp 1093-1100 (Oct 1978) 10 figs, 18 refs

Key Words: Strings, Superharmonic vibrations

Superharmonic vibrations of order 3 in stretched strings driven by a single-mode planar simple-harmonic force are investigated. After giving a few analytical results, the problem is thoroughly investigated numerically.

79-287

Transmission Line Vibrations

M.S. Dhotarad, N. Ganesan, and B.V.A. Rao
Dept. of Appl. Mech., Indian Inst. of Tech., Madras 600036, India, J. Sound Vib., 60 (2), pp 217-237 (Sept 22, 1978) 11 figs, 13 tables, 22 refs

Key Words: Transmission lines, Vibration dampers

Various forms of dampers are used to suppress vibrations in transmission lines. In the present paper a study has been made on vibrations of transmission lines having one or more dampers (Stockbridge type) near each end of the span for different cable lengths. An attempt is made here to study the effect of the location of dampers on maximum strains produced in the line. A comparative study of the maximum strains produced is also made for various wind power input assumptions. In addition, a finite difference method is used to find the natural frequency and a finite element method is used to find the natural frequency and mode shapes of the cable with and without a damper.

BEARINGS

79-288

Critical Inspection of Bearings for Life Extension

J.R. Barton, F.N. Kusenberger, and R.T. Smith
Southwest Res. Inst., San Antonio, TX, In: AGARD, Non-destructive Inspection Relationships to Aircraft Design and Material, 29 pp (Mar 1978)
N78-26472

Key Words: Ball bearings, Nondestructive tests, Testing techniques

Research with the object of developing more definite nondestructive inspection methods for improved reliability and quality of rolling element bearings is reviewed. Inspection of precision mainshaft and transmission bearing assemblies in which the individual components – outer race, rolling elements, (balls or rollers) and inner race – can be separated is emphasized. Results obtained with magnetic perturbation for flaw detection, Barkhausen Noise Analysis for residual stress assessment, and laser scattered radiation for surface finish and surface anomaly detection are presented. The critical inspection of bearings for life extension program concept is described.

79-289

Sound Noise Generated from Ball Bearing in High Speed Rotation

A. Nagamatsu and M. Fukuda
Tech. Dept., Tokyo Inst. of Tech., Tokyo, Japan, Bull. JSME, 21 (158), pp 1306-1310 (Aug 1978)

13 figs, 11 refs

Key Words: Ball bearings, Noise generation

The noise generated from ball bearings rotating vertically at high speeds up to 900 rps is measured and analyzed under many kinds of outer race supports. The results are compared with those at low speed rotation of about 50 rps. The main components of frequencies are composed of integral multiples of the rotating frequency as well as the natural frequencies of the outer races, the retainer, the rotor, and other parts of the rotating instrument.

BLADES

(Also see No. 216)

79-290

Experimental Study of the Aeroacoustic Mechanism of Rotor-Vortex Interactions

L.J. Leggat and T.E. Siddon

Defence Res. Establishment Atlantic Dartmouth, Nova Scotia, Canada, J. Acoust. Soc. Amer., 64 (4), pp 1070-1077 (Oct 1978) 14 figs, 13 refs

Key Words: Fans, Rotor blades, Noise generation, Vortex-induced vibration

The interaction of a naturally occurring vortex and an axial flow fan is investigated using cross-correlation and real-time observation techniques. The experiments indicate that the rotor-vortex interaction can be a significant source mechanism producing discrete-tone fan noise.

79-291

The Use of Skewed Blades for Ship Propellers and Truck Fans

N.A. Brown

Bolt Beranek and Newman, Inc., Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 201-208, 11 figs, 8 refs

Key Words: Fan blades, Marine propellers, Trucks

The noise performance of fans is improved by the application of skewed blade technology. Substantial reductions are achievable in the fluctuating aerodynamic forces and/or their radiation efficiency which yield both discrete frequency and continuous spectrum fan noise components. Examples are given of the design of a pair of engine cooling system fans for a heavy truck, one of which incorporated skewed blades.

79-292

Aeroelastic Characteristics of a Cascade of Blades

B.M. Rao and L. Kronenberger, Jr.

Texas A&M Res. Foundation, College Station, TX, Rept. No. AFOSR-TR-78-1027, 32 pp (Feb 1978) AD-A055 619/1GA

Key Words: Compressor blades, Flutter, Computer programs

A general aerodynamic theory and a numerical lifting surface technique based on velocity potential formulation for predicting aerodynamic derivatives of a cascade of blades in subsonic flow is described. The unsteady airload prediction method is applied for predicting the flutter boundaries of a single degree-of-freedom in torsion of a cascade of blades. Also, a general flutter program is developed for a two degree-of-freedom staggered cascade in subsonic flow. By utilizing an iterative procedure which permits frequency variation, the flutter frequency and the flutter speed of the reference airfoil are obtained as a function of cascade parameters. The computer program uses very efficient techniques in computing unsteady loads, the flutter frequency, and the flutter speeds.

79-293

Unsteady Blade Rows in High-Speed Flow

M. Kurosaka

General Electric Corporate Res. and Dev., Schenectady, NY, Rept. No. SRD-78-063, AFOSR-TR-78-1055, 158 pp (May 1978) AD-A055 620/9GA

Key Words: Compressor blades, Flutter

This report covers analytic investigations toward defining the instability boundaries of low incidence supersonic compressor flutter. A closed form expression was developed for the unsteady pressure distribution for a flat plate cascade in supersonic flow which is valid for a frequency range of practical interest. The work was extended to symmetric parabolic arc airfoils in cascade. Finite thickness was shown to have a first order effect on the flow field. Coupling the flow analysis with blade vibration modes indicates a bending instability in the frequency range of conventional design in general agreement with experimental data. An expression for the frequency of the unsteady pressure along the stationary rotor casing due to a vibrating blade row was derived. It indicates casing treatment tuned approximately to blade passing frequency and its harmonics should be effective in absorbing this unsteady flow energy.

79-294

Hydroelastic Variables Influencing Propeller and

Hydrofoil Singing

W.K. Blake, L.J. Maga, and G. Finkelstein
David W. Taylor Naval Ship R&D Center, Bethesda, MD, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 191-200, 14 figs, 17 refs

Key Words: Propeller blades, Turbine blades, Airfoils, Fluid-induced excitation, Noise generation

This paper summarizes the results of a series of experimental and analytical investigations of propeller singing. These basic studies are directed at determining the effects of both geometric and structural modifications on the flow-induced vibration of streamlined bodies. The phenomenon is examined within the framework of an analytical model of the excitation of transverse bending modes of the hydrofoil or propeller blade by speed-dependent hydrodynamic pressures.

COLUMNS

79-295
Flexural-Flexural Oscillations of Beck's Column Subjected to a Planar Harmonic Excitation

M.R.M. Crespo Da Silva
Dept. of Engrg. Science, Univ. of Cincinnati, Cincinnati, OH 45221, J. Sound Vib., 60 (1), pp 133-144 (Sept 8, 1978) 6 figs, 16 refs

Key Words: Columns, Flexural vibration, Harmonic excitation

The non-linearly coupled flexural-flexural oscillations of a non-conservative column with two independent load parameters are investigated by analytical methods with the objective of determining the quantitative and the qualitative behavior of the response. The column is subjected to a planar periodic distributed load whose frequency is near the eigenfrequency of its free bending oscillations. The analytical results of the analysis are compared with those obtained by numerical integration of a set of non-linear differential equations obtained by the application of Galerkin's method to the original equations.

CONTROLS

79-296
Use of Silencers is One Way to Reduce Vent, Valve Noise

J.K. Floyd
American Air Filter Co., Power, 122 (10), pp 64-67 (Oct 1978) 7 figs, 2 tables

Key Words: Valves, Noise reduction

When valve noise emissions exceed the designated criteria, a silencer generally is installed to attenuate the noise. Since vent noise has broadband frequency characteristics, a combination absorptive/reactive silencer is needed to effectively abate the noise. A typical silencer of this type includes a diffuser, inlet expansion chamber, and a dissipative muffler section. The purpose of the perforated inlet diffuser is to reduce steam velocity to subsonic levels and to lower thrust loadings. Low-frequency noise also is reduced when it is used in conjunction with an inlet expansion chamber. The remainder of the silencer is designed to absorb the higher-frequency sound components of the noise source using perforated metal tubes backed by long-strand gas-fbers.

CYLINDERS

79-297
Natural Vibrations of Orthotropic Cylinders Under Initial Stress

L.G. Bradford and S.B. Dong
Dept. of Mechanics and Structures, Univ. of California, Los Angeles, CA 90024, J. Sound Vib., 60 (2), pp 157-175 (Sept 22, 1978) 6 figs, 6 tables, 9 refs

Key Words: Cylinders, Layered materials, Orthotropism, Finite element technique, Natural frequencies

A finite element method is presented for the analysis of the vibratory characteristics of laminated orthotropic cylinders. The cylinder may have an arbitrary number of bonded elastic orthotropic cylindrical laminates, each with distinct thickness, density and mechanical properties. The formulation is capable of treating a three-dimensional initial stress state which is radially symmetric. Biot's incremental deformation theory is the basis for this study. A homogeneous, isotropic cylinder was analyzed and these numerical results were in excellent agreement with those from an exact analysis. Additional examples of two geometries of a three-layer composite and a sandwich cylinder are given to further illustrate the influence of the initial stress on the physical behavior of such structures.

DUCTS

(Also see No. 326)

79-298
Non-Linear Duct Acoustics and Its Application to Fan Noise
P.G. Vaidya
Boeing Commercial Airplane Co., Seattle, WA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 137-144, 2 figs, 12 refs

Key Words: Ducts, Fans, Noise generation, Nonlinear theories

It is often assumed that if the intensity of sound is not too high, linear acoustics is valid. This paper points out that this assumption is not justified in many cases of interest. The paper describes some of the clues to detect such nonlinear effects. This is followed by a case-study type analysis of the problem of Multiple Pure Tones (or the buzzsaw noise) which are radiated by aeroengine fans at supersonic tip speeds. The analysis illustrates several interesting features of nonlinear duct acoustics.

