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SVIC NOTES

Modal Testing of Nonlinear Structures

Modal testing methods are quite advanced these days. However, the modal testing community still has a way to go in both recognizing and dealing with the nonlinear behavior of structures. My guess is that many of the varying results obtained with different modal testing techniques could be traced to nonlinear effects. In this brief note I'll discuss three subjects: (1) how to become aware of the possible linearizing effects during each phase of a modal test, (2) how to recognize classical nonlinear behavior and (3) methods available for detecting nonlinear behavior.

Each choice of excitation source, fixture and data processing methods has a different potential for linearizing system response data. Among excitation methods sinusoidal is best for revealing and characterizing nonlinear behavior. Fast swept sine or CHIRP excitation may reveal slight response differences between an up or down frequency sweep. And finally there is random excitation, which is known to be the least efficient excitation method available for revealing nonlinear behavior. Nonlinear response can also be suppressed by attaching large shakers and massive fixtures. Lightly loading the structure with carefully designed stingers will let the nonlinear behavior show through. For the same reasons single point excitation will in general reveal more nonlinearities than multipoint excitation because you don't load the structure as much with single point excitation. And finally it is also known that controlling on the response of a structure rather than on the input will tend to obscure nonlinear behavior.

How does one recognize classical nonlinear behavior? The best solution is to become familiar with the response characteristics of simple nonlinear systems such as softening or hardening springs, springs with bilinear stiffness, systems with gaps and systems with coulomb damping. There are many recent papers in the literature which report experimental and theoretical response characteristics for the above simple nonlinear systems.

There are many detection and identification methods available which rely on sinusoidal excitation. The most basic of all principles to verify is superposition which uniquely defines linearity. If excitation is doubled or halved the response should double or drop by half. Other methods for detecting nonlinearity rely on noticing a particular type of distortion in a graphical plot of some measured or calculated output parameter. These techniques are usually limited to well isolated modes. Nonlinearities will distort Nyquist plots; specific types of nonlinearities will warp frequency isochrones in a specific manner. One very useful plot is the three-dimensional carpet plot which characterizes damping around a resonance. A perfectly flat carpet plot indicates a linear system; nonlinear behavior will cause out of plane distortions to the plot. Harmonic distortion, or responses at frequencies other than at the sinusoidal input frequency indicates a nonlinear system. Two methods that detect harmonic distortions are the beat frequency locus method and the SIG-function method. One very promising new method involves the use of Hilbert Transforms. It is known that the real and imaginary parts of the frequency response function (FRF) of a linear system are directly related by a Hilbert transform. If the system is linear both the real and Hilbert transformed response functions can be overlaid on a single plot. Nonlinearities will show up as two separate curves.

My goal in writing this note is to make the modal testing community more aware of potential problems arising out of ignoring the nonlinear nature of structures. My somewhat philosophical point of view is that one can't change the nonlinear response of a structure into a linear response. But, one can make the response appear to be more or less nonlinear depending on one's choice of shaker, fixture, excitation method, data processing and data analysis method.

JGS

EDITORS RATTLE SPACE

ON THE DEVELOPMENT OF MACHINE VIBRATION STANDARDS

Through my contacts with many vibration engineers and technicians I have found a growing need for vibration standards on measurement and analysis techniques and on acceptable levels for specific machine types. Existing machinery vibration standards, developed in the early seventies, do not reflect the data analysis capabilities of today. These standards are for general machinery having *once-per-revolution* problems. The fact that machines have rotors, bearings, and structures of diverse dynamic characteristics means that there are wide differences in their response to mechanical defects. Since present machinery vibration standards give similar acceptable overall levels for all equipment based on once per rev defects, condition cannot be adequately judged by these documents. The measured overall amplitude of vibration whether it is RMS or Peak cannot be used to evaluate machine condition on an absolute basis. Therefore, spectrum analysis must be performed to determine the condition of a machine when it is measured for the first time -- whether it is in service or new.

While work continues on machine standards by a dedicated few, the current pace will not yield badly needed standards for years. The present work is being performed under the sponsorship of the Acoustical Society of America by volunteers for the American National Standards Institute Committee on Mechanical Vibration and Shock -- S2. This group badly needs support from industry and government -- those who would use the standards. It is time to stop talking about the need and desirability of this work and start placing a committment that will aid in the development of standard procedures for vibration measurement and analysis and levels for judging the condition of machines. This would require support in travel and time for some experienced technical personnel. While several large companies have been supporting the standards efforts for years the companies who need the work most (manufacturers) have been absent from the work.

The next general meeting of the ANSI Committee S-2 on Mechanical Vibration and Shock will be held in New Orleans in October in conjunction with the Shock and Vibration Symposium. Committees on standards for machines, vehicles, and structures meet regularly at various locations around the U.S.A. If you are interested in this program and attending these important meetings to offer your technical expertise, please call me and I will direct you to the proper committee.

R.L.E.

DYNAMIC BALANCING WITH MICRO PROCESSORS

D.G. Stadelbauer*

Abstract. This article discusses the advantages of balancing using a micro processor. The balancing procedure is outlined and illustrated.

As is the case in so many other areas of industry, dynamic balancing is being invaded by micro processors. In fact, there is probably no balancing machine under development that will not be controlled by a micro processor. To the user this means greater operating convenience due to the versatility of the software. It also means better control of the balancing operation through the creation of a permanent record of initial unbalance, number of correction cycles (possibly including time), and residual unbalance. In turn quality control can be improved.

Quality control in balancing has been a much avoided subject. In the high-volume balancing practiced in the automotive and electric armature industry, residual unbalance can be spot checked on a separate (manual) inspection machine for every tenth part or after a certain period of operation; in low-volume or repair balancing balance checks are seldom done. The balancing machine and its operator are relied on to do a good job. If they don't, problems may or may not be discovered when the assembled product is tested for excessive vibration. A typical case is the airline industry; engines are rebalanced every time they are overhauled. After the engine is reassembled, it is run in a test cell. Rejection at that point due to excessive unbalance is costly because disassembly, rebalancing, and reassembly must be repeated. Jet engine manufacturers and users were thus among the first to recognize the advantage of computerized balancing.

Less sophisticated manufacturing and repair operations usually have no proof of residual unbalance. Work that comes off other machine tools is carefully checked, but no verification of residual unbalance is done on parts having undergone a balancing operation. Part of the reason has been that relatively inexpensive tools such as a micrometer can be used to check machining tolerances; however, a balance check of a rotor requires another balancing machine. Because one balancing machine can usually handle the output of an entire shop full of machine tools, there usually is no second machine for balance quality control. Neither is it economical to have an inspector verify the work of operators on every rotor. But that is exactly what a micro processor can do! It will record the balancing operation on every rotor from beginning to end and then provide a printout as permanent proof that the desired quality was achieved.

Quality control is only one of many advantages offered by a micro processor-controlled balancing machine. Other soft- and hardware features make life easier for the operator, speed up the process, or provide capabilities that did not exist before.

PROCEDURES

The illustrations below show some typical micro processor-controlled instruments for indicating unbalance.

Indication of unbalance. The primary purpose of a balancing machine is to indicate the amount and angular location of unbalance, usually in two preselected correction planes. Therefore, the digital readout of these values dominates the front panel; balancing speed is indicated in the center. Such an indication is important to assure the proper sensitivity range and also because rotor unbalance can vary with speed.

Simplification of setup. A balancing machine senses all unbalances in a rotor; they are resolved into the two bearing planes. Because unbalance correction rarely takes place in the bearing planes, the measured values must be translated into two other rotor planes where mass can be added or subtracted more easily. For this purpose the instrument in Figure 1 displays six rotor configurations; they represent all possible bearing plane/correction plane locations.

The operator selects the pertinent configuration and keys in the A-B-C dimensions (i.e., distances between bearings and correction planes) and the correction radii R_1 and R_2 (see Figure 2).

***Executive Vice President, Schenck Trebel Corporation, Deer Park, NY 11729**

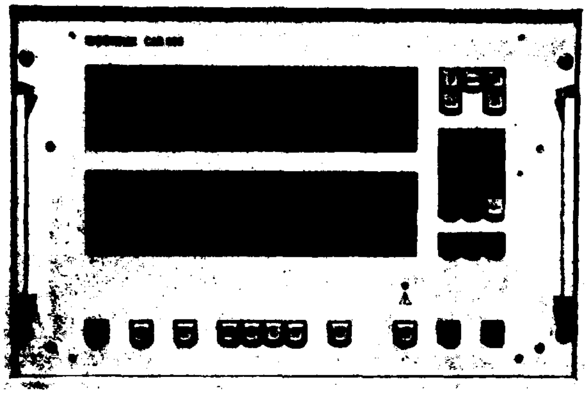

Figure 1. Unbalance Indicating Instrument for Hard-bearing Balancing Machine, with Rotor Diagrams for A-B-C Setting

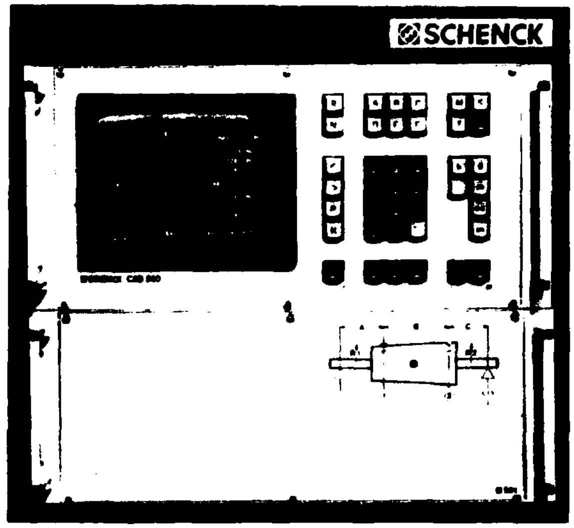

Figure 3. Unbalance Indication Instrument for Hard-bearing Balancing Machine with CRT for Digital as well as Vectorial Display of Unbalance Data

Figure 2. A-B-C Settings and Correction Radii (Replace Amount and Angle Readouts from Figure 1)

The amount and angle indications of unbalance now refer to the selected correction planes in the rotor. Setting need never be repeated for a given rotor size because it can be assigned a rotor file number and stored in memory. If the same size rotor is to be balanced at some future date, only the file number need be recalled via the keyboard.