79-299
Flow-Generated Noise in Ducts
G.P. Succi
Massachusetts Inst. of Tech., Cambridge, MA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 145-152, 9 figs, 10 refs

Key Words: Ducts, Noise generation, Fluid-induced excitation

A turbulent jet was used to excite high order acoustic modes in a rectangular duct. The measured pressure spectra exhibited asymmetric singularities (pressure spikes) at the cutoff frequencies of the first few transverse modes. In the high frequency limit, where the number of propagating modes is large, the spectra resembles free space jet spectra. The spectra in these limits are determined by the acoustic response of the duct. A linear theoretical analysis, based on an isotropic model of the turbulent fluctuations, is developed to predict this spectra.

79-300
Effect of Flow on the Acoustic Impedance of a Duct Exit
M. Abrishaman
Spectral Dynamics Res. Corp., Cincinnati, OH, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 177-178, 8 figs, 12 refs

Key Words: Ducts, Acoustic impedance

An experimental investigation of the effect of mean flow on the acoustic impedance of a duct exit is reported. The impedance tube technique was used to measure the standing wave directly in front of the duct exit for both no flow and superimposed mean flow cases. A revision of the well-known transmission theory is used to calculate the reflection coefficient and complex acoustic impedance of the duct exit from the standing wave data.

79-301
Acoustic Energy Flux in Nonhomogeneous Ducts
W. Mohring
Max-Planck-Institut f. Stromungsforschung, 3400 Gottingen, Federal Republic of Germany, J. Acoust. Soc. Amer., 64 (4), pp 1186-1189 (Oct 1978) 1 fig, 10 refs

Key Words: Ducts, Sound propagation

A study of the scattering matrix S of sound waves propagating in an inhomogeneous duct which consists of two semi-infinite ducts, connected somehow, is undertaken. The scattering matrix contains all reflection and transmission coefficients from the nth into the mth propagating mode for upstream and downstream propagation. A mean flow is included.

79-302
Large Amplitude Wave Propagation in Exhaust Systems of Two-Stroke Engines
M.J. Murphy and D.L. Margolis
Lawrence Livermore Lab., Livermore, CA, SAE No. 780708, 16 pp, 15 figs, 8 refs

Key Words: Motorcycles, Exhaust systems, Ducts, Geometric effects, Wave propagation

The characteristics of large amplitude wave propagation in variable area ducts were investigated in order to gain a more thorough understanding of exhaust systems for power tuned two-stroke engines. An apparatus to simulate the power stroke of a two-stroke motorcycle engine was developed, using a stock Yamaha 360 MX barrel, cylinder head, piston and ring. In this way, a single pulse of pressurized air could be introduced into virtually any duct geometry. An oscilloscope trace of the subsequent exhaust pulse and duct interaction was photographed. The resulting pressure-time histories were used to experimentally evaluate the effects of several duct terminations on the shape and timing of the reflected wave. The investigation resulted in quantifying the effects of an orifice plate and converging cone termination and in determining the best termination for a Yamaha 360 MX engine.

79-303

A Cross Correlation Technique for Investigating Internal Flow Noise

A.V. Karvelis and G. Reethof

Res. and Dev. Division, The Babcock & Wilcox Co., Alliance, OH, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 153-160, 9 figs, 19 refs

Key Words: Ducts, Piping, Cross correlation technique

The correlation technique can be of great value in studies of internal flow noise. Considerable quantitative data can be extracted by cross correlation computations of dynamic wall pressure transducers in ducted flow applications. A series of correlation experiments, concerned with valve noise, are presented which serve to identify the advantages and limitations of cross correlation techniques. It is seen that the acoustic component of pressure in a turbulent flow duct can be obtained, and its power calculated in certain octave bands if the gross flow is nearly fully developed. This information can also be used to deduce the nature of the internal excitation of piping.

FRAMES, ARCHES

(Also see No. 326)

79-304

The Effect of Spatial Distribution on Dynamic Snap-Through

E.R. Johnson and I.K. McIvor

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Appl. Mech., Trans. ASME, 45 (3), pp 612-618 (Sept 1978) 5 figs, 2 tables, 10 refs

Key Words: Arches, Snap-through problems

The effect of the spatial distribution of impulsive loads on dynamic snap-through of a shallow circular arch is considered in detail. The Budiansky-Roth criterion is used to establish critical magnitudes of the load for many distributions by numerical integration of an approximate set of equations obtained by Galerkin's method. It is necessary to distinguish between snap-through on the initial oscillation (immediate) and snap-through occurring during a finite time of the response. Critical magnitudes for both cases are compared to a distribution independent lower bound obtained from an analysis of the critical points.

GEARS

(Also see No. 275)

79-305

Load Distribution Between Harmonic Drive Teeth

Y.P. Fuks and V.A. Finogenov

Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-Lib-Trans-1929; BR6919, 14 pp (Aug 1977) (Engl. transl. from Isv. Vyssh. Uchebn. Zaved. Machinostr. USSR, v. 12, pp 23-28 (1971)) N78-27431

Key Words: Gears

A harmonic tooth gear consisting of an immobile rigid gear, a rotating flexible gear and a cam generator are examined. A method is given for determining the load acting on the teeth of this harmonic gear.

MEMBRANES, FILMS, AND WEBS

79-306

On the Dynamic Snap-Out Instability of Inflated Non-Linear Spherical Membranes

N. Akkas

Dept. of Civil Engrg., Middle East Tech. Univ., Ankara, Turkey, Intl. J. Nonlin. Mech., 13 (3), pp 177-183 (1978) 4 figs, 12 refs

Key Words: Dynamic stability, Membranes (structural members)

The dynamic behavior of a spherical membrane, made of Mooney material and subjected to a uniform inflating step-pressure, is studied. Its phase-planes and nondimensional radius versus time curves are plotted for different values of the material constants. The conditions for dynamic snap-out instability are discussed. The relations between the static behavior of the membrane and the dynamic instability are pointed out.

PANELS
(Also see No. 333)

79-307
Effects of Environment, and Damping and Coupling Properties of Composite Laminates on Panel Flutter
S.N. Chatterjee and S.V. Kulkarni
Materials Sciences Corp., Blue Bell, PA, Rept. No. MSC/TFR/802/1151, AFOSR-TR-1066, 135 pp (Jan 1978)
AD-A055 753/8GA

Key Words: Panels, Composite structures, Geometric effects, Variable material properties, Flutter

The dynamic response of composite materials has been investigated with the objective of assessing the influence of the geometry and the material variables upon the vibrational frequencies and dispersion characteristics in composite laminates. These studies are an essential first step in assessing the response of a structure subjected to more complex transient and aerodynamic loads which are frequently experienced in aerospace structures.

PIPES AND TUBES
(Also see No. 260)

79-308
Vibro-Impact Responses of a Tube with Tube-Baffle Interaction
Y.S. Shin and J.A. Jendrzejczyk
Argonne National Lab., Argonne, IL, ASME Paper No. 78-PVP-20

Key Words: Tubes, Heat exchangers, Finite element technique

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

79-309
Dynamic Response of a Circular Cylinder Subjected to Liquid Cross Flow
S.S. Chen and J.A. Jendrzejczyk
Argonne National Lab., Argonne, IL, ASME Paper No. 78-PVP-15

Key Words: Circular cylinders, Tubes, Fluid-induced excitation

This paper describes a series of experimental investigations of single tubes subjected to cross flow. The experiments have two distinct features: the fluid damping in the lift and drag direction is measured as a function of reduced flow velocity, and the detailed response characteristics of the tube are obtained at various reduced flow velocities.

79-310
Cross Flow Induced Vibrations in a Tube Bank
D.S. Weaver and L.K. Grover
McMaster Univ., Hamilton, Ontario, Canada, ASME Paper No. 78-PVP-25

Key Words: Tubes, Fluid-induced excitation, Wind tunnel tests

This paper presents results from a wind tunnel investigation of a parallel triangular tube array in cross flow. Vortex shedding, turbulent buffeting, and fluid-elastic instability were observed.

79-311
Excitation Sources of the Flow-Induced Vibrations and Noise in Tube Bank Heat-Exchangers
Y.N. Chen
Research Lab. for Vibration and Acoustics, Sulzer Brothers Ltd., Winterthur, Switzerland, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 239-243, 7 figs, 21 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Vortex shedding, Acoustic resonance

This paper shows that there are several sources in addition to the Karman vortex shedding for the excitation of the acoustic resonance of the lateral fluid column at the shell side of the staggered tube bank heat-exchangers. The Karman vortex shedding is confined to the large tube spacings.

79-312
Pipes Supported at Both Ends Cannot Flutter
P.J. Holmes
Dept. of Theoretical and Appl. Mech., Cornell Univ.,

Ithaca, NY 14853, J. Appl. Mech., Trans. ASME, 45 (3), pp 619-622 (Sept 1978) 3 figs, 12 refs

Key Words: Pipes (tubes), Fluid-filled containers, Fluid-induced excitation, Flutter, Supports

A development of Liapunov's second method is used to study the local and global stability of the equilibrium positions adopted by a pipe conveying fluid. The pipe is simply supported at both ends and the analysis includes first-order (structural) nonlinearities. The major conclusion is that, contrary to the suggestions of linear analyses and of recent nonlinear numerical studies, sustained flutter motions are impossible in the case of the equation studied here.

79-313

An Experimental Study of Controlling the Sound Distribution in a Tube by Using Auxiliary Driving Sources

D.N. Dutt and B.S. Ramakrishna

Dept. of Electrical Communication Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Sound Vib., 60 (2), pp 267-271 (Sept 22, 1978) 5 figs, 14 refs

Key Words: Tubes, Active control, Sound propagation

This paper deals with an experimental method of actively controlling the sound distribution in a tube. A tube is driven by a simple harmonic sound source and the sound wave pattern inside the tube is controlled by applying external (control) sound sources which are electrically connected to the driving source. The control is achieved by changing the position and magnitude of the control sources. It is experimentally shown that it is possible to reduce the sound energy over a portion of the length of the tube without reducing at the same time the sound energy over the remaining length of the tube. Possible application to the control of transmission of noise through air-conditioning ducts is discussed.

79-314

Computing the Effect of Plastic Deformation of Piping on Pressure Transient Propagation

C.K. Youngdahl and C.A. Kot

Argonne National Lab., Argonne, IL, Rept. No. CONF-771120-20, 15 pp (1977)

N78-28490

Key Words: Piping systems, Computer programs, Fluid hammer

The computer program PTA-1 performs pressure transient analysis of large piping networks using the one dimensional method of characteristics applied to a fluid hammer formulation. The effect of elastic plastic deformation of piping on pulse propagation is included in the computation. Each pipe is modeled as a series of rings, neglecting axial effects, bending moments, and inertia. The fluid wave speed is a function of pipe deformation and, consequently, of position and time. Comparison with existing experimental data indicate that this simple fluid structure interaction model gives surprisingly accurate results for both pressure histories in the fluid and strain histories in the piping.

79-315

Design and Analysis of a Compact Array of (Class 1) Nuclear Piping for Large Anchor Movements and Seismic Supports

P.H. Stubley and T.W. Ricker

Sheridan Park Res. Community, Mississauga, Ontario, Canada, ASME Paper No. 78-PVP-29

Key Words: Piping systems, Cooling systems, Nuclear reactor components, Seismic response

The design of the system which supplied coolant to each fuel channel in the core of a CANDU reactor involves layout, sizing, and analysis of a tightly packed array of small-diameter pipes, called feeders. This paper describes the design and analysis of these feeders, with emphasis on two features.

PLATES AND SHELLS

(Also see No. 284)

79-316

Optimum Dynamic Design of Nonlinear Plates Under Blast Loading

J.M. Ferritto

Civil Engrg. Lab. (Navy), Port Hueneme, CA, Rept. No. CEL-TN-1518, 3 pp (Mar 1978)

AD-A055 601/9GA

Key Words: Plates, Blast loads, Design techniques, Computer programs, Blast resistant structures, Containment structures

A computer program was developed to determine the approximate nonlinear dynamic response of plates subjected to blast pressure loading. Given the explosive parameters and geometry of the plate, the program computes the blast environment and the structural resistance, mass, and stiffness of the plate and solves for the dynamic response. The program contains optimization subroutines that provide for automatic optimum design of least-cost plates. The report gives a user's guide and sample problems with data input and program output.

79-317

Force and Moment Impedance of Infinite Plates

S. Ljunggren

Swedish Council for Building Res., Stockholm, Sweden, Rept. No. ISBN-91-540-2824-8, 175 pp (1978)

PB-283 260/8GA

Key Words: Plates, Structural members, Impedance

The mechanical excitation of a plate with infinite extent is studied and described in terms of impedances. Two cases of excitation are treated: a force perpendicular to the plane of the plate and a moment with its axis in the plane of the plate. The force and moment respectively are applied to the plate over an indenter with finite dimensions. This indenter is for the most part considered as an infinitely stiff body, but some results are also obtained for a non-rigid indenter. In the first part of the theoretical analysis, the classical two-dimensional bending-wave theory is used for describing the reaction of the plate. Exact solutions in closed form are obtained for a stiff indenter with a circular area of contact. In the second part, the general three-dimensional theory is used for describing the reaction of the plate.

79-318

Parametric Resonance of Annular Plates Under Pulsating Uniform Internal and External Loads with Different Periods

J. Tani and T. Nakamura

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Sound Vib., 60 (2), pp 289-297 (Sept 22, 1978) 5 figs, 13 refs

Key Words: Plates, Pulse excitation, Parametric resonance

A study is made of the parametric instability of annular plates under pulsating uniform loads applied simultaneously along the inner and outer edges, with different periods. The instability regions for both principal and combination resonances are determined by using Galerkin's method in conjunction with the procedure proposed by Hsu. Calculations are carried out for a typical annular plate. It is found that the number of instability regions of the annular plate under pulsating uniform internal and external loads with different periods becomes twice that of the case where a pulsating uniform load acts along only the inner or outer edge. The effects of the static uniform load on the instability regions are found to be entirely different in respect to the loads applied along the inner and outer edges.

79-319

The Imaginary Part of Input Admittance: A Physical Explanation of Fluid-Loading Effects on Plates

P.W. Smith, Jr.

Bolt Beranek and Newman, Inc., 50 Moulton St., Cambridge, MA 02138, J. Sound Vib., 60 (2), pp 213-216 (Sept 22, 1978) 6 refs

Key Words: Plates, Fluid-induced excitation

Crighton has remarked on the surprising behavior of the input admittance (particularly the imaginary part or susceptance) of an infinite flat plate with heavy fluid loading: for a point force, it has asymptotically the sign appropriate to a spring, while for a line force the sign is that for a mass. However, it was observed in both cases that the susceptance is more nearly spring-like with than without fluid loading; in a vacuum, the susceptance vanished for the point source and is strongly massive for the line source. Physical explanations of these phenomena are found through an identity between the input admittance and a linear combination of time-averaged energy functions. The lower the wavenumber of a response component, the greater is its contribution to kinetic as compared to potential energy. The addition of fluid loading causes, through the virtual mass effect, a greater reduction of response at low wavenumber than at high. Hence, the fluid causes the input admittance to become more nearly spring-like for both types of source, as observed in the precise analysis.

79-320

Free Vibration of Circular Plates of Arbitrary Thickness

K.T.S.R. Iyengar and P.V. Raman

Dept. of Civil Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Acoust. Soc. Amer., 64 (4), pp 1088-1092 (Oct 1978) 2 tables, 11 refs

Key Words: Circular plates, Free vibration, Method of initial functions

Free vibration of circular plates of arbitrary thickness is investigated using the method of initial functions. State-space approach is used to derive the governing equations of the above method. The formulation is such that theories of any desired order can be obtained by deleting higher terms in the infinite-order differential equations. Numerical results are obtained for flexural and extensional vibration of circular plates. Results are also computed using Mindlin's theory and they are in agreement with the present analysis.

79-321

Deflection of a Very Flexible Spinning Disk Due to a Stationary Transverse Load

R.C. Benson and D.B. Bogy
Xerox Corp., Rochester, NY 14644, J. Appl. Mech., Trans. ASME, 45 (3), pp 636-642 (Sept 1978) 5 figs, 7 refs

Key Words: Disks (shapes), Rotation, Flexural vibration, Stiffness

This paper addresses the problem of steady deflection of a very flexible spinning disk due to transverse loads that are fixed in space. Membrane theory is used to approach this problem. The problem is also formulated with bending stiffness retained. The concentrated load problem is solved by use of a Fourier series expansion in the angular direction in conjunction with a numerical solution for the radial modes. Graphical results are presented for various values of the stiffness parameter and load location.

79-322

Dynamics of Viscoelastic Plate with Curved Boundaries of Arbitrary Shape

K. Nagaya
Dept. of Mech. Engrg., Faculty of Engrg., Yamagata Univ., Yonezawa, Japan, J. Appl. Mech., Trans. ASME, 45 (3), pp 629-635 (Sept 1978) 6 figs, 9 refs

Key Words: Circular plates, Plates, Hole-containing media, Viscoelastic properties, Forced vibration, Free vibration

This paper is concerned with vibration and transient response problems of viscoelastic plates with curved boundaries of arbitrary shape subjected to general dynamic loads. The results for free and forced vibration problems are given in generalized forms for arbitrary-shaped viscoelastic plates. As examples of this problem, the free vibration of a circular clamped viscoelastic plate with an eccentric hole and the dynamic response of a circular solid viscoelastic plate subjected to an eccentric annular impact load are discussed. Numerical calculations are carried out for both the problem, and experimental results are also obtained as an additional check of this study.

79-323

A General Mode Approach to Nonlinear Flexural Vibrations of Laminated Rectangular Plates

C.Y. Chia and M.K. Prabhakara
Dept. of Civil Engrg., Univ. of Calgary, Calgary, Alberta, Canada, J. Appl. Mech., Trans. ASME, 45 (3), pp 623-628 (Sept 1978) 8 figs, 3 tables, 16 refs

Key Words: Rectangular plates, Laminates, Flexural vibration

This paper is concerned with an analytical investigation of free flexural large-amplitude vibrations of rectangular composite plates. Solutions of the dynamic von Karman-type equations of these plates in conjunction with different boundary conditions are obtained by use of generalized double Fourier series and the method of harmonic balance. Numerical calculations for multimode vibrations of unsymmetric cross-ply and angle-ply plates having various material properties and lamination geometry were performed for all-clamped and all-simply supported stress-free edges. The present results indicate that the effect of coupling of vibrating modes on nonlinear frequencies is not appreciably significant for isotropic plates but considerably significant for composite plates, especially for clamped high-modulus laminates.

79-324

A Note on Transverse Vibrations of Rectangular Plates Subject to In-Plane Normal and Shear Forces

L. Diez, C.E. Gianetti, and P.A.A. Laura
Inst. of Appl. Mechanics, 8111 Base Naval Puerto Belgrano, Argentina, J. Sound Vib., 59 (4), pp 503-509 (Aug 22, 1978) 7 figs, 9 refs

Key Words: Rectangular plates, Flexural vibrations, Fundamental mode

To determine the fundamental frequency of transverse vibration of rectangular plates with edges elastically restrained against rotation and subjected to uniformly distributed in-plane normal and shear stresses, the plate displacement function is first expressed in terms of polynomial co-ordinate functions which identically satisfy the boundary conditions. A frequency equation is then generated by using a variational formulation. Numerical results for both the fundamental mode and the first fully antisymmetrical mode are given.

79-325

Analysis of Elastic-Plastic Plates and Shells Under Cyclic Loading

K.W. Neale and Z. Nazli
Universite de Sherbrooke, Sherbrooke, Quebec Canada, ASME Paper No. 78-PVP-11

Key Words: Plates, Shells, Elastic plastic properties

The behavior of elastic-plastic plate and shell structures under repeated loading is considered. The typical problem is formulated in incremental or "rate" form, and a variational method is applied to furnish an approximate solution in a step-wise fashion.

79-326

The Role of Median Surface Curvature in Large Amplitude Flexural Vibrations of Thin Shells

G. Prathap and K.A.V. Pandalai
Fibre Reinforced Plastics Res. Center, Indian Inst. of Tech., Madras 600036, India, J. Sound Vib., 60 (1), pp 119-131 (Sept 8, 1978) 11 figs, 23 refs

Key Words: Shells, Flexural vibration, Rings, Arches

General conclusions regarding the non-linear vibration of structural components like curved beams, rings and thin shells are derived from the study of two specific examples, the circular ring and shallow spherical shell. It is seen that with careful judgment in the use of mode shapes of one or more terms, modal equations help one to appreciate much better the physics of the problem, whereas sophisticated mathematical models tend to obscure this.