Vectorial unbalance indication. The CRT screen on the instrument in Figure 3 permits simultaneous digital indication of unbalance (amount and angle in two planes) with a vectorial display as shown in Figure 4. The half-circle/dot symbols [(· and ·)] show the left and right unbalance in a 90° coordinate system. This display also represents the location of the principal inertia axis as it intersects each correction plane. The central zero point then represents the shaft axis.

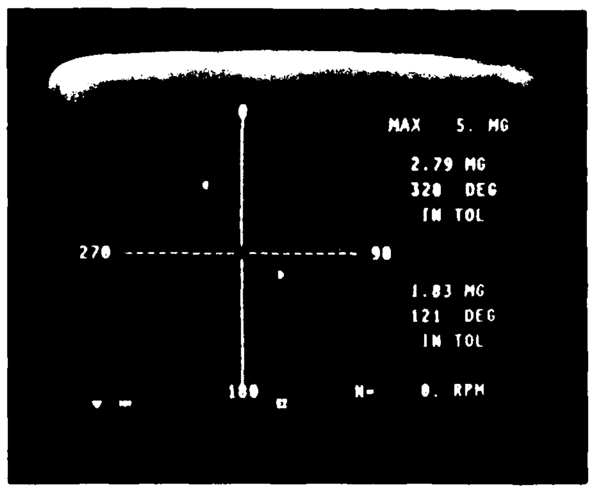

Figure 4. Amount and Angle of Unbalance Shown in Both Digital and Vectorial Form. Also Shown are Balance Tolerance and Balancing Speed

Component indication. Unbalance is not always most conveniently indicated in terms of amount and angle in each plane. It is sometimes more convenient to indicate unbalance components that relate directly to certain locations in a rotor correction plane in which prefabricated weights can be added or holes drilled. The micro processor then can be set up to indicate the amount of correction required at each of two component positions in each plane (see Figure 5).

Because rotor design can provide for any number of components per correction plane, the applicable number is keyed in by the operator along with the start angle of the first component (see last line of Field 2 in Figure 5). The amount indicated in the right plane, where correction is to be made, consists of two quantities (Pos. 10: 11.7 grams and Pos. 11: 9.19 grams) and no angle. The tolerance indications T1 and T2 at the bottom of Field 5 show that the initial unbalance represents 89.1 times the balance tolerance in the left plane and 51.3 times the tolerance in the right plane.

Soft-bearing machine calibration. Soft-bearing machines do not have the permanent calibration feature of hard-bearing machines; therefore, they must be individually calibrated for rotors of different weight and configuration. A micro processor-controlled instrument can do the calibration by establishing two influence coefficients (one for each correction plane) based on three runs at a precisely repeated speed: in run 1, rotor is in an as is condition; in run 2, a calibration weight of known value is added in the left correction plane; in run 3, a calibration weight of known value is added in the right correction plane (left weight removed).

After the values and units (grams, ounces) as well as the locations of the calibration weights have been entered, the instrument will read out the initial unbalance in terms of the same units and angle reference system. The influence coefficients can be stored in memory under a designated rotor file number. If that file is recalled at a later date, the initial unbalance of a rotor with the same weight and configuration can be measured in the first run. This type of instrument can also be used to upgrade any older style soft-bearing machine.

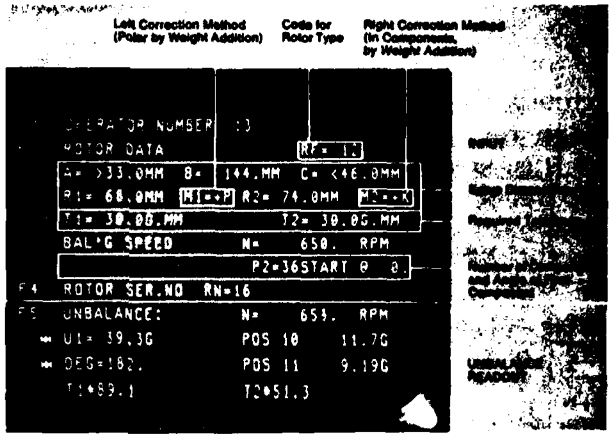

Figure 5. Setup Data (Fields F1-F4) and Unbalance Readout (F5) on CRT. Left Plane Correction in Polar Form, Right Plane Correction in Components

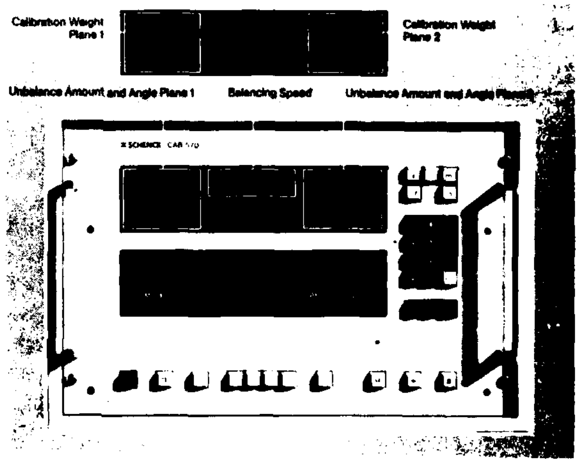

Figure 6. Unbalance Indicating Instrument for Soft-Bearing Balancing Machine. Included are Calibration with Known Trial Masses and Storage of Influence Coefficients

ADVANTAGES

Accuracy of indication. The micro processor is not a cure all insofar as accuracy is concerned. It provides mathematically accurate signal processing over an almost unlimited range but cannot overcome errors introduced by the mechanical components of the machine and the unbalance sensors, usually velocity type pickups, piezo crystals, or magneto-strictive transducers. The mechanical components in the rotor support system are particularly critical: they must provide a linear response to unbalance and therefore have no play or friction. Otherwise, the accuracy of the subsequent signal processing is defeated. The old computer axiom holds: garbage in - garbage out!

Accuracy in balancing refers to the ability of a machine to indicate the initial unbalance within a given plus/minus variation; it does not refer to the smallest unbalance a machine can detect. The latter is called the minimum achievable residual unbalance, or U_{mar}. It is stated in terms of gram·inches or ounce·inches. Alternately, it is expressed as minimum achievable residual specific unbalance in terms of inches displacement of the center of gravity, or e_{mar}.

Performance. Performance of a balancing machine is expressed in terms of its unbalance reduction ratio (URR). The URR is generally stated as a percentage; it is the ability of a machine to reduce a given initial unbalance in a single correction step to the smallest possible residual unbalance. The URR capability of a given machine is generally enhanced by the use of a micro processor because of its mathematically correct signal processing capability. However, a lack of accuracy will defeat it.

Convenience features. Some of the more commonly available aids are given. Automatic sensitivity scale ranging is available. When a measuring run is started, the instrument finds the most sensitive scale containing the initial unbalance. Some units even provide independent ranging for each correction plane.

Amount can be indicated not only in grams or ounces but directly in practical correction units such as drill depth or designation of prefabricated weights. With plane translation dimensional data of the rotor can be changed after a measuring run to indicate unbalance in two different planes without the need for another run.

With automatic indexing the rotor can be stopped with the correction location at a predetermined position -- e.g., in front of the operator or under the point of a drill. Readout can be in terms of the angle between two sliding correction weights, assymetric components, or distribution of standardized correction weights. Password protection, software and hardware tests, and customized programs -- e.g., for statistical evaluation, quality audits, correction procedures, or connection to other peripherals or central computer -- are available. For flexible rotor balancing multiplane data acquisition is possible at several speeds, as are calculation of optimum set of correction weights, continuous refinement of influence coefficients, simulated correction with weighting factors, and modal shape plotting. Available for aerospace balancing is complete determination of mass properties; namely, center of gravity offset, products of inertia, inclination of principal inertia axis from design axis, and (with additional hardware) moment of inertia.

CONCLUSION

The micro processor has brought about rapid advances in balancing technology. It is hoped that this article will help industry recognize and accept the new capabilities of micro processor-controlled balancing machines.

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 reviews 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.

RESEARCH IN RAIL VEHICLE DYNAMICS — STATE OF THE ART

T.S. Sankar* and M. Samaha*

Abstract. A survey of the state of the art of research investigations in railway dynamics is presented. Emphasis is given to evaluating the dynamic response of rail vehicles subject to excitations arising from rail input. The nature of rail vehicles and the dynamic loads they experience are described. A review of rail vehicle models employing deterministic and stochastic forms of excitation due to track input is presented. Vehicles and trucks are generally modeled using linear and nonlinear formulations for response determination and stability evaluation. Methods for solving such mathematical models as nonlinear systems under stochastic excitation are briefly described. Optimization techniques utilized in the design solution of the problems are reviewed.

During the past two decades, effort in rail vehicle dynamics has been directed to the development of design concepts including analytical solutions, computer simulations, experimental techniques, and operating strategies. A comprehensive review of some of these efforts has been presented [1, 2]. The introduction of new concepts in the design of suspensions has not been without problems. The loads imposed on moving car bodies result from intercar coupler forces and forces arising from wheel-rail interaction. At high speed wind forces are also significant. Track-induced rail-input forces can be derived from: a) lateral and vertical variations of rails due to rail joints, subgrade changes, rail-tie material characteristics, rail design, and rail spacing; b) flange forces that occur on curves; and c) friction forces at the wheel rail interface. Vehicle responses to these excitations are dictated by such dynamic characteristics of the vehicle as mass, suspension elements, and vehicle geometry; elasticity and dynamics of track structure; wheel-rail interactions; and operating conditions.

Railway vehicles are comprised of a car body supported by trucks at each end through a secondary suspension system. Each truck frame in turn has two wheel-axle sets mounted through a primary suspension system. The wheels are rigidly fixed to the axle and are tapered or profiled to provide a self-centering action as the axle traverses the track. The performance objectives for the rail vehicle suspension system as defined by early researchers [3, 4] are to provide: appropriate support for the vehicle, sufficient traction capability, guidance with adequate stability, and effective vibration isolation for passenger comfort and minimal freight damage. It is often desirable to minimize the dynamic fluctuations of guidance and support forces to minimize wear and damage to both vehicle components and track.