79-327

Dynamic Elastic-Plastic Response of a Containment Vessel to Fluid Pressure Pulses

G.A. Nikolakopoulou
Ph.D. Thesis, Columbia Univ., 53 pp (1978)
UM 7819404

Key Words: Containment structures, Fluid-filled containers, Elastic-plastic properties, Shells

The dynamic analysis of the wall of a fluid-filled unstiffened nuclear containment vessel, to the fluid pressure exerted on it when the relief valve discharge piping is cleared, is extended into the plastic range using two versions of an elastic-plastic shell theory.

79-328

Experimental Studies of Effects of Tilt and Structural Asymmetry on Vibration Characteristics of Thin-Wall Circular Cylinders Partly Filled with Liquid

R.W. Herr
Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TP-1211; L-12049, 41 pp (July 1978)
N78-28480

Key Words: Cylindrical shells, Fluid-filled containers

The effects of tilt and structural asymmetry on the vibration characteristics of partly liquid-filled thin-wall cylinders were experimentally studied. It was found that tilting the longitudinal axis of a partly filled axisymmetric cylinder from the vertical could markedly reduce its resonant frequencies and change significantly the shape of the circumferential modes. For the minimum frequency modes, vibratory motion occurred only on that side of the cylinder where the liquid was deepest. An empirical equation was derived that gives the equivalent liquid depth of an untilted cylinder having the same minimum resonant frequency as a tilted, partly filled cylinder. Circumferential mode shapes of an untilted asymmetric cylinder were similar to those of the tilted, partly filled axisymmetric cylinder. Vibratory motion in the minimum frequency modes occurred in most instances only on the side of minimum thickness. Correlation between test data and results from a reformulated NASTRAN hydroelastic analysis was excellent.

79-329

Dynamics of Submerged Cylindrical Shells with Eccentric Stiffening

K.K. Chu
Ph.D. Thesis, New Jersey Inst. of Tech., 80 pp (1978)
UM 7815892

Key Words: Cylindrical shells, Stiffening, Submerged structures

A theoretical analysis is presented for treating the free vibrations of submerged, ring stiffened cylindrical shells with simply supported ends. The effects of the eccentric stiffeners are averaged over the thin-walled isotropic cylindrical shell. The energy method is utilized and the frequency equation is derived by Hamilton's Principle. All three degrees of freedom are considered. Numerical results are presented for frequencies and mode separation for several cases of interest. Comparisons with previous theoretical and experimental results indicate good agreement. The cylindrical wave approximation and the plane wave approximation for the field equation were investigated.

79-330

Acoustical Reflections from Aluminum Cylindrical Shells Immersed in Water

W.W. Ryan, Jr.
Applied Res. Labs., The Univ. of Texas at Austin, TX 78712, J. Acoust. Soc. Amer., 64 (4), pp 1159-1164 (Oct 1978) 7 figs, 16 refs

Key Words: Submerged structures, Cylindrical shells, Periodic response, Acoustic reflection

The purpose of this study was to examine and compare theoretical and experimental steady-state response functions for two thin aluminum cylindrical shells immersed in a water medium. Theoretical steady-state response functions are presented for air-filled and water-filled cylinders of infinite

extent for the nondimensional frequency (ka) ranges from near 0 to 52. Experimental measurements are shown for the air-filled cylinders of finite length. Two sets of circumferential waves which are analytically derived from the steady-state response functions are also described and compared with photographs of the corresponding experimental echoes. Good agreement between calculated and measured values is demonstrated.

79-331

Non-Linear Static and Dynamic Response of Spherical Shells

Y. Nath and R.S. Alwar

Dept. of Appl. Mech., Indian Inst. of Tech., Madras, India, Intl. J. Nonlin. Mech., 13 (3), pp 157-170 (1978) 6 figs, 2 tables, 13 refs

Key Words: Spherical shells, Shallow shells, Dynamic response

In the present investigation an analytical technique using Chebyshev series expansion has been presented and used to study the non-linear transient behavior of shallow spherical shells with and without damping. The two coupled non-linear differential equation governing the shallow shell behavior are initially linearized using Taylor's series expansion. Results have been presented for three types of transient loadings, namely, step function, N-shaped pulse and sine wave pulse. It is shown that accurate results can be obtained using a five terms Chebyshev series expansion which is unlikely in the conventional methods.

79-332

Finite Amplitude Oscillations of a Hyperelastic Spherical Cavity

R. Balakrishnan and M. Shahinpoor

College of Engrg., Pahlavi Univ., Shiraz, Iran, Intl. J. Nonlin. Mech., 13 (3), pp 171-176 (1978) 4 figs, 12 refs

Key Words: Spherical shells, Free vibrations, Forced vibrations

Numerical results for the finite oscillations of a hyperelastic spherical cavity by employing the governing equations for finite amplitude oscillations of hyperelastic spherical shells and simplifying it for a spherical cavity in an infinite medium and then applying a fourth-order Runge-Kutta numerical technique to the resulting non-linear first-order differential equation. The results are plotted for Mooney-Rivlin type materials for free and forced oscillations under Heaviside type step loading. The results for Neo-Hookean materials are also discussed. Dependence of the amplitudes and frequencies of oscillations on different parameters of the problem is also discussed in length.

STRUCTURAL

(Also see No. 217)

79-333

The Shock Tunnel: History and Results. Volumes I-V

C. Wilson, K. Kaplan, and B.L. Gabrielsen

Scienctific Service Inc., Redwood City, CA, Rept. No. SSI-7618-1, 447 pp (Feb 1978)

AD-A055 518/5GA

Key Words: Panels, Walls, Blast resistant structures, Shock tube tests

This report summarizes the results of a program conducted by the Defense Civil Preparedness Agency to determine blast resistance of wall panels typically found in existing structures. The objective of this program was to determine the blast sheltering capability of structures in the National Fallout Shelter Survey inventory and to obtain information which could be used to upgrade these structures.

SYSTEMS

ABSORBER

79-334

Dynamic Tests on Metallic Impact Limiters

M.J. Sagartz

Simulation Div., Sandia Labs., Albuquerque, NM, Rept. No. SAND-77-1939, 31 pp (Jan 1978)

N78-28470

Key Words: Energy absorption

Different types of metallic impact limiters were tested: plain fins, laterally stiffened fins and tubes whose axes were aligned with the direction of impact. All specimens were made of 304 stainless steel and were annealed before testing. A heavy steel drop table of variable mass and moving at about 13.4 m/s (44 ft/s) was used to impact the specimens which were mounted on a stationary base. Impact velocity, drop table acceleration vs. time and force vs. time were measured on each test and were used to calculate the energy absorbed by the impact limiters.

79-335

Beamlike Dynamic Vibration Absorbers

J.C. Snowdon and M.A. Nobile
Applied Res. Lab., Pennsylvania State Univ., University Park, PA, Rept. No. ARL/PSU/TM-77-46, 54 pp (Feb 17, 1977)
AD-A056 099/5GA

Key Words: Dynamic vibration absorption (equipment), Cantilever beams

The performance of several beamlike dynamic vibration absorbers is analyzed and, in one case, confirmed by experiment. The dynamic absorbers are employed to suppress the transmissibility at resonance across a simple mass-spring vibrator, a stanchion, and a simply supported rectangular panel. Generally the beams provide both the absorber stiffness and damping – although, once, the beams are considered to possess little damping, and supplemental viscous damping is introduced by dashpots that link the absorber masses to the vibrating primary system of concern. Graphical or tabular design information is specified for the absorbers in each situation considered. Analyses are based throughout on the Bernoulli-Euler beam and thin-plate theories without simplification. In several of the situations analyzed, transmissibility curves are calculated to emphasize that the beamlike absorbers are broadly effective.

79-336

Experimental Evaluation of a Portable Energy Absorbing System for Highway Service Vehicles

J.F. Carney, III
Dept. of Civil Engrg., Connecticut Univ., Storrs, CT, Rept. No. FHWA/CT/RD-402-1-77-3, 127 pp (Jan 1977)
PB-283 075/0GA

Key Words: Energy absorption, Ground vehicles

A portable energy absorbing system which is attached to the rear of a standard 14,000 pound highway service vehicle used in maintenance operations has been designed and fabricated. Four full scale crash tests have been conducted to evaluate the structural integrity and performance of the portable energy absorbing system.

79-337

Improved Fender Systems for Shallow and Deep Draft Berths. Phase 1

E. Han, G. Priori, and D. Juran
Dravo Van Houten, Inc., New York, NY, Rept. No. MA/GEN-970/78046, 218 pp (June 1978)
PB-283 268/1GA

Key Words: Energy absorption, Shock absorbers, Ship structural components

This report presents investigations and descriptions of the following: state-of-the-art of fender design: available fender units; comparison of fender unit performance; common system configurations; adequacy of systems function; docking procedures; fender system costs; mooring practices; types of damage to fender systems; problems with fenders; maintenance and repair practices; examination of trends in ships' characteristics. The functions of various fender systems are described, and types of damage and problems that may occur are presented. Problems with fender systems are ranked, and design objectives are identified.

NOISE REDUCTION

(Also see No. 313)

79-338

Sound of Low-Speed Fans

B.E. Murray and E.W. Wood
Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. CONF-770151-7, 15 pp (1977)
N78-28894

Key Words: Cooling towers, Fans, Noise generation, Noise reduction

A general view of reported studies and prediction techniques for cooling tower noise is given. Fan noise generation is discussed with respect to the control of low- to mid-frequency noise from mechanical draft cooling towers. An exploratory aerodynamic analysis of fan noise generation is provided leading to empirical relationships for trailing-edge turbulent boundary layer noise, a major noise source in propeller fans.

79-339

Induced Draft Cooling Tower Noise and Its Control

J.S. Wang
Exxon Res. and Engrg. Co., Florham Park, NJ, Rept. No. CONF-770151-6, 22 pp (1977)
N78-28895

Key Words: Cooling towers, Fans, Noise generation, Noise control

Noise data measured at process plants were correlated into a prediction technique for estimating induced draft cooling tower noise in communities adjacent to a plant. Predictions are given in A weighted decibels corresponding to the manner in which regulations are commonly expressed, and in the octave band basis required for design purposes when a noise control measure is found to be necessary.

79-340

Some New Scaling Rules for Use in Muffler Design

F. Laville and W. Soedel

School of Mech. Engrg., Ray W. Herrick Labs., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 60 (2), pp 273-288 (Sept 22, 1978) 13 figs, 17 refs

Key Words: Mufflers, Scaling, Design techniques, Computer-aided techniques

Buckingham's pi principle is applied to mufflers. The severe restrictions of the principle are pointed out and non-classical scaling rules are developed by using a combination of basic principles and computer simulation searches. The characteristics of one cylinder four stroke engines are also included in the scaling.

79-341

Modeling of Engine Exhaust System Noise

J.W. Sullivan

School of Mech. Engrg., Ray W. Herrick Labs., Purdue Univ., West Lafayette, IN, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed, ASME, N.Y., NY: 1977, pp 161-170, 13 figs, 41 refs

Key Words: Engine mufflers, Internal combustion engines, Mathematical models

This paper is an attempt to review some recent advances in modeling exhaust system noise in IC engines. Emphasis is placed on both single and multi-cylinder engines; and in the proper utilization of both theoretical and empirical methods.

79-342

Field Study of a Variable-Height Highway-Noise Barrier

J.E. Manning and C.N. Blair

Cambridge Collaborative, Inc., Cambridge, MA, Rept. No. DOT-TSC-NHTSA-78-23, DOT-HS-803 290, 74 pp (Mar 1978)

PB-283 556/9GA

Key Words: Noise barriers, Experimental data

This study describes the design, construction, and evaluation of a variable-height highway-noise barrier. The barrier was constructed along a 100-ft-long segment of Interstate 93 in Andover, Massachusetts. A test plan was prepared, and measurements were taken at a number of points behind the barrier and at an adjacent open site by personnel using the DOT-TSC Mobile Noise Laboratory. Data were collected over a series of eight tests, each extending over a two- or three-day period, to determine the noise reduction provided by barriers of different heights with reflecting and absorbing surfaces. Test results are presented and compared with predictions.

ACTIVE ISOLATION

(See Nos. 234, 313, 354)

AIRCRAFT

(Also see Nos. 209, 266, 267)

79-343

Airframe Noise of the DC-9-31. Final Report

A.B. Bauer and A.G. Munson

Douglas Aircraft Co., Inc., Long Beach, CA, Rept. No. NASA-CR-3027, 54 pp (July 1978)

N78-28887

Key Words: Aircraft noise, Noise measurement

Airframe noise measurements are reported for the DC-9-31 aircraft flown at several speeds and with a number of flap, landing gear, and slat extension configurations. The data are corrected for wind effects, atmospheric attenuation, and spherical divergence, and are normalized to a 1 meter acoustic range. The sound pressure levels are found to vary approximately as the fifth power of flight velocity. Both lift and drag dipoles exist as a significant part of the airframe noise.

79-344

Community Noise Exposure Resulting from Aircraft Operations: Volume 6. Acoustic Data on Navy Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-6, 508 pp (Mar 1978)

AD-A056 217/3GA

Key Words: Aircraft noise, Noise measurement

This series of reports presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 F temperature and 70% relative humidity.

79-345

Prospects for Supersonic Jet Noise Suppression

D.S. Dosanjh, P.K. Bhutiani, K.K. Ahuja, and M. Gharib

Syracuse Univ., Syracuse, NY, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 79-88, 7 figs, 30 refs

Key Words: Aircraft noise, Jet noise, Noise reduction

The aero-acoustic characteristics of an effective and practical supersonic jet-noise suppressor are noted and the prospects for the suppression of supersonic jet-noise are briefly examined.

79-346

Prediction of Aircraft Sideline Noise Attenuation

W.E. Zorumski

Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TM-78717, 52 pp (June 1978)
N78-27871

Key Words: Aircraft, Noise reduction

A computational study is made using the recommended ground effect theory by Pao, Wenzel, and Oncley. It is shown that this theory adequately predicts the measured ground attenuation data by Parkin and Scholes, which is the only available large data set. It is shown, however, that the ground effect theory does not predict the measured lateral attenuations from actual aircraft flyovers.

79-347

Acoustic Tests of Duct-Burning Turbofan Jet Noise Simulation

P.R. Knott, E.J. Stringas, J.F. Brausch, P.S. Staid, P.H. Heck, and D. Latham

Aircraft Engine Group, General Electric Co., Cincinnati, OH, Rept. No. NASA-CR-2966; DOC-R77-AEG524, 345 pp (July 1978)
N78-28043

Key Words: Jet noise, Noise reduction, Nozzles

The results of a static acoustic and aerodynamic performance, model-scale test program on coannular unsuppressed and multielement fan suppressed nozzle configurations are summarized. The results of the static acoustic tests show a very beneficial interaction effect. The measured noise levels were compared with the predicted noise levels of two independent but equivalent conical nozzle flow streams.

79-348

Evaluation of Airframe Noise Prediction Methods

M.R. Fink

United Technologies Res. Center, East Hartford, CT, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 69-78, 16 figs, 13 refs

Key Words: Aircraft noise, Noise prediction

Predictions by Revell's drag element model, and Hardin's total aircraft noise method where applicable, are compared with measured flyover noise spectra for different configurations of a large commercial jet transport, a business jet, a small twin-propeller aircraft, and a sailplane.

79-349

Measurement of the Pitch Damping on Two AGARD B Models in the FFA S4 and S5 Wind Tunnels

S. Lundgren

Aerodynamics Dept., Aeronautical Research Inst. of Sweden, Stockholm, Sweden, Rept. No. FFA-AU-556, 29 pp (1977)
N78-26112

Key Words: Aircraft, Wind tunnel tests, Damping effects

Transonic/supersonic wind tunnel measurements of the pitch damping of two AGARD B models of wing spans 120 mm and 240 mm, respectively, were made using free oscillation techniques. The purpose of the investigation was to measure stability derivatives in pitch of the models and to study interference effects on the pitch damping in the two tunnels.

79-350

Structural Modifications on a Swept Wing Model with Two External Stores by Means of Modal Perturbation and Modal Correction Methods (Anwend. u. Vergleich modaler Perturbationsmethoden u. modaler Korrekturverfahren am Beispiel eines Pfeilflugels mit zwei 'Pylonaussenlasten')

R. Freymann

DFVLR, Goettingen, West Germany, Rept. No. DLR-FB-77-21 (May 1977) translated by European Space Agency, Paris, France, Rept. No. ESA-TT-463, 48 pp (May 1978)
N78-28064

Key Words: Wing stores, Perturbation techniques, Modal analysis

Investigations on swept wing model structure with two external stores were carried out by applying modal perturbation methods and modal correction procedures to inertia modifications on the external stores. Experimental modal data resulting from ground vibration tests on the same model structure in two different configurations were partially compared with calculated modal data in order to check the accuracy and suitability of the different modification methods.

79-351

Evaluation of Seating and Restraint Systems and Anthropomorphic Dummies Conducted During Fiscal Year 1977

R.F. Chandler and E.M. Trout

Office of Aviation Medicine, Federal Aviation Administration, Washington, D.C., Rept. No. FAA-AM-78-24, 75 pp (June 1978)
AD-A056 905/3GA

Key Words: Safety restraint systems, Aircraft seat belts, Aircraft seats, Anthropomorphic dummies, Crash research (aircraft)

The results of test programs conducted by the Protection and Survival Laboratory (FAA) to investigate the performance of prototype or operational seating and restraint systems relative to their ability to provide protection against crash injury and to investigate the performance of anthropomorphic dummies in the dynamic environment are reported.

BRIDGES

79-352

The Action of Flexible Bridges Under Wind. I: Flutter Theory

R.H. Scanlan

Dept. of Civil Engrg., Princeton Univ., Princeton, NJ 08540, J. Sound Vib., 60 (2), pp 187-199 (Sept 22, 1978) 3 figs, 16 refs

Key Words: Bridges, Suspension bridges, Flutter, Wind-induced excitation

The action of long-span bridges, notably suspension bridges, under wind has long been of concern. This first of two papers summarizes the pertinent experimental and other prerequisite data and proceeds to the linear dynamic analysis of bridge flutter for bridges having vibration modes that are not necessarily simple, i.e., that may involve motions beyond pure flexure and torsion. A review is made of the energy considerations involved in the assessment of aerodynamic stability. The paper lays the groundwork for the one that follows.

79-353

The Action of Flexible Bridges Under Wind. II: Buffeting Theory

R.H. Scanlan

Dept. of Civil Engrg., Princeton Univ., Princeton, NJ 08540, J. Sound Vib., 60 (2), pp 201-211 (Sept 22, 1978) 1 fig, 1 table, 21 refs

Key Words: Bridges, Wind-induced excitation

By using the analytical and conceptual format set forth in the first of these two companion papers, the problem of bridge buffeting under natural wind is considered. Again, bridges having vibration modes that are not necessarily simple are dealt with. The buffeting action of random wind forces in the presence of self-excited, or bridge motion-induced, forces is discussed, as are energy considerations associated with bridge stability. A possible explanation is offered for the well-known fact that turbulence in the incident wind often delays the onset of flutter.

79-354

Dynamic Analysis and Active Control of Two Cable-Stayed Bridge

F. Giannopoulos

Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 125 pp (1978)
UM 7818549

Key Words: Suspension bridges, Cables, Active flutter control

The feasibility of applying active control theory to control both the transient and steady state response of a two cable-stayed bridge has been investigated. The bridge has been modeled as a two degree of freedom system in bending and torsion, excited by both buffeting and self-excited loads. The existing suspension cables have been used as active tendons by which the control forces are applied to the bridge deck at the points of the anchorage. The control force from each suspension cable is actuated through a hydraulic-servomechanism which is regulated by the sensed motion of the bridge deck at the anchorage of the cable. Stability and steady state response analyses have been presented for both controlled and uncontrolled motion. The power requirement for the control devices has been derived. Finally, numerical examples have been worked out to demonstrate the feasibility of the derived theory for two cable-stayed bridges.