Railway dynamic research investigations dealing with these four objectives consider track structure, wheel-rail interface, truck stability, and overall vehicle dynamics. This survey focuses on vehicle dynamics. The conflict between suspension design and research directed at understanding design implications of such objectives are discussed. The nature of various investigations underway on track dynamics is briefly described in the following section.

TRACK STRUCTURE DYNAMICS

Research in track structure has been directed toward developing analytical techniques for predicting track behavior under service conditions. The goal of earlier research was to evaluate bending stresses in rails, cross-tie and ballast, and ballast and subgrade [5, 7]. Such investigations provided a tool for estimating the rate of track deterioration and for establishing such dynamic properties of track as stiffness and damping. Other important criteria include specification of the temperature above which buckling of a continuously welded rail will occur and the response of track subjected to temperature changes due to train movement.

Mathematical models include a weightless beam on a Winkler foundation, a beam of uniform weight resting on a rigid base, and finite element configurations of linear and nonlinear track systems [5, 6, 8]. Analysis of steady-state responses of continuously supported rail including

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damping have been carried out when axial forces due to temperature changes and moving loads are present. Analytical models for studying track dynamics and a lumped parameter model of the track are available [9, 10, 13]. Test data for evaluating track performance in a statistical sense and providing quantitative measurements of track performance under known conditions of track construction and loading have also been published [9-12].

The dynamic forces transmitted through the contact area between wheel and rail contain vertical, lateral, and longitudinal components. The vertical component has been well established with experimental and mathematical models using a simple continuous elastic foundation model [14]. The precise source of excitation for lateral vibration is not as readily apparent as that for vertical motion. Investigations [9, 11] relate the lateral motion to coupling with vertical excitation caused by a corrugated running surface through the conicity of the wheel.

Experiments [11] have shown that lateral curves of receptance obtained were strikingly similar in general character to vertical ones. It was suggested that simple continuous elastic foundation models developed for vertical motion could be adopted for lateral motion also. These investigators [11] concluded that, by a suitable choice of parameters, the lateral receptance of both wooden and concrete sleepered track can, in fact, be predicted from simple models. Theoretical and experimental responses due to longitudinal forces have been evaluated [12].

The results of extensive measurements of dynamic loads employing both wayside and onboard instrumentation have been summarized [10, 14]. Statistical analyses are presented and techniques for predicting extreme value loads and for extrapolating the load environment for other track traffic and operating conditions are described.

WHEEL RAIL INTERFACE INVESTIGATIONS

Exact knowledge of the location of wheel-rail contact points is important. It is at these contact points that vehicle-rail interaction forces are applied. Decuypere [15] modified an earlier method for predicting double contact between wheel and rail on the tread and on the flange. Investigators [16-18] have described analytical models and their experimental verification to determine the relations between wheelset steady state force and displacement. These analyses also include nonlinear geometric constraints that characterize wheel/rail contact, creep forces in the contact plane due to wheel/rail differential velocities, limits on adhesion at each contact point, and equilibrium conditions that apply to wheelset body forces.

Theoretical estimations for spin creep and motion of a railway wheel on a straight track have been presented [19-21]. Linearization techniques have also been effectively employed to predict the response of nonlinear wheel-rail systems [22, 23]. Hedrick and Castelaza [22] treated the problem under stochastic excitation due to random track alignment irregularities. Their lateral wheelset model included a large contact angle, wheel/rail geometric nonlinearities, and nonlinear creep force saturation effects. The rms response of the system was accurately predicted using statistical linearization; the onset of hunting was determined with surprising accuracy.

Criteria for predicting wheel climb derailment under steady rolling conditions have been described [24, 25]. The criteria were developed analytically and verified using experimental wheelset model on a tangent track. Criteria for dynamic wheel-climb derailment were more complex than those for steady-state rolling conditions and were dependent on wheelset initial conditions, forward velocity, and duration of applied load. A mathematical model to analyze the dynamics of railway and road vehicles during grade crossing collisions has been developed [26]. The objective of this simulation study was to relate the probability of derailment to rail vehicle speed.

TRUCK STABILITY PROBLEMS

The guidance function of a conventional rail vehicle truck requires that the truck respond to specified heading changes of track with minimal steady-state error and a sufficiently small overshoot to avoid large contact. One problem associated with wheel-rail vehicles with conic or tapered wheels is hunting; hunting is the tendency of a vehicle to become dynamically unstable as a result of the motion of wheels on the track.

Lateral displacement of a set of wheel axles introduces a difference in rolling radii between the two wheels. For a pure rolling situation, a sinusoidal lateral motion or kinematic oscillation occurs. Creep forces, when present, also introduce friction forces; a transient response is then exhibited at the kinematic frequency. At low speeds this transient response may be damped out, but dynamic instability can occur at high speeds [27]. The instability is a limit cycle oscillation controlled by flange contact forces and slipping at the treads. Many studies have focused on the lateral dynamics of rail vehicles and the effects of truck parameters on the critical hunting speed; this is the speed at which dynamic instability begins [28-31].

The hunting phenomenon is aggravated by the fact that requirements of truck suspensions for a straight track [27] differ from those for curved track [32]. To obtain a high critical speed -- say greater than 60 mph, which is well within operating range -- the overall yaw stiffness of the truck should be high, and wheel treads should have a relatively low conicity (1/20 taper). However, this is incompatible with curing requirements, where yaw flexibility is necessary to avoid excessive flange forces. Furthermore, local wear at the wheel tread results in an increase in effective wheel conicity above the design value of 1/20.

Actual operating conditions thus tend to improve curving performance because of the tendency for flange forces to be reduced, but the effective increase in taper increases the hunting potential at lower speeds. This instability can excite large oscillations of a suspended car body. A rough ride and high flange impact forces are characteristics of truck instability. The potential for derailment at high speeds is thus real.

Research with regard to wheelset instability involves suspension characteristics and wheel-rail interaction. Suspension characteristics have been investigated with the objective of raising the critical hunting speed to an acceptable level while avoiding severe curving forces [28-30]. Wheel-rail interaction phenomena governing truck response, especially hunting, have also been studied. Linear mathematical models [33] cannot deal with a problem that was proven experimentally [31] to be nonlinear. Nonlinear analyses that consider the influence of contact geometry [29], axle load, track gage, and wheel profile on stability have been presented [30].

The stability of a truck with a torsionally flexible wheel has been investigated [28]. A stochastic model has been developed [34]. A number of efforts have been devoted to the stability of passenger trucks [35, 36]. Active suspension systems for stability considerations have been studied [37]. Examples of the ongoing experimental studies have been described [38-41].

VEHICLE SYSTEM DYNAMICS: MATHEMATICAL MODELS AND ANALYSIS

The major function of rail vehicle suspension system is to isolate a vehicle body from disturbances caused by train operation or track-led irregularities. This function is met in passenger vehicles by keeping the motions of the car body within the accepted range of human comfort. With freight vehicles, the car body motions are constrained so as not to damage cargo.

Modern heavy and high-volume freight cars have a high center of gravity; riding on tracks with uneven surfaces can set up harmonic resonant motions. The most important component of the motion results from surface variation in the track due to alternately staggered joints. Excessive car body roll motions of hopper cars are induced at speeds from 15-25 mph. Resonant conditions can literally lift wheels off the rail; derailment can occur. Severe car rocking produces wheel-track dynamic forces as great as two to three times nominal static force levels; rocking also causes car body-bolster forces that approach three times normal static magnitudes [64, 65]. Such large dynamic forces during severe rocking resonance conditions lead to gradual degradation of both track and equipment performance and thus directly affect vehicle operation and safety.

As early as 1926 the problem of excessive *rocking vibrations* of 70 ton hopper cars -- at that time considered high capacity -- was identified [42]. The relation between car rocking and rail-joint stagger was discussed; a theoretical treatment and possible remedies for minimizing excessive rocking of such high center of gravity cars were given. Experimental field investigations were later carried out by Pullman-Standard [43], American Association of Railroad (AAR) [44], Stuki Company [45, 46], Canadian National Railways [47, 48], and Southern Railway [49]; the objective was to prevent 100 ton hopper cars from frequency derailment. Four important dynamic phenomena can be summarized from these test results:

> When traveling at certain low speeds, cars with specified truck centers 39.5 feet (12.04 m) will rock violently enough to lift the wheel off both tangent and curved tracks; that is, the curvature does not significantly affect the rocking response of the vehicle.
>
> Such cars can rock independently or as a series; that is, rocking is independent of car-to-car coupling.

When excessive rocking is taking place and if the train slows, the amplitude of rocking tends to increase momentarily.

Such remedies as long travel springs with additional damping, introduction of lateral motion, and decreasing the side bearing distance by a certain amount tend to increase the stability of the system.

Recently the U.S. Department of Transportation in cooperation with the AAR established a major test facility at Pueblo, Colorado. The Vibration Test Unit (VTU) at the Rail Dynamics Laboratory was used to study the suspension characteristics of rail vehicles, vehicle natural frequencies, ride quality and comfort, component fatigue, and rock and roll tendencies [50]. The natural frequencies and vibration modes of 70 ton empty and fully loaded box cars were experimentally evaluated [51]. Quasi-static tests have been carried out to measure the stiffness and friction forces on a freight car truck [52].

A linear three-dimensional model of a freight car has been used to predict the basic responses of rail vehicles due to track inputs [43]. Rail inputs to this model were obtained using a graphical technique that characterizes rail disturbances as a function of truck-center distance for any desired rail length, wheel base, track profile, and rail stagger. The simplified linear equations of motion formulated for the three-dimensional model can be used only to determine car body rock or roll frequency and its dependence on roll amplitude. Such linear models in general do not yield reliable results, especially for describing the dynamic behavior associated with severe rocking conditions of a vehicle. During this rocking motion, the system nonlinearities arising from large vibratory motions cause separation of car body from center plate and wheels from rails. Liepins [53] proposed the first nonlinear model for such problems. His model included the nonlinear effects of separation of body from center plate and subsequent contact with side bearings as well as suspension friction damping effects. However, he neglected other important nonlinearities due to wheel lift, gib stops contact, and spring bottoming. The type of input function used in the model simulation is not clearly defined in the paper but seems to have been taken from previous experimental measurements of track irregularities specified as a function of time.