FOUNDATIONS AND EARTH

79-355

Earthquake Response of Dam-Reservoir-Foundation Systems

S.K. Sharan

Ph.D. Thesis, Univ. of Waterloo (Canada) (1978)

Key Words: Dams, Earthquake response, Finite element technique, Interaction: structure-fluid

A method is developed to analyze the earthquake response of dam-reservoir-foundation systems by using a finite element discretization of the complete system. Nodal displacements and nodal pressures are assumed to be the basic unknowns for the structure and the fluid respectively. The present method removes several limitations of the existing methods. Triple interactions between the dam, reservoir and the foundation, compressibility of water, arbitrary geometries of the reservoir and the interfaces, and the spatial variation in the excitation have been included in the analysis. Several two-dimensional example problems are solved to demonstrate the effectiveness of the present method.

HELICOPTERS

79-356

Comparison of the Effect of Structural Coupling Parameters on Flap-Lag Forced Response and Stability of a Helicopter Rotor Blade in Forward Flight

D.P. Schrage and D.A. Peters

Army Aviation Res. and Dev. Command, St. Louis, MO, 15 pp (June 1978)

AD-A056 485/6GA

Key Words: Helicopter rotors, Rotor blades (rotary wings), Modal analysis, Eigenvalue problems

An eigenvalue and modal decoupling method to predict helicopter rotor stability and forced response has been successfully developed. The advantages of this method are: Stability and forced response are obtained from the same method, thus allowing direct comparison of parametric effects.

HUMAN

79-357

Community Noise

K.M. Eldred

Bolt Beranek and Newman, Inc., Cambridge, MA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 1-7, 2 figs, 6 tables, 11 refs

Key Words: Urban noise, Human response

This paper briefly reviews the magnitude and causes of the National Community Noise Problems, as assessed by surveys of public opinion. It then summarizes the general relationships between outdoor community noise levels, as measured on the Day/Night Average sound level scale, with the percentage of people highly annoyed and the average community reaction.

ISOLATION

79-358

Dynamic Analysis of Shipping Container Suspension System for the Canister Launched Version of the HARPOON Missile RGM-84A-3A

Y. Trask

Naval Weapons Handling Center, Colts Neck, NJ, Rept. No. NWHC-7760, 97 pp (Apr 1, 1978)

AD-A055 719/9GA

Key Words: Vibration isolators, Shock absorbers, Shipping containers, Missiles

This center conducted an analysis to determine isolation system parameters for a shipping and storage container for the canister launched version of the HARPOON missile. This report presents the details of the analysis and information concerning the predicted shock and vibration forces on the packaged item as well as the container caused by the hazards of handling and transportation. A packaging configuration is presented, which uses isolators previously approved for the ASROC version of the HARPOON missile.

MATERIAL HANDLING

79-359
Analysing the Vibrating Conveyor

G. Winkler
School of Engrg., Univ. of Bath, UK, Intl. J. Mech. Sci., 20 (9), pp 561-570 (1978) 13 figs, 4 refs

Key Words: Conveyors

Several possible vibrating conveyor designs – the "sealskin" conveyor, the "jerk" conveyor, the conveyor with inclined motion and the conveyor with out-of-phase motion – are first discussed and their relative performances are compared. The most promising (and most widely employed) design, namely the conveyor with inclined motion, is then analyzed in detail. The analysis is in all cases limited to conveyors with a horizontal track and with vertical track accelerations not exceeding g, the gravitational constant. Since the analytical performance prediction of the conveyor with sinusoidal motion is very difficult, an alternative type of motion having a triangular velocity profile is introduced. This allows analytical expressions for conveyor performance by simple methods to be derived.

METAL WORKING AND FORMING

79-360
Analysis and Design of Machine Tool Chatter Control Systems Using the Regeneration Spectrum

K. Srinivasan and C.L. Nachtigal
Shell Development Co., Houston, TX 77001, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (3), pp 191-200 (Sept 1978) 10 figs, 1 table, 12 refs

Key Words: Machine tools, Chatter

This paper introduces a new concept in the analysis and design of machine tool chatter control systems, the regeneration spectrum. This development follows from a recognition of the fact that the stability analysis of time delayed systems such as machining systems is considerably simplified for large values of the time delay.

PUMPS, TURBINES, FANS, COMPRESSORS
(Also see Nos. 291, 298, 338, 339)

79-361
Noise Reduction in Hydraulic Equipment

R.J. Becker
Sperry Vickers, Troy, MI, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 215-217, 7 figs

Key Words: Pumps, Noise reduction

Noise radiated from a pump is generated in two ways. First, the external housing reacts to the internal pressure changes in the individual chambers as they index through the pumping cycle. Secondly, the pump radiates noises produced by impacts or resonances of moving parts. This energy may reach the radiating surface of the housing through the fluid medium or direct contact with the part itself.

79-362
The Internal Impedance of Centrifugal and Positive Displacement Pumps

L.C. Davidson
David W. Taylor Naval Ship R&D Center, Annapolis, MD, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 225-231, 8 figs, 2 refs

Key Words: Pumps, Centrifugal pumps, Acoustic impedance

A centrifugal pump and a positive displacement pump (internal gear) were operated under known conditions of acoustic load by using an accumulator to simulate an open column at the pump discharge. The internal impedance of each pump was obtained from the observed resonant interactions with columns of various lengths. The blocked acoustic pressures were then computed from measured pressures under known load conditions.

79-363
Nonlinear Transient and Spectrum Response Seismic Analysis of a Reactor Coolant Pump

L.C. McNutt
Westinghouse Electric Corp., Cheswick, PA, ASME Paper No. 78-PVP-36

Key Words: Pumps, Cooling systems, Nuclear reactor components, Seismic response, Computer programs

Two solution techniques are employed in the dynamic seismic analysis of a nuclear steam supply system reactor coolant pump (RCP). The time history response of the RCP from a nonlinear transient analysis is compared with the modal solution from a spectrum response analysis. Finite element models and general-purpose finite-element computer programs are utilized in both analyses.

79-364

Pulsation Dampeners and Stabilizers Help Protect Pump Systems in Nuclear Plants

G.D. Heveron

General Atomic Co., Power, 122 (10), pp 28-31 (Oct 1978) 4 figs

Key Words: Pumps, Nuclear power plants, Cavitation

High-pressure positive-displacement reciprocating pumps in safety-related boron-charging systems of pressurized-water nuclear plants have caused pipe vibration and weld fatigue, and have experienced excessive wear. Devices that can reduce cavitation and pressure pulsation, as well as piping layout is described.

79-365

Critical Speeds and Response of a Large Vertical Pump

M.S. Darlow, A.J. Smalley, and J. Ogg

Mechanical Technology, Inc., Latham, NY, ASME Paper No. 78-PVP-34

Key Words: Pumps, Cantilever beams, Fluid-induced excitation, Critical speeds, Unbalanced mass response

A detailed rotor dynamic analysis of a large vertical pump design has been conducted. The structural features of this class of pump lead to some special dynamic characteristics.

79-366

Transient Response to Three-Phase Faults on a Wind Turbine Generator

L.J. Gilbert

Ph.D. Thesis, The Univ. of Toledo, 143 pp (1978) UM 7818530

Key Words: Wind turbines, Transient response, Mathematical models

As a consequence of the world energy supply problems large kilowatt and megawatt capacity wind turbine generators are being designed and built to take advantage of the energy in the wind. The model and simulation developed for this study of transient stability are applicable for more extensive investigations of power systems involving wind turbine generators, and will continue to be useful until the extent that standard power system technology applies directly to wind turbine power systems is fully determined.

79-367

Eight-Stage Steam Turbine Rotor Dynamics Analysis

G. Siegrist and A.E. Richey

Mechanical Technology, Inc., Latham, NY, Rept. No. C00-2835-5; TR-78TR13, 33 pp (Nov 1977) N78-28465

Key Words: Steam turbines, Propulsion systems, Design techniques

Reports of a design review and dynamic analysis of the rotor system of an 8 stage steam turbine for propulsion systems are presented. Analysis of the rotor system indicates the potential of a rotor dynamics problem in the first critical speed range. Good balance and an effective turbine end bearing damper are required to control the rotor dynamic response. The existing turbine end bearing damper is inadequate.

79-368

On the Mechanism of Noise Generation by a Hermetic Reciprocating Compressor with Automatic Reed Valves

M.C.C. Tsao

Westinghouse Res. Labs., Pittsburgh, PA, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 233-237, 9 figs, 8 refs

Key Words: Compressors, Noise generation, Noise reduction

The present paper discusses the noise problems of a hermetic reciprocating compressor with automatic reed valves. It presents a brief literature review, a sound theory, an experiment to test the noise sources, and a redesign of the compressor piston, valves, and head plate to achieve a low noise level of the compressor.

79-369

Noise Mechanisms in Automotive Cooling Fans

R.E. Longhouse

Fluid Dynamics Research Dept., General Motors Res. Labs., Warren, MI, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 183-190, 13 figs, 17 refs

Key Words: Fans, Noise reduction

Noise and performance tests were conducted on a series of low tip-speed, half-stage, axial-flow fans such as used in automotive applications. The fans have a 356 mm diameter, and either four or eight equally spaced, variable pitch blades. The tests were conducted in both free-field and reverberant-field environments. Various degrees of rotational noise were artificially introduced by installing circular rods upstream from the fan. The non-rotational noise was varied by adjusting the fan tip clearance and by using boundary layer trip devices on the blades. These tests were conducted in order to determine the dominant fan noise mechanisms, their relative importance, and how they may be controlled.

79-370

Experimental Distinction Between Monopole and Dipole Sources of Fan Noise

P.K. Baade

Acoustics and Dynamics, Res. Div., Carrier Corp., Syracuse, NY, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 209-214, 7 figs, 19 refs

Key Words: Fans, Sound generation, Noise source identification, Experimental data

The dipole nature of fan sound generation is occasionally questioned in the literature. Proper identification of the source mechanism is particularly important for the development of low noise fans.

79-371

VSTOL Tilt Nacelle Aerodynamics and Its Relation to Fan Blade Stresses

R.J. Shaw, R.C. Williams, and J.L. Koncsek

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-78899; E-9635, 15 pp (July 1978) N78-26099

Key Words: Nacelles, Fans, Wind tunnel tests

A scale model of a VSTOL tilt nacelle with a 0.508 m single stage fan was tested in a low speed wind tunnel to ascertain inlet aerodynamic and fan aeromechanical performance over the low speed flight envelope. Fan blade stress maxima occurred at discrete rotational speeds corresponding to integral engine order vibrations of the first flatwise bending mode. Increased fan blade stress levels coincided with internal boundary layer separation but became severe only when the separation location had progressed to the entry lip region of the inlet.

79-372

Foundation Design for Rotating Fans

J.P. Lee and N.C. Chokshi

Brown and Root, Inc., Houston, TX, Hydrocarbon Processing, 57 (10), pp 131-136 (Oct 1978) 5 figs, 4 tables, 8 refs

Key Words: Rotating structures, Fans, Foundations, Vibration control

A dynamic analysis technique, incorporating a multi-degree of freedom model, is presented to limit the resonance vibration of a rotating fan to an acceptable level by insuring the separation of the frequencies of the fan and of its support.

79-373

Radiated Noise of Cavitating Propellers

L. Noordzij, P. van Oossanen, and A.M. Stuurman

Netherlands Ship Model Basin, Wageningen, The Netherlands, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 101-108, 14 figs, 7 refs

Key Words: Propellers, Marine propellers, Cavitation noise

In this paper noise characteristics of three different propeller models are discussed. Each propeller displays a different type of cavitation, viz. tip vortex cavitation, bubble cavitation at mid-chord region of the propeller blades on suction side and sheet cavitation also on the suction side of the propeller blades. The propellers were tested at the same operating conditions behind a towed ship model. The investigation was performed to gain insight into a basic problem in propeller cavitation noise, i.e., what is the acoustical behavior of individual types of cavitation.

79-374

Propeller Cavitation Noise After 35 Years of Study

M. Strasberg

David W. Taylor Naval Ship R&D Center, Bethesda, MD, Noise and Fluids Engineering, Winter Annual

Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 89-100, 9 figs, 1 table, 15 refs

Key Words: Cavitation noise, Hydraulic equipment, Propellers, Marine propellers

The paper concentrates on one area of cavitation noise research; the use of scale models for estimating the noise generated by cavitating propellers and hydraulic machinery. Noise measurements obtained over 30 years ago with scale models and their full-size prototypes are shown to verify the scaling laws proposed for predicting cavitation noise levels and spectra.

RAIL

(Also see No. 212)

79-375

Nonlinear Kinematics of Wheel-Rail Contact

T.D. Burton and A.M. Whitman

General Electric Co., Valley Forge, PA, J. Appl. Mech., Trans. ASME, 45 (3), pp 664-668 (Sept 1978) 2 figs, 8 refs

Key Words: Interaction: rail-wheel

Relations which describe the nonlinear geometry of contact between a railway vehicle wheelset and rail are derived. Geometric constraint relations are derived and expanded about the central (rest) positions. These are solved for the rolling and vertical motions, instantaneous left and right wheel rolling radii, angles between the contact and horizontal planes, and lateral and longitudinal creepages. The results are given explicitly in terms of the lateral and yawing motions for mildly noncircular wheel and rail profiles.

REACTORS

(Also see Nos. 315, 327, 363)

79-376

Mass Coupling Effects in the Dynamic Analysis of Nuclear Power Plant Systems

T.S. Aziz and C.G. Duff

Atomic Energy of Canada, Ltd., Sheridan Park Res. Community, Mississauga, Ontario, Canada, ASME Paper No. 78-PVP-28

Key Words: Nuclear power plants, Modal analysis

The effect of interaction between the primary and the secondary systems on the maximum response of the secondary system is studied. Some of the mathematical fallacies of the conventional modal analysis approach are pointed out. A two-step approach is formulated to quantify the effects of mass coupling.

79-377

Modal Summing Rules for Seismic Qualification

J.M. Gwinn and J.C. Waal

Stone & Webster Engrg. Corp., Boston, MA, ASME Paper No. 78-PVP-32

Key Words: Nuclear power plants, Modal analysis, Seismic response, Seismic design

Seismic qualification of nuclear power plant structures, systems, and components is frequently accomplished by modal analysis using amplified response spectra and the square-root-sum-of-the-squares (SRSS) rule for combining modal responses.

79-378

Development of Criteria for Seismic Review of Selected Nuclear Power Plants

N.M. Newmark and W.J. Hall

Newmark (Nathan M.) Consulting Engrg. Services, Urbana, IL, Rept. No. NUREG-CR-0098, 57 pp (May 1978)

PB-282 817/6GA

Key Words: Nuclear power plants, Earthquake resistant structures

The report sets forth the seismic criteria and design concepts that are applicable to the review of analyses and upgrading of the older operating plants. This report deals with the selection of earthquake hazard for review and design, design seismic loadings, soil-structure interaction, damping and energy absorption, methods of dynamic analysis, review analysis and design procedures, special topics including equipment qualification, and probability concepts. It is indicated that a major part of the review and analysis procedure for an operating plant involves audits which include the verification of the existing design and analysis for the seismic qualification of structures, equipment, and components.

79-379

Decoupling Criteria for Seismic Analysis of Nuclear Power Plant Systems

T.S. Aziz and C.G. Duff
Atomic Energy of Canada, Ltd., Sheridan Park Res. Community, Mississauga, Ontario, Canada, ASME Paper No. 78-PVP-27

Key Words: Nuclear power plants, Seismic response

Practical design considerations necessitate many systems in a nuclear power plant to be decoupled for the purpose of seismic analysis. Current decoupling criteria used in the industry appear to be arbitrary, intuitive in nature, and somewhat conflicting. A rational perturbation approach for developing decoupling criteria is presented. The approach is based on limiting the changes in eigenvalues of the coupled system from those of the uncoupled systems. A family of new decoupling criteria is presented.

RECIPROCATING MACHINE

(See Nos. 268, 341)

ROAD

(Also see Nos. 210, 223, 224, 248, 249, 275)

79-380

The Effect of Road Unevenness on Subjectively Perceived Driving Comfort and the Dynamic Wheel Loads (Abhängigkeit des subjektiv empfundenen Fahrkomforts und der dynamischen Radlasten von Strassenunebenheiten)

R. Stenschke

Fortschrift-Berichte der VDI-Zeitschriften, Series 12, No. 32 , 84 pp (1978) 7 *figs, Avail: VDI Verlag* GmbH, Postfach 1139, 4000 Düsseldorf, West Germany; Taken from VDI-Z, 120 (3), pp 639-640 (July 1978)
(In German)

Key Words: Road roughness, Measurement techniques

The report proposes a method for the determination of the effect of road unevenness and ride velocity on the driving comfort and dynamic wheel loads.

79-381

Repetitive Loading Tests on Membrane-Enveloped Road Sections During Freeze-Thaw Cycles

N. Smith, R.A. Eaton, and J.M. Stubstad

Cold Regions Res. and Engrg. Lab., Hanover, NH, Rept. No. CRREL-78-12, 24 pp (May 1978)

AD-A056 744/6GA

Key Words: Roads (pavements), Dynamic tests

Road test sections of membrane-enveloped silt and clay soils overlain with asphalt cement concrete were subjected to repetitive dynamic plate-bearing loadings to determine *their strength variations during freeze-thaw cycles.* The recoverable surface deformations in the load deflection bowl were continuously measured during the loading cycles and analyzed using the Chevron layered elastic computer program *to obtain the in situ resilient deformation modulus of the* various section layers at different stages of the freeze-thaw cycles.

79-382

In-Use Motorcycle Sound Levels

W.E. Marcus

Motorcycle Industry Council, Newport Beach, CA, SAE No. 780707, 12 pp, 4 figs

Key Words: Motorcycles, Noise generation

Among the surface transportation noise control policies under consideration by governmental bodies are the methods of noise control, the magnitude of noise standards, and the priority each vehicle type will receive during the legislative and regulatory processes. A factor in the determination of these policies ought to be the relative contributions of each vehicle type to overall surface transportation noise. To help develop the substantial data base necessary for objective determinations, an investigation crew conducted two days of motor vehicle traffic sound level monitoring. The results indicate significant differences in noise levels and sound energies between motorcycles with stock exhaust systems and motorcycles with modified exhaust systems, and also between garbage trucks, other truck types, automobiles, and motorcycles.

79-383

The Calculation of the Vibrations of a Four-Wheeled Vehicle, Induced by Random Road Roughness of the Left and Right Track

G. Ruf

Porsche-Entwicklungszentrum 7251 Weissach 1, West Germany, Vehicle Syst. Dyn., 7 (1), pp 1-23 (Jan 1978) 15 figs, 1 table, 7 refs

Key Words: Suspension systems (vehicles), Road roughness

When applying the known power spectra of the random road roughness to the suspension behavior of a four-wheeled *vehicle*, each of the four vertical input signals together with their related interdependence are to be considered, if exact results are to be obtained. The correlations are determined by way of calculation. The resulting roughness spectra of bounce, pitch, roll and torsional excitations will be applied to various vehicles, characterized by different design parameters. By means of a three-dimensional simulation model the virtual values of the random vehicle vibrations are calculated, while determining at the same time the influence of vehicle speed, waviness exponent, track width, wheel base, and axle design feature as well as the relationship between the vertical vibrations and the reference point in the vehicle body.

79-384

Tests: A Vital Part of the '79 Cars

Product Engr. (NY), 49 (9), pp 69-72 (Sept 1978)

Key Words: Automobiles, Testing techniques

Testing conditions, facilities and methods are described.

SHIP

(Also see No. 208)

79-385

An Analysis on the Vibrations Levels on the Bridge of H.M.A.S. Labuan in Rough Seas

G. Long and P.A. Farrell

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC-TM-272, 14 pp (Feb 1978)

AD-A056 354/4GA

Key Words: Ships, Vibration dampings

The fore-and-aft vibration levels occurring on the bridge of H.M.A.S. Labuan in rough seas have been recorded and analyzed. The results for the frequency range 0-10 Hz are presented.

79-386

Seismic Analysis of an Offshore Structure Supported on Pile Foundations

D.D.-N. Liou and J. Penzien

Earthquake Engrg. Res. Center, California Univ., Richmond, CA, Rept. No. UCB/EERC-77/25, 116 pp (Nov 1977)

Sponsored by the National Science Foundation

PB-283 180/8GA

Key Words: Off-shore structures, Pile structures, Seismic structures, Interaction: structure-foundation

This report presents an analytical study of the seismic response characteristics of an offshore structure supported on pile foundations. To allow the basic modeling of the structure-foundation system, a simple mathematical model of pile foundation based on the three-dimensional theory of elasticity is developed. The earthquake surface ground motion is prescribed in the time domain, the solution of the system is carried out in the frequency domain, and the desired response quantities are transformed back to the time domain. Foundation-structure interaction effects are examined by comparing response quantities obtained for models with and without foundation flexibility. The interaction effects are found to be quite significant.