Mecham and Ahlbeck [54] studied a similar nonlinear model under periodic excitation and discussed the dynamic loads due to wheel-rail interactions. They presented the effects of various track structure parameters on dynamic loads and the resulting stresses. However, they did not emphasize the reasons for the nonlinearities proposed in the mathematical model and did not describe the sensitivity of vehicle responses to variations in suspension parameters; consequently, no design solutions to the vehicle rocking problem were proposed.

Simplified mathematical models that have been investigated at Massachusetts Institute of Technology [55, 56] assume that a vehicle is either a two- or three-degree-of-freedom system excited by periodic rail input; nonlinear effects due to gib contact, bolster, and wheelset inertias are neglected. These models are used to study the magnitude and duration of wheel lift and the maximum loading exerted on the vehicle as a function of vehicle speed. The effects of suspension parameters on these loading conditions and on overall vehicle responses were not investigated.

Investigations carried out at the AAR [44] and Illinois Institute of Technology [57] describe the development of extremely complicated digital computer simulation programs to obtain rocking responses in the time domain under cross-level track variations. These complex models and others [58-63] require evaluation of as many as 20, 30, and sometimes 100, degrees of freedom under harmonic or other periodic excitations.

Development of an accurate mathematical model of a complete railroad freight vehicle that includes all nonlinearities and allows each mass six degrees of freedom poses a formidable computer simulation problem. It is thus advisable for practical reasons to seek compromise solutions using slightly simpler model formulations. Therefore, emphasis will have to be on reducing the degrees of freedom of system models to the specific dynamic performance under study. Nine degree of freedom nonlinear planar model have been successfully utilized by the authors [64, 65] to describe all the important vibration modes including the rocking mode of vibration of a vehicle. The model proposed places a reasonable demand on digital and analog computing resources to simulate results for the equations of motion; consequently, appropriate optimization techniques can be used to search for a practical solution to the rocking problem.

OPTIMAL SUSPENSION DESIGN

A few examples of the use of optimization techniques in the design of mechanical system are available [67]. Cases include gears, bearings, various machine elements, rotating discs, pressure vessels, shafts under bending and torsion, and problems of elastic contact and load distribution in an overall mechanical system. In the area of optimum design of vibration isolation systems one of the earliest problems investigated was the optimum design of dynamic absorbers for isolating vibrating equipment.

Den Hartog [68] presented functional relations for the absorber parameters that minimize the response of the main mass when it is subjected to sinusoidal excitation. Seireg and Howard [69] utilized a computer optimization algorithm to determine absorber parameters that minimize the mean square response of a main mass subjected to white noise or delta correlated random excitation. Other studies in design and optimization of multi-degree-of-freedom linear shock isolation systems in the literature are available [70-72, 75].

Kemper [76] proposed means for determining optimum damping in nonlinear systems subjected to shock loads. This attempt to locate near-optimum damping parameters seems to have been done manually by plotting response curves for various combinations of the system and for input parameters. McMunn [71] developed a more formal optimization technique for obtaining the multi-parameter optimum damping. He minimized the maximum of all possible resonant responses for a linear dynamical system. Examples include a continuous uniform column, a three-degree-of-freedom discrete system with two dampers, and a five-degree-of-freedom discrete system with three dampers.

Multi-variable optimization techniques have been applied to a linear model of a locomotive to obtain the minimax response of the system in a critical frequency range of practical interest [73]. Vertical and lateral linear suspension systems of a high speed vehicle subjected to guideway and aerodynamic inputs have been optimized [77]. A constrained optimization algorithm has been used to maximize the operating speed of 15-degree-of-freedom lateral dynamic model for a passenger rail car subject to random alignment irregularities [80].

Nonlinear programming techniques have been used to optimize a passive suspension as well as dynamic loads of a vehicle [81]. Minimizing the maximum dynamic response of nonlinear freight vehicle models by appropriately adjusting viscous and friction damping and spring rates were discussed by the authors [64, 66].

The minimax principle and available search algorithms [78, 79] for multi-variable optimization have been utilized to evaluate optimum design variables for an existing freight vehicle suspension system [64]. The algorithm has also been used to specify requirements for installing additional energy dissipation devices to reduce the risk of derailing. The objective function, in this case, is the maximum car rocking response over the critical frequency range of interest. The objective function is minimized when the vehicle is subjected to inputs generated from the rail track that are purely periodic or a combination of periodic and random. A review of earlier investigations for identifying the two types of input processes due to track irregularities, techniques for modeling these irregularities in a functional form, and available closed form and numerical techniques that can be adopted when a nonlinear vehicle system is subjected to such stochastic inputs are discussed in the following sections.

STOCHASTIC MODELING AND ANALYSIS

Earlier investigations [14, 82] described two forms of track irregularities in each homogeneous segment of rails -- namely, a deterministic periodic input process and a stationary random input process. Power spectral density is statistical measurement technique suited for describing both types. Previous investigations considered excitation of a rail vehicle system as purely periodic; however, study of the problem under both periodic and random conditions is essential to evaluate the contribution of each type to the dynamic response of the system.

Solutions for a proposed stochastic nonlinear model subject to both types of excitation have been reported using methods developed by the authors [101, 102]. The methods are sufficiently general for applications to other multi-degree-of-freedom mechanical systems subjected to similar types of random excitation. Examples of these applications vary from high-speed passenger vehicles (200-300 mph or 321.8 - 482.7 km/hr) under aerodynamic forces and guideway irregularities [83, 84] to machine tool systems excited by random cutting forces [85, 86] and high-rise buildings subjected to strong earthquake ground motions.

Solutions of a nonlinear system under periodic deterministic input processes often involve methods of numerical integration [87, 88]. However, the solution of a nonlinear stochastic model when excitations are represented as filtered white noise power spectral density requires a different approach.

Analytical techniques to solve multi-degree-of-freedom nonlinear systems under Gaussian white noise input have been discussed [89, 90]. One technique [89] utilizes the stationary Fokker-Planck equation [91, 92], which can be solved for the transitional probability density of system responses. The main advantage of the Fokker Planck method is that theoretically exact solutions can be obtained when excitations are in the form of Gaussian white noise. Unfortunately, the versatility of this approach is limited because of severe restrictions that must be placed on the form of nonlinearities present in the differential equation and on the spectral density matrix of the excitation process. Because an exact solution for response probability is available only for limited stationary cases, several other approximate approaches have been devised.

The normal mode approach originated by Caughey [93] involves computational difficulties. The perturbation method first developed by Crandall [94] can be applied to dynamic systems that have only weak nonlinearities and not to the problem under investigation here. The statistical linearization technique [95-97] is the best suited method for a variety of problems; it is therefore utilized in a modified form suitable for cases in which the stochastic forcing function appears as nonlinear force vectors in the governing equations [101, 102].

The statistical linearization approach has been shown to generate acceptable solutions [96] even for systems with fairly strong nonlinearities. This method involves defining an equivalent linear system by minimizing certain measurable differences between the original nonlinear system and the equivalent linear system. Analytical procedures for obtaining the instantaneous correlation matrix for the response of the equivalent system have been described [98, 99]. The solution generally requires excessive algebraic computation because it involves an inversion of $n^2 x n^2$ matrix when there exist n state variables for the system. A numerical technique developed by Davison and Man [100] and successfully used to solve a Liapunov system of equations [77] has been utilized by the authors [101, 102] to minimize computer time and storage.

SUMMARY

A comprehensive literature survey has been presented on the subject of rail vehicle dynamics. The performance objectives of rail vehicle suspension are discussed. Research in the areas of track structure, wheel-rail interface, truck stability, and vehicle dynamics are presented. Emphasis is given to analytical methods for obtaining the dynamic response of rail vehicles. Methods for tackling nonlinear models under stochastic excitation are briefly described.

REFERENCES

1. Cooperrider, N.K., Law, E.H., Fries, R.H., and Tsai, N.T., "Theoretical and Experimental Research on Freight Car Lateral Dynamics," Proc. Heavy Haul Railways Conf., Perth, Western Australia (1978).

2. Cooperrider, N.K. and Law, E.H., "A Survey of Rail Vehicle Testing for Validation of Theoretical Dynamic Analyses," J. Dynam. Syst., Meas. Control, Trans. ASME, 100, pp 238-251 (1978).

3. Law, H.E. and Cooperrider, N.K., "A Survey of Railway Vehicle Dynamics Research," J. Dynam. Syst., Meas. Control, Trans. ASME, pp 132-146 (1974).

4. Bhatti, M.H. and Garg, V.K., "A Review of Railway Vehicle Performance and Design Criteria," Intl. J. Vehicle Des., 5 (1/2), pp 232-254 (1984).

5. Mecham, H.E. and Ahlbeck, D.R., "A Computer Study of Dynamic Loads Caused by Vehicle-Track Interaction," J. Engrg. Indus., Trans. ASME, pp 808-816 (1969).

6. Keer, A.D., "Elastic and Viscoelastic Foundation Models," J. Appl. Mech., Trans. ASME, pp 491-498 (1964).

7. Salem, M.T. and Hay, W.W., "Vertical Pressure Distribution in the Ballast Section and on the Subgrade beneath Statically Loaded Ties," Civil Engrg. Studies, Transportation Series No. 1, University of Illinois (1966).

8. Korr, A.D., "Viscoplastic Winkler Foundation with Shear Interaction," ASCE J. Engrg. Mech., 87, pp 13-30 (1961).

9. Helms, H. and Strothmann, W., "Lateral Rail Irregularities -- Measurement and Application," Proc. 6th IAVSD-Symp., Berlin (1979).

10. Ahlbeck, D.A., "Predicting the Load Environment on Railroad Track," ASME Paper No. 80-RT-7 (1980).

11. Grassie, S.L., Gregory, R.W., and Johnson, K.L., "The Dynamic Response of Railway Track to High Frequency Lateral Excitation," J. Mech. Engrg. Sci., 4 (2), (1982).

12. Grassie, S.L., Gregory, R.W., and Johnson, K.L., "The Dynamic Response of Railway Track to High Frequency Longitudinal Excitation," J. Mech. Engrg. Sci., 24 (2), (1982).

13. Manke, P., Henhenberger, W., Perger, K., and Gruber, J., "Track Dynamics at High Vehicle Speeds," Proc. 6th IAVSD Symp., Berlin (1979).

14. Corbin, J.C. and Kaufman, W.M., "Classifying Track by Power Spectral Density," Proc. ASME Symp. Mech. Transportation Suspension Syst., AMD-Vol. 15, pp 1-20 (1975).

15. Decuyper, M., "Geometry of Wheel-Rail Contact: Extended Envelope Method," Intl. J. Vehicle Des., 61.4 (1), pp 36-52 (1982).

16. Elkins, J.A. and Eickhoff, B.M., "Advances in Nonlinear Wheel/Rail Force Prediction Methods and Their Validation," J. Dynam. Syst., Meas. Control, Trans. ASME, 104 (1982).

17. Sweet, L.M. and Sivak, J.A., "Nonlinear Wheelset Forces in Flange Contact. Part I: Steady State Analysis and Numerical Results," J. Dynam. Syst., Meas. Control, Trans. ASME, 101 (1979).

18. Sweet, L.M., Sivak, J.A., and Putman, W.F., "Nonlinear Wheelset Forces in Flange Contact. Part II: Measurement Using Dynamically Scaled Models," J. Dynam. Syst., Meas. Control, Trans. ASME, 101 (1979).

19. Burton, T.D., "Influence of Wheel/Rail Contact Geometry on Large Amplitude Wheelset Equations of Motion," J. Dynam. Syst., Meas. Control, Trans. ASME, 103 (1981).

20. Newland, D.E., "On the Time-dependent Spin Creep of a Railway Wheel," J. Mech. Engrg. Sci., 24 (2), (1982).

21. De Pater, A.D., "The Exact Theory of the Motion of a Single Wheelset Moving on a Perfectly Straight Track," Proc. 6th IAVSD Symp., Berlin (1979).

22. Hedrick, J.K. and Castelazo, "Statistical Linearization of the Nonlinear Rail Vehicle Wheelset," Proc. 6th IAVSD Symp., Berlin (1979).

23. Hanschild, W., "The Application of Quasilinearization to the Limit Cycle Behavior of the Nonlinear Wheel-Rail System," Proc. 6th IAVSD Symp., Berlin (1979).

24. Sweet, L.M. and Karmel, A., "Evaluation of Time-Duration Dependent Wheel Load Criteria for Wheelclimb Derailment," J. Dynam. Syst., Meas. Control, Trans. ASME, 103 (1981).

25. Sweet, L.M., Karmel, A., Moy, P.K., "Wheel Climb Derailment Criteria under Steady Rolling and Dynamic Loading Conditions," Proc. 6th IAVSD Symp., Berlin (1979).

26. Cherchas, D.B., English, G.W., Ritchie, N., McIlveen, E.R., and Schwier, C., "Prediction of the Probability of Rail Vehicle Derailment during Grade Crossing Collisions," J. Dynam. Syst., Meas. Control, Trans. ASME, 104 (1982).

27. D'Souza, A.F. and Caravavatna, P., "Analysis of Nonlinear Hunting Vibrations of Rail Vehicle Trucks," J. Mech. Des., Trans. ASME, 102, (1980).

28. Doyle, G.R. and Prause, R.H., "Hunting Stability of Rail Vehicles with Torsionally Flexible Wheelsets," J. Engrg. Indus., Trans. ASME (1977).

29. Hull, R. and Cooperrider, N.K., "Influence of Nonlinear Wheel/Rail Contact Geometry on Stability of Rail Vehicles," J. Engrg. Indus., Trans. ASME, 99 (1), pp 172-185 (1977).

30. Hannebrink, D.N., Lee, H.S.A., Weinstock, H., and Hedrick, J.K., "Influences of Axle Load, Track, Gage and Wheel Profile on Rail-Vehicle Hunting," J. Engrg. Indus., Trans. ASME (1977).

31. Horak, D. and Wormley, D.N., "Nonlinear Stability and Tracking of Rail Passenger Trucks," Trans. ASME, 104, (1982).

32. Weinstock, H. and Greif, R., "Analysis of Wheel Rail Force and Flange Force during Steady State Curving of Rigid Trucks," ASME Paper No. 81-RT-5 (1981).

33. Michelbergar, P., Simonyi, A., and Ferenczi, M., "Lateral Running Quality and Stability Design of Railway Carriages," Intl. J. Vehicle Des., 3 (4), pp 424-435 (1982).

34. Cooperrider, N.K., "Railway Truck Response to Random Rail Irregularities," J. Engrg. Indus., Trans. ASME (1975).

35. Horak, D. and Wormley, D.N., "Nonlinear Stability and Tracking of Rail Passenger Trucks,"

J. Dynam. Syst., Meas. Control, Trans. ASME, 104, p 256 (1982).

36. Doyle, G.R., "Conventional vs Self-Steering Radial Trucks for High-Speed Passenger Trains," J. Dynam. Syst., Meas. Control, Trans. ASME, 104, p 290 (1982).

37. Sinha, P.K., Wormley, D.N., and Hedrick, J.K., "Rail Passenger Vehicle Lateral Dynamic Performance Improvement through Active Control," J. Dynam. Syst., Meas. Control, Trans. ASME, 100, p 270 (1978).

38. Elkins, J.A. and Allen, R.A., "Verification of a Transit Vehicle's Curving Behavior and Projected Wheel/Rail Wear Performance," J. Dynam. Syst., Meas. Control, Trans. ASME, 104, pp 247 (1982).

39. Marcotte, P., Caldwell, W.N., and List, H.A., "Performance Analysis and Testing of a Conventional Three-Piece Freight Car Truck Retro-fitted to Provide Axle Steering," J. Dynam. Syst., Meas. Control, Trans. ASME, 104, p 93 (1982).

40. El Madany, M.M. and Ramachandran, P.V., "Lateral Stability of Flat Rail Cars -- An Over-the-Road Investigation," Intl. J. Vehicle Des., 2 (2), pp 162-173 (1981).

41. Fries, R.H., Cooperrider, N.K., and Law, E.H., "Experimental Investigation of Freight Car Lateral Dynamics," J. Dynam. Syst., Meas. Control, Trans. ASME, 103, p 201 (1981).

42. Leffler, B.R., "The Relation between the Swaying of Hopper Car and Stagger of Rail Joint in Track," AREA Proc., 27, (1926).

43. Manos, W.P. and Shang, J.C., "Dynamic Analysis of Rolling Freight Cars," ASME, Anthol. Rail Vehicle Dynam., 2, pp 135-145 (1972).

44. "Harmonic Roll Series," Track Train Dynam. Project Rept., Assoc. Amer. Railroads (1975).

45. Weibe, D., "The Effects of the Lateral Instability of High Center of Gravity Freight Cars," J. Engrg. Indus., Trans. ASME, 90B (4), pp 727-736 (Nov 1968).

46. "Computer Simulation of the Response of 70 Ton Box Cars," A Stucki Co. Rept., Pittsburgh, PA (1970).

47. Henderson, K.A. and Johnson, J., "A Criterion for the Control of 100-ton Hopper Car Roll Motion," J. Engrg. Indus., Trans. ASME, 90B (4), pp 717-724 (Nov 1968).

48. Scott, J.F., Johnson, J., and Charenko, A., "Roll Motion of 100-ton Hopper Cars," summary of test work, Canadian Natl. Railways, Montreal (Sept 1969).

49. Reynolds, D.J. and Blank, R.W., "A Car Rocking Mechanism," ASME Paper No. 77-WA/-RT-11 (Nov 1977).

50. Rajkumar, B.R., Irani, F.D., and Orth, C.L., "Replication of Revenue Track Input Using Vibration Test Unit for Freight Car Structure and Loading Damage Evaluation," J. Engrg. Indus., Trans. ASME, 106, pp 1-10 (1984).

51. Orth, C.L. and Kachadourian, G., "Vibration Modes of a 70-Ton Box Car," J. Engrg. Indus., Trans. ASME, 106, pp 21-27 (1984).

52. Kachadourian, G., Orth, C.L., and Inskeep, D.W., "Stiffness and Friction Force Measurement on a Freight Car Truck from Quasi-Static Tests," J. Engrg. Indus., Trans. ASME, 106, pp 16-20 (1984).

53. Liepins, A.A., "Digital Computer Simulation of Railroad Freight Car Rocking," J. Engrg. Indus., Trans. ASME, 90B (4), pp 701-707 (1968).

54. Mecham, H.C. and Ahlbeck, D.R., "A Computer Study of Dynamic Loads Caused by Vehicle-Track Interaction," J. Engrg. Indus., Trans. ASME, pp 808-816 (Aug 1969).

55. Emerson, G., "Freight Car Rocking Dynamics Using Analog Simulation," Dissertation, Massachusetts Institute of Technology (1975).

56. Platin, B.E. and Beaman, J.J., "Computational Methods to Predict Rail Car Response to Track Cross-Level Variation," DOT Final Rept., No. FR-OR and D-76-293 (1976).

57. Willis, T. and Shum, K., "A Nonlinear Mathematical Model of the Dynamics of a Railroad Freight Car/Freight Element," ASME Paper No. 76-DE-42 (Apr 1976).

58. Willis, T., "Nonlinear Analysis of Rail Vehicle Dynamics Survey of Rail Vehicle Dynamics Research," I.I.T. RI, Chicago, IL, Rept. No. 111-60616 (1976).

59. Healy, M.J., "A Computer Method for Calculating Dynamic Responses of Nonlinear Flexible Rail Vehicles," ASME Paper No. 76-RT-5 (Apr 1976).

60. Hedrick, J.K., "Simulation and Analysis of Rail Vehicle Dynamics," Mini-Conf. Transportation, Univ. Michigan, Ann Arbor (Apr 20-22, 1977).

61. Hedrick, J.K., Cooperrider, N.K., and Law, E.H., "The Application of Quasi-Linearization to Rail Vehicle Dynamics," Final Rept., Transportation System Center, U.S. Dept. Trans., Cambridge, MA (Mar 1977).