79-387

Self-Exciting Gate Vibrations

P.A. Kolkman

Delft Hydraulics Lab., The Netherlands, Rept. No. PUB1-186, 12 pp (Oct 1977)

N78-28394

Key Words: Hydraulic valves, Sluice gates, Self-excited vibrations

The theory presented is valid for culvert valves and sluice gates. It describes the interaction of three elements: gate movement, forces due to flow around the gate, and fluid inertia upstream and downstream of the gate. The last of these is especially typical for gate vibrations. As an illustration of these elements a bathtub plug is introduced.

SPACECRAFT

(Also see Nos. 225, 226, 227, 358)

79-388

A Comparative Study of Liapunov Stability Analyses of Flexible Damped Satellites

H.B. Hablani and S.K. Shrivastava

Aeronautical Engrg. Dept., Indian Inst. of Science, Bangalore, India, J. Appl. Mech., Trans. ASME, 45 (3), pp 657-663 (Sept 1978) 3 figs, 10 refs

Key Words: Spacecraft, Stability, Lyapunov's method

A literal Liapunov stability analysis of a spacecraft with flexible appendages often requires a division of the associated dynamic potential into as many dependent parts as the number of appendages. The first part of this paper exposes the stringency in the stability criteria introduced by such a division and shows it to be removable by a "reunion policy." The policy enjoins the analyst to piece together the sets of criteria for each part. Employing reunion the paper then compares four methods of the Liapunov stability analysis of hybrid dynamical systems illustrated by an inertially coupled, damped, gravity stabilized, elastic spacecraft with four gravity booms having tip masses and a damper rod, all skewed to the orbital plane. The four methods are the method of test density function, assumed modes, and two and one-integral coordinates. The design plots demonstrate how elastic effects delimit the satellite boom length.

79-389
Noise Control in Spacelab

D. Wyn-Roberts and H. Hassan

European Space Agency, ESTEC, Domeinweg, Noordwijk, The Netherlands, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 219-224, 5 figs, 5 tables, 8 refs

Key Words: Spacecraft, Noise reduction

Spacelab is the European manned orbital laboratory which will form one of the space shuttle payloads in the 1980s. It will contain a shirt sleeve environment in which the astronaut scientists will work. The noise level in this volume will be strictly controlled. During the course of development of this program the Environmental Control Subsystem fans were identified as being major noise sources leading to unacceptably high noise levels in the module. Analysis of noise generating paths led to noise control recommendations including lining of ductwork, incorporation of mufflers, incorporation of anti-vibration mounts and wrapping of fan casings. Finally a comprehensive test program was identified and implemented which provides the required design data for noise control implementation together with a continuous verification of the noise control methods used.

79-390
Dynamics of Spinning Spacecraft with Tubular Appendages Including Large Amplitude Deflections

P.D. Nguyen

Inst. for Aerospace Studies, Toronto Univ., Ontario, Canada, Rept. No. UTIAS-223, 155 pp (Feb 1978)
N78-27169

Key Words: Spacecraft, Vibration response

The flexible spinning spacecraft under consideration is of the Alouette type. It consists of a relatively rigid center body to which are appended one or more pairs of diametrically opposed, long, slender booms, all lying in the same plane. Both constrained and unconstrained vibrational frequencies of the spacecraft are investigated in detail. A Galerkin solution is presented for boom bending with large amplitudes and nonlinear inertial accelerations taken into acocunt.

79-391
Study of Hydraulic Generators for Vibration Tests of Large Space Objects (Etude Des Generateurs Hydrauliques Pour les Essais aux Vibrations D'Objets Spatiaux de Grandes Dimensions)

Merlet and Lemonde

Societe pour le Perfectionnement des Materiels et Equipements Aerospatiaux, Toulouse, France, Rept. No. ESA-CR(P)-1044, 117 pp (Nov 24, 1977)
(In French)
N78-28145

Key Words: Test equipment, Spacecraft

Test equipment necessary for future payloads of Ariane and Spacelab is discussed. The state of the art of vibration simulation techniques using hydraulic exciters is presented. Phase 1 of the study deals with the search for high power installations. In phase 2 the available facilities and their limitations are discussed. Phase 3 is concerned with safety systems and with the studies to be undertaken in order to improve existing installations.

TRANSMISSIONS

79-392
On the Transient Control of a Power System Via Dynamic Braking

V.R. Sherkat

Ph.D. Thesis, Cornell Univ., 132 pp (1978)
UM 7817775

Key Words: Power transmission systems, Braking effects

This dissertation is concerned with the study of two problems related to the transient control of a power system with the aid of dynamic braking. The first problem deals with the issue of model complexity, and in particular, the significance of the fast electrical transient terms, present in the detailed description of the synchronous machine and the transmission system. The second problem investigated is concerned with the impact of dynamic braking on the turbine-generator torsional shaft torques, and the possibility of undesirable high torisonal stressing on the various shaft sections; due to the insertion or removal of a dynamic brake at the generator bus.

79-393

Comparison and Selection of Couplings

E.I. Rivin

Research Dept., Ford Motor Co., Dearborn, MI, 5th Natl. Conf. on Power Trnasmission, Proc., Chicago, IL, pp 189-194 (Nov 7-9, 1978) 5 figs, 1 table, 3 refs

Key Words: Power transmission systems, Couplings

The purpose of this paper is to formulate more precisely a classification of couplings and to establish criteria for the designs of torsionally flexible and misalignment-compensating couplings so that the optimal types can be recommended.

79-394

Hydrodynamic Power Transmission (Fluid Couplings with Constant Filling and Drain-Type Couplings)

E. Koerber

Voith Turbo GmbH 7 Co. KG, Crailsheim, West Germany, 5th Natl. Conf. on Power Transmission, Proc., Chicago, IL, pp 215-226 (Nov 7-9, 1978) 43 figs

Key Words: Power transmission systems, Mechanical drives, Fluid couplings

Hydrodynamic power transmission using fluid couplings or torque convertors which plays an important role in modern-day engineering is described.

TURBOMACHINERY

79-395

Rotor-Stator Interaction Noise with Hindsight

N.A. Cumpsty

Dept. of Engrg., Whittle Lab., Univ. of Cambridge, UK, Noise and Fluids Engineering, Winter Annual Meeting of ASME, Atlanta, GA; Nov 27-Dec 2, 1977, R. Hickling, ed., ASME, N.Y., NY: 1977, pp 179-182

Key Words: Turbomachinery, Noise reduction, Interaction: rotor-stator

Probably the most studied aspect of turbomachinery noise is the interaction of rotors and stators to give a tone at blade passing frequency and harmonics. This paper briefly examines what is known about this type of noise and, more particularly, what gaps there are in our knowledge. The conclusion is that our knowledge and capability are little better than they were a decade ago! Nevertheless the potential for reduction in noise, particularly from low speed machinery, exists and disappointments associated with high speed, aeronautical machines should not be allowed to prevent this being realized.

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FEBRUARY 1979

26-Mar 2 **Congress & Exposition,** [SAE] Cobo Hall, Detroit, MI ***(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)***

MARCH 1979

12-15 **Gas Turbine Conference and Exhibit,** [ASME] San Diego, CA ***(ASME Hq.)***

APRIL 1979

4-6 **Structures, Structural Dynamics and Materials Conference,** [AIAA-ASME] Chase-Park Plaza Hotel, St. Louis, MO ***(ASME Hq.)***

30-May 2 **NOISE-CON 79,** [INCE] Purdue University, IN ***(NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 - Tel (317) 749-2533)***

30-May 2 **Environmental Sciences Meeting,** [IES] Seattle, WA ***(Dr. Amiram Roffman, Energy Impact Assoc., Inc., P.O. Box 1899, Pittsburgh, PA 15230 - Tel. (412) 256-5640)***

30-May 3 **1979 Offshore Technology Conference,** [ASME] Astrohall, Houston, TX ***(ASME Hq.)***

MAY 1979

7-10 **Design Engineering Conference & Show,** [ASME] McCormick Place, Chicago, IL ***(ASME Hq.)***

20-25 **Spring Meeting and Exposition,** [SESA] San Francisco, CA ***(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)***

JUNE 1979

12-16 **Acoustical Society of America, Spring Meeting,** [ASA] Cambridge, MA ***(ASA Hq.)***

18-20 **Applied Mechanics, Fluid Engineering and Bioengineering Conference,** [ASME-CSME] Niagra Hilton Hotel, Niagra Falls, NY ***(ASME Hq.)***

JULY 1979

9-13 **5th World Congress on the Theory of Machines and Mechanisms,** [ASME] Montreal, Quebec, Canada ***(ASME Hq.)***

SEPTEMBER 1979

10-12 **ASME Vibrations Conference,** [ASME] St. Louis, MO., ***(ASME Hq.)***

10-13 **Off-Highway Meeting and Exposition,** [SAE] MECCA, Milwaukee, WI ***(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)***

11-14 **INTER-NOISE 79,** [INCE] Warsaw, Poland, ***(INTER-NOISE 79, IPPT PAN, ul. Swietokrzyska 21, 00-049 Warsaw, Poland)***

OCTOBER 1979

7-11 **Fall Meeting and Workshops,** [SESA] Mason, OH ***(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)***

16-18 **50th Shock and Vibration Symposium,** Colorado Springs, CO ***(H.C. Pusey, Director, The Shock and Vibration Information Center, Code 8404, Naval Research Lab., Washington, D.C. 20375 - Tel (202) 767-3306)***

16-18 **Joint Lubrication Conference,** [ASLE-ASME] Dayton, OH ***(ASME Hq.)***

NOVEMBER 1979

4-6 **Diesel and Gas Engine Power Technical Conference,** San Antonio, TX ***(ASME Hq.)***

5-8 **Truck Meeting,** [SAE] Marriott, Ft. Wayne, IN ***(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)***

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

DECEMBER 1979

2-7 **Winter Annual Meeting,** [ASME] Statler Hilton, New York, NY ***(ASME Hq.)***

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