62. Hussain, S.M.A. and Garg, S.P., "Users Manual: Flexible Car Body Vehicle Model," Version 2, Assoc. Amer. Railroads, Res. Rept. No. R-372, Chicago, IL (Apr 1979).

63. Hussain, S.M.A., Garg, V.K., and Singh, S.P., "Harmonic Roll Response of a Railroad Freight Car," ASME Paper No. 80-RT-2 (1980).

64. Samaha, M. and Sankar, T.S., "Dynamic Rocking Response and Optimization of the Nonlinear Suspension of a Railroad Freight Car," J. Mech. Des., Trans. ASME, 102, pp 86-93 (1980).

65. Samaha, M. and Sankar, T.S., "An Analog Simulation Study of the Rocking Response of a Railroad Freight Vehicle," J. Sound Vib., 63 (1), pp 109-124 (1979).

66. Samaha, M., "Dynamic Response and Optimization of a Railroad Freight Car under Periodic and Stochastic Excitation," Doctor of Engineering Thesis, Concordia University (1978).

67. Seireg, A., "A Survey of Optimization of Mechanical Design," J. Engrg. Indus., Trans. ASME, 94B (1), pp 495-499 (May 1972).

68. Den Hartog, J.P., Mechanical Vibrations, 4th Ed., McGraw-Hill, New York (1956).

69. Seireg, A. and Howard, L., "An Approximate Normal-Mode Method for Damped Lumped-Parameter Systems," J. Engrg. Indus., Trans. ASME, 89B (4), pp 597-604 (Nov 1967).

70. Liber, T. and Sevin, E., "Optimal Shock Isolation Synthesis," Shock Vib. Bull., U.S. Naval Res. Labs., Proc. No. 35, Pt. 5 (1966).

71. McMunn, J.C., "Multi-Parameter Optimum Damping in Linear Dynamical Systems," Ph.D. Thesis, University of Minnesota (1967).

72. Nelson, J.A. and Hapemann, M.J., "A New Transient Propulsion Unit Suspension-Proved on Northeast Corridor High-Speed Test Cars," J. Engrg. Indus., Trans. ASME, 91B (3), pp 897-907 (Aug 1966).

73. Elmaraghy, W.H., Dokainish, M.A., and Siddall, J.N., "Minimax Optimization of Railway Vehicle Suspension," ASME Paper No. 74-WA/RT-3 (Nov 1974).

74. Sewall, J.L., Parrish, R.L., and Durling, B.J., "Rail Vehicle Dynamic Studies," Shock Vib. Bull., U.S. Naval Res. Labs., Proc. No. 40, Pt. 6, pp 109-126 (Dec 1969).

75. Sevin, E. and Pilkey, W.D., "Optimum Shock and Vibration Isolation," Shock Vib. Information Ctr., U.S. Dept. Defense, No. SVM6, pp 105-114 (1971).

76. Kemper, J., "Optimization Damping in Nonlinear System Subjected to Shock Load," Ph.D. Thesis, University of Colorado (1969).

77. Hedrick, J.K., Billington, G.F., and Dreesbach, D.A., "Analysis Design and Optimization of High Speed Vehicle Suspension Using State Variable Technique," J. Dynam. Syst., Meas. Control, Trans. ASME, 96G (2), pp 193-203 (June 1974).

78. Jacoby, S.L.S., Kowalik, J.S., and Pizzo, J.T., Iterative Methods for Nonlinear Optimization Problems, Prentice-Hall, NJ, pp 71-79 (1972).

79. Kowalik, J. and Osborne, M.R., Methods for Unconstrained Optimization Problems, Prentice-Hall, NY, pp 22-24 (1968).

80. Cox, J.J., Hedrick, J.K., and Cooperrider, N.K., "Optimization of Rail Vehicle Operating Speed with Practical Constraints," J. Dynam. Syst., Meas. Control, Trans. ASME, 100, pp 260 (1978).

81. Xiao-Pei lu, Li, Heng-Lung, and Papalambros, P., "A Design Procedure for the Optimization of Vehicle Suspension," Intl. J. Vehicle Des., 5 (1/2), pp 129-142 (1984).

82. Sayers, M. and Hedrick, J.K., "Railroad Track Description," Modified excerpt for a final Rept., U.S. D.O.T., Univ. Res. Contract DOT-OS-50107.

83. Kotb, M., Sankar, T.S., and Samaha, M., "Suspension Bounce Response of Canadian MAGLEV Vehicle under Guideway Excitation. Part I: Deterministic Analysis," J. Vib., Acoust., Stress Rel. Des., Trans. ASME, 105 (2), pp 261-266 (1983).

84. Kotb, M., Sankar, T.S., and Samaha, M., "Suspension Bounce Response of Canadian MAGLEV Vehicle under Guideway Excitation. Part 2: Stochastic Modeling and Analysis," J.

Vib., Acoust., Stress Rel. Des., Trans. ASME, 105 (2), pp 261-266 (1983).

85. Samaha, M. and Sankar, T.S., "Dynamic Acceptance Test for Machine Tools Based on a Nonlinear Stochastic Model," J. Mech. Des., Trans. ASME, 102, pp 58-63 (1980).

86. Sankar, T.S., "A Reliability Estimate for Machine Tool Spindles Subjected to Random Forces," J. Mech. Mach. Theory, 10, pp 131-138 (1975).

87. Lapidus, L. and Seinfeld, J.H., Numerical Solution of Ordinary Differential Equations, Academic Press, NY, pp 39-150 (1971).

88. Milne, W.E., Numerical Solution of Differential Equations, John Wiley & sons Inc., NY, pp 72-93 (1962).

89. Lin, Y.K., Probabilistic Theory of Structural Dynamics, McGraw-Hill, NY, pp 164-172 (1967).

90. Atalik, T.S. and Utku, S., "Stochastic Linearization of Multi-Degree-of-Freedom Nonlinear Systems," Intl. J. Earthquake Engrg. Struc. Dynam., 4, pp 411-420 (1976).

91. Caughey, T.K., "Derivation and Application of the Fokker-Planck Equation to Discrete Nonlinear Dynamic Systems Subjected to White Random Excitation," J. Acoust. Soc. Amer., 35 (11), pp 1683-1692 (Nov 1963).

92. Ariaratnam, S.T., "Random Vibrations of Nonlinear Suspensions," J. Mech. Engrg. Sci., 2 (3), pp 195-201 (1960).

93. Caughey, T.K., "Equivalent Linearization Techniques," J. Acoust. Soc. Amer., 35 (11), pp 1706-1711 (Nov 1963).

94. Crandall, S.T., "Perturbation Techniques for Random Vibration of Nonlinear Systems," J. Acoust. Soc. Amer., 35 (11), pp 1700-1705 (Nov 1963).

95. Foster, E.T., "Semi-linear Random Vibrations in Discrete Systems," J. Appl. Mech., Trans. ASME, 90E (3), pp 560-564 (Sept 1968).

96. Yang, I.M., "Stationary Random Response of Multi-degree-of-freedom Systems," Ph.D. Thesis, California Institute of Technology (June 1970).

97. Iwan, W.D. and Yang, I.M., "Application of Statistical Linearization Techniques to Nonlinear Multi-degree-of-freedom Systems," ASME Paper No. 71-WA-APM-5.

98. Gresch, W., "Mean-Square Responses in Structural Systems," J. Acoust. Soc. Amer., 48 (1), Pt. 2, pp 403-413 (July 1970).

99. Yang, I.M. and Iwan, W.D., "Calculation of Correlation Matrices for Linear Systems Subjected to Nonwhite Excitation," ASME Paper No. 71-APMW-10.

100. Davison, E.J. and Man, F.T., "The Numerical Solution of $A^TQ + AQ = -C$," Trans. Automatic Control, IEEE, AC-13, pp 448-449 (Aug 1968).

101. Samaha, M. and Sankar, T.S., "Stochastic Analysis of Railroad Freight Car Rocking Problem. Part I: Spectral Characterization of Track Input and System Analysis," Tenth Biennial ASME Des. Engrg. Tech. Conf., Mech. Vib. Noise, Cincinnati, OH (Sept 1985).

102. Sankar, T.S. and Samaha, M., "Stochastic Analysis of Railroad Freight Car Rocking Problem. Part 2: Stochastic Response and Optimization of the Truck Suspension," Tenth Biennial ASME Des. Engrg. Tech. Conf. Mech. Vib. Noise, Cincinnati, OH (Sept 1985).

BOOK REVIEWS

INTRODUCTION TO DYNAMICS AND CONTROL

L. Meirovitch
John Wiley & Sons, New York, NY
1985, 392 pages

This is an excellent text for undergraduate courses in dynamics, vibrations, and control written by a well known educator in these areas. As the author states, the book is suitable when there is no room in the curriculum for three separate courses in dynamics of systems or when a unified approach is desired. The book contains 11 chapters in four parts and an appendix. The first part contains the mathematical background that serves the other three: dynamics, vibration, and control.

The first chapter deals with concepts from linear system theory. The concepts of open- and closed-loop control systems are explained using physical and engineering systems. Another concept is the principle of superposition as applied to linear differential equations. The solution of differential equations is treated in a general way through the impedance function, frequency response, and the transfer function. Response to excitations in the form of singularity functions is also treated.

The kinematics of a particle and rigid bodies are topics of chapter 2. The calculus of unit vectors is well demonstrated for various coordinate systems. The concepts of instantaneous center, space centrode, and body centrode are introduced. No physical interpretation of the Coriolis acceleration, which is often troublesome for undergraduate students, is provided.

Chapter 3 introduces the dynamics of a particle in terms of Newton's laws of motion, impulse, momenta, work, and energy. The motion of a particle in a central-forced field and orbits of planets and satellites are included. This chapter does not provide enough applications of Newton's second law to problems described in terms of curvilinear coordinate systems.

The background provided in the first three chapters will enable the reader to move smoothly to the dynamic response of first- and second-order systems, which are treated in chapter 4. The author has successfully arranged this chapter to serve vibrations and control. The explanations of free and forced responses of first- and second-order systems utilize both control and vibration terminologies. Such a format will help the student realize that the two subjects are not independent.

The dynamics of systems of particles presented in chapter 5 follows the same pattern as in the dynamics of a particle. In addition, the dynamics of a variable-mass system is analyzed with reference to rocket motion. The same treatment is extended to the motion of rigid bodies in chapter 6. The angular momentum of a rigid body is derived, as are the equations of motion. Special cases include planar motion of a rigid body, rotation of a rigid body about a fixed axis, and motion of a torque-free symmetric body. Gyroscopic motion is introduced. Chapter 7 deals with the elements of analytical dynamics, including such basic topics as generalized coordinates, principle of virtual work, D'Alembert principle, and Lagrange's equations.

The dynamic characteristics of linear multi-degree-of-freedom systems are treated in chapter 8. The mass, stiffness, and damping matrices of discrete systems are derived via the Lagrangian formulation. Emphasis is placed on the eigenvalue problem and the orthogonality properties of normal modes. The treatment is extended to the response of undamped and damped systems.

An excellent introduction to system stability is given in chapter 9. The stability of single degree-of-freedom systems in the neighborhood of equilibrium positions in the phase plane is discussed. For conservative systems, the stability analysis is described in terms of energy levels. The concept of the state space is introduced for multi-degree-of-freedom systems. The stability of these systems is determined in terms of the eigenvalues of the coefficient matrix associated with the state equations. The Routh-Hurwitz criterion for asymptotic stability is also introduced.

Chapter 10 contains a number of computational techniques for the response of multi-degree-of-freedom systems in both continuous time and discrete time. Included are the transition matrix approaches, the Euler method, and the Runge-Kutta methods. The computational aspects of response by the transition matrix and its applications to damped systems are discussed. The stability of discrete-time systems is analyzed in terms of the transition matrix.

Chapter 11 introduces feedback control theory. The Laplace transformation plays an important role in the mathematical analysis of feedback control systems. The performance criteria of a position control system is demonstrated for a unit step input. Graphical techniques such as the root-locus method, Nyquist method, and Bode diagrams are well explained and illustrated by a number of simple engineering problems. The author gradually takes the reader to other topics in control systems such as servomechanisms, compensator design, and feedback control of multi-variable systems. The method of modal control of undamped multi-degree-of-freedom systems is outlined; modal control forces are expressed in terms of modal control gains. The elements of the Laplace transformation are outlined in the appendix. The text is thus self-contained.

The book is clearly written and is suitable for an undergraduate course that corporates dynamics, vibration, and control. For this purpose, the number of examples and problems in each chapter is adequate.

R.A. Ibrahim
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STRUCTURAL DYNAMIC TESTING AND ANALYSIS

A.W. Kabe, Organizer
SAE, Warrendale, PA
SAE-SP596, 1984, 96 pages, $30.00

This symposium was held in October, 1984. Ten of the 12 papers are published. The first paper employs Ibrahim time domain method (ITD). Accelerometer data from space shuttle flights are used to obtain modal components of decaying response. Modal response coherences are identified; more suitable damping rates are used to calculate more uniform series of damping ratios.

The second paper considers multi-input techniques in modal analysis of ground vibration testing. Multiple input random excitation and polyreference are employed instead of the sine level method. Additional experimental data and theoretical verification are necessary.

The third paper considers force response using component mode synthesis. The authors omit constraint modes that agree with applied loads in the system and propose a correction for the omitted constraint modes. An axial rod-spring system is used to investigate the effect of the omitted constraint modes in static, steady-state harmonic and transient responses. The author provides a good representation of commonly used component modes.

The next paper discusses modal techniques applied to a spacecraft structure. Comparisons are made between time standard multiple shake sine dwell (MSSD) -- which is time consuming --and both single point and multiple point random tests. The authors show the feasibility of random tests when compared to MSSD; MSSD is more accurate, however. The random tests are less time consuming but require more experimental investigations.

The fifth paper describes a parametric study of weapon systems using computer aided engineering (CAD). Nonlinear finite elements are used to optimize the energy absorbers in weapon systems. The analytical tests are used to create trends; extensive tests are not considered.

The sixth paper reports on a stochastic model for a flexible structure. A stochastic model is generated using the best available model, including modeling errors. The performance of an optimal stochastic control is compared with the determination controller and the stochastic model using a deterministic controller. The author points out difficulties in stochastic modeling and suggests future research.

The seventh paper presents practical guidelines for transient response calculations and peak response estimation for linear structural dynamic systems. A response spectrum of the dynamic environment is used to assess low frequency behavior; superposition of modal transient responses are used. High-frequency quasi-static behavior is approximated by the residual vector response. A rational vectored access to the modal response superposition is used to calculate peak response excitation. This new procedure indicates that previous methods of shock response furnish conservative results and at times spurious answers. The method requires further evaluation before it can be applied to complicated problems.

The next paper describes the vibration screening of deliverable equipment. The screening process weeds out manufacturing defects. The author reviews rules for vibration screens and where they are used. Included are locales where enhancements are necessary.

The ninth paper considers the probabilistic approach to spacecraft solar array deployment. It is necessary to simultaneously deploy four solar arrays from the inertial upperstage booster; mechanical systems tolerances, in-orbit temperature variations, and the possibility of satellite tumbling play important roles in success. Actually, the problem is a nonstationary stochastic procedure. A Monte Carlo approach is employed to arrive at a workable answer.

The concluding paper focuses on the problem of experimentally justifying an analytical model of a dynamic system using data from system-level and component tests. The statistical parameter estimation is used to affirm the structure of the model and its parametric values. The authors use an example to show its feasibility. This paper would be better if an appendix on Bayesian statistics had been included.

A paper on acoustic intensity should have been included and a state-of-the-art paper on modal testing should have introduced the symposium. The reviewer recommends this symposium to readers interested in modal analysis and structural dynamic testing.

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STANDARDS NEWS

Avril Brenig, Standards Manager

ASA Standards Secretariat, Acoustical Society of America, 335 East 45 Street, New York, New York 10017

William A. Yost

Parmly Hearing Institute, Loyola University of Chicago, 6525 North Sheridan Road, Chicago, Illinois 60626

American National Standards (ANSI Standards) in the areas of physical acoustics, bioacoustics, mechanical shock and vibration, and noise are published by the American Institute of Physics for the Acoustical Society of America (ASA). In addition to these standards, other Acoustical Society documents, a Catalog of Acoustical Standards—ASA Catalog 6-1985, and an Index to Noise Standards—ASA STDS Index 3-1985 (national and international) are available from the Standards Secretariat of the Acoustical Society. To obtain a current list of standards available from the Acoustical Society, write to Avril Brenig, at the above address. Telephone number: (212) 661-9404.

Calendar

The next meetings of the ASA standards committees are scheduled for 12–16 May 1986.

1986 May 12, ASA Committee on Standards, 7:30 p.m., The Bond Court, Cleveland, Ohio. Meeting of the Committee that directs the ASA Standards Program.

1986 May 14, Accredited Standards Committee S2 on Mechanical Shock and Vibration (also Technical Advisory Group for ISO/TC/108 and IEC/SC/50A), 2:00 p.m., The Bond Court, Cleveland, Ohio Review of international and S12 activities and planning for future meetings.

1986 May 15, Accredited Standards Committee S12 on Noise (also Technical Advisory Group for ISO/TC43/SC1), 9:30 a.m., The Bond Court, Cleveland, Ohio. Review of international and S12 activities and planning for future meetings.

1986 May 15, Accredited Standards Committees S1 (Acoustics) and S3 (Bioacoustics) (also Technical Advisory Group for ISO/TC/43, IEC/TC/29, and IEC/TC108/SC4) at 1:30 p.m., The Bond Court, Cleveland, Ohio. The S3 meeting will be held first. Review of S1, S3, and international standards activities and planning for future meetings.

1986 April 14–16, Committee E-33 on Environmental Acoustics, Charleston, South Carolina. Contact ASTM (215) 279-5400 for additional information.

Standards News from the United States

The following news items have been received since the last issue of *Standards News*:

ANSI to publish style manual revision

ANSI will soon be issuing a revised *Style Manual for Preparation of Proposed American National Standards*. Its purpose is to help committees and organizations prepare American National Standards that are to be published by ANSI.

The manual provides guidelines on the content to be applied by the standards developer; general style; style for special elements, such as tables, figures, and mathematical expressions; special ANSI policies; and format.

The manual's requirements, which are supplied by ANSI's Communications Department in preparing standards for printing, are intended to ensure that a standard is clear and that it is consistent in style and presentation within itself and with other ANSI-published standards.

This edition contains a number of modifications and additions, many made in response to suggestions received from standards developers. Requirements for constructing titles and referencing documents have been amended; the section on special ANSI policies expanded; and reference and source material updated.

By following the manual's rules in preparing drafts, standards developing groups will help ANSI speed publication and will thus make the product of their work available for publication in as short a time as possible following approval.

The Institute also recommends that sponsors that publish ANSI-approved standards follow the manual wherever possible to help create a consistent set of American National Standards. Consistency will serve to enhance their usefulness in national and international applications.

A copy of the manual will be mailed to Institute-accredited committees, organizations, and canvass users in early September.

The manual costs $3.00. To order, contact ANSI's Sales Department. Discount prices for multiple copies are available.

ASTM guide for measurement of outdoor A-weighted sound levels

Information about the use of ASTM Standard Guide E 1014 for Measurement of Outdoor A-Weighted Sound Levels is sought by the Task Group on Community Noise of American Society for Testing and Materials (ASTM) Committee E-33 on Environmental Acoustics. The Task Group announced that information about usage will be considered when E 1014 is revised. The announcement was made during the meetings of Committee E-33 at the City Line Mariott Hotel in Philadelphia on 14–16 October.

The scope of the Task Group on Performance of Building Systems will be redefined to address the needs of architects, building code officials, and specifications writers. This Task Group asked for comments by these professionals on their needs for standards to aid in assessing the acoustical performance of building systems.

A new test method to measure sound transmission loss in the field will be developed by the Task Group on Sound Intensity Measurement Techniques. The new method will use sound intensity measurement apparatus.

An interlaboratory test series (round robin) using Standard Test Method C 384 for Impedance and Sound Absorption of Acoustical Materials by the Impedance Tube Method is being planned by the Task Group on Impedance Tube Tests. This round robin will be run in parallel with a round robin using Standard Test Method E 1050 for Impedance and Absorption of Acoustical Materials using a Tube, Two Microphones, and a Digital Frequency Analysis System in order to compare the test results provided by the two test methods. The Task Group seeks participation by testing laboratories equipped to perform either test.

Three new E-33 standards, Guide E 1041 for Measurement of Masking Sound in Open Offices, Classification E 1042 for Acoustically Absorptive Materials Applied by Trowel or Spray, and Test Method E 1050 for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones, and a Digital Frequency Analysis System, have been published in the *1985 Annual Book of ASTM Standards*, Part 04.06.

The next meeting of Committee E-33 will be held in Charleston, SC, on 14–16 April 1986. Visitors are welcome at all E-33 meetings.

Information about the Committee and its activities can be obtained from David R. Bradley at ASTM, 1913 Race Street, Philadelphia, PA 19103. Telephone: (215) 299-5504.

Independent appraisal of OMB Circular A-119

Dr. Steven Spivak of the University of Maryland has prepared a report for the U.S. Department of Commerce titled "Implementation of OMB Circular A-119: An Independent Appraisal of Federal Participation in the Development and Use of Voluntary Standards."

This report which does not necessarily reflect the official views of the U.S. government is intended for those who *need* to know about OMB circular A-119, *want* to know about A-119, or *should* know about A-119.

The report number is NBS-GCR-85-495 and can be obtained from U.S. Department of Commerce, NBS, Office of Product Standards Policy, Gaithersburg, MD 20984.

FTC's rulemaking on standards terminated

The Federal Trade Commission voted unanimously on 16 September to end its rulemaking proceedings on standards and certification and follow a program of case-by-case enforcement, where necessary.

Termination of the rule was recommended to the Commission by FTC staff. It advised the Commission that "a case-by-case approach can address whatever problems may exist, because it focuses on the possible anticompetitive effects of individual decisions rather than on the procedures developers use to reach the decisions."

The current rulemaking began in 1978 and included months of hearings during which ANSI was lead counsel for a number of standards developers.

Copies of the FTC staff memorandum may be obtained from the FTC's Public Reference Branch, Room 130, 6th Street and Pennsylvania Avenue, N.W., Washington, DC 20580; Telephone (202) 523-3598.

Paul F. Glaser elected to Board of Directors

Paul F. Glaser, senior vice-president of Citibank, has been elected to ANSI's Board of Directors.

Mr. Glaser is a member of Citibank's Policy Committee, and chairman of the Corporate Technology Committee. He is responsible for establishment of technology policy and standards, and for the introduction of new technologies within the company.

Eight directors are nominated to ANSI Board

Eight people have been nominated to ANSI's Board of Directors by the Board Nominating Committee on recommendation of various councils.

Nominations for the office of director may also be made by written petition signed by ten or more ANSI voting members. Petitions were filed with the secretary of the Institute by 25 October 1985.

The nominees for director are:

Bruce R. DeMaeyer, chairman, Exchange Carriers Standards Association

Vico E. Henriques, president, Computer and Business Equipment Manufacturers Association

George F. Leyh, executive vice-president, American Concrete Institute

Robert A. Mercer, assistant vice-president, Network Compatibility Planning Center, Bell Communications Research, Inc.

Robert H. Preusser, assistant vice-president, Brooklyn Union Gas Co.

Max E. Rumbaugh, Jr., vice-president, Society of Automotive Engineers

Richard J. Schulte, vice-president, AGA Laboratories

Steven M. Spivak, professor, Department of Textiles and Consumer Economics, College of Human Ecology, University of Maryland.

EPA adopts ANSI S12.6-1984

The Safety Equipment Institute (SEI) has announced that it will apply an American National Standard in a program for certifying hearing protectors that has the approval of the U.S. Environmental Protection Agency.

SEI will, in effect, carry on an EPA program for testing and rating hearing protectors that has not been implemented recently because of a lack of funds. The EPA program called for uniform testing of hearing protectors and the assignment of a noise reduction rating. This rating was communicated to purchasers through labels that were applied to the product packaging.

EPA has now recognized the SEI testing and certification program for hearing protectors and authorized use of the SEI mark on labels giving the noise reduction rating.

"This means that for the first time in several years an active program exists for the testing of hearing protection products," said SEI Chairman of the Board, George E. Smith.

The testing and certification program covers ear plugs, circumaural devices, cap-mounted devices, and supra-aural devices. American National Standard Method for the Measurement of the Real-Ear Attenuation of Hearing Protectors, ANSI S12.6-1984, will be used in testing.

To ensure that manufacturers of certified hearing protectors maintain consistent quality control, SEI will conduct periodic audits of their production facilities.

Standards News from Abroad

The following news items have been received since the last issue of *Standards News*:

ISO elects president, appoints secretary-general

Isamu Yamashita, a prominent Japanese industrialist, has been elected president of the International Organization for Standardization for a three-year term, beginning 1 January 1986.

Dr. Lawrence D. Eicher has been unanimously appointed secretary-general of ISO. An American, Dr. Eicher had a distinguished career in administration of standards-related programs at the U.S. National Bureau of Standards before joining ISO in 1980 as assistant secretary-general. He will take office in 1986 on retirement of Olle Sturen.

ISO has also approved a budget for 1986, elected new members to its Council, accepted recommendations for bringing about closer cooperation with IEC, and authorized a study of ways to make ISO documents more readily available.

These and other actions were taken by ISO's General Assembly and Council in Tokyo in September.

The Council is the governing body of ISO. It is made up of the president and eighteen member bodies. ANSI and five other major contributors have permanent seats on the Council, which meets annually to review programs and approve new work items and the budget for the ensuing year. Every three years, ISO also holds a General Assembly to which all of the organization's ninety members are invited. Election of a president and new members to Council are among the Assembly's major responsibilities.

Standards approved and published by ANSI

The following standards were approved and published by ASA:

ASA STDS INDEX 3-1985	Index to Noise Standards, 3rd Edition
ANSI S12.7-1985	Impulse Noise, Methods for the Measurement of
ANSI S3.35-1985	Methods of Measurement: Performance Characteristics of Hearing Aids under Simulated *In-Situ* Working Conditions
ANSI S3.36-1985	Methods for Simulated *In Situ* Airborne Acoustic Measurements
ANSI S12.3-1985	Stated Noise Emission Values of Machinery and Equipment. Statistical Methods for Determining and Verifying
ANSI S1.30-1979 (R1985)	Guidlines for the Use of Sound Power Standards and for the Preparation of Noise Test Codes
ANSI S1.35-1979 (R1985)	Precision Methods for the Determination of Sound Power Levels of Noise Sources in Anechoic and Hemi-Anechoic Rooms
ANSI S1.36-1979 (R1985)	Survey Methods for the Determination of Sound Power Levels of Noise Sources
ANSI S1.42-1985	Design Response of Weighting Networks for Acoustical Measurements
ANSI S1.4A-1985	Sound Level Meters

ANSI S12.5-1985 Requirements for the Performance and Calibration of Reference Sound Sources

The above standards are available from the Standards Secretariat at the following address: AIP Publication Sales Department, Department STD, 335 East 45th Street, New York, NY 10017. (A 20% discount is available to individual and sustaining members of the Society.)

International documents on acoustics received in the United States

The documents listed below have been received by the Standards Secretariat of the Society and have been announced to S1, S2, S3, or S12. The document number is listed to the left of each document and the Accredited Standards Committee to which the document was announced is listed in parentheses below *the document number. Further information on each document can be obtained from the Standards Secretariat.*

The following documents have been received from ISO for vote:

ISO/DIS 226 (S3)	Normal Equal-Loudness Contours for Pure Tones under Free-Field Listening Conditions
ISO/DIS 2373 (S2)	Mechanical Vibration of Certain Rotating Electrical Machinery with Shaft Heights between 80 and 400 mm—Measurement and Evaluation of the Vibration Severity
ISO/DIS 1999.2 (S3)	Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment
ISO/DIS 8201 (S3)	Audible Emergency Evacuation Signal

Reports on International Activities

ISO/TC 43 meets in Berlin

The following resolutions were adopted during the 8th meeting of ISO/TC 43/SC 2 held in West Berlin, Germany, on 27 and 28 June 1985:

RESOLUTION 1

ISO/TC 43/SC2 resolves that document 43/2N379 "Acoustics; Measurement of sound insulation in buildings and of building elements; Part 2: Determination, checking, and application of precision data" shall be forwarded to the ISO Central Secretariat for registration as draft proposal ISO/DP 140/2.

RESOLUTION 2

ISO/TC 43/SC2 resolves that its Secretariat shall take the appropriate steps for confirmation of work item no. 73 "Short test method of airborne sound insulation between rooms."

RESOLUTION 3

ISO/TC 43/SC2 approves document 43/2N377 (second ISO/DP 9052/1) "Acoustics; Determination of dynamic stiffness; Part 1: Materials used under floating floors in dwellings" as amended at this meeting. This document shall be transmitted to the ISO Central Secretariat for circulation as a draft international standard for combined voting.

RESOLUTION 4

ISO/TC 43/SC2 resolves that the document 43/2N375 (second draft proposal ISO/DP 9053) "Acoustics; Materials for acoustical applications; Determination of airflow resistance" (with revised definitions in accordance with ISO 4638, and amendments as agreed at this meeting) shall be circulated to the members of ISO/TC 43/SC2 for voting.

RESOLUTION 5

ISO/TC 43/SC2 resolves that a study group be established without delay to review comments in documents 43/2N351 to N358 and N364 (except items 19 and 20), and that a working group be established to revise ISO 140 (with the exception of Part 2) with a program of work as recommended by the study group after a review within 9 months.

RESOLUTION 6

ISO/TC 43/SC2 resolves that the addenda to ISO 140 Part 1 and Part 3 with respect to the measurement of airborne sound insulation of windows and glazing as proposed by ISO/TC 43/SC2/WG 11 (documents 43/2N380 and 34/2N381) shall be forwarded to the ISO Central Secretariat for registration as draft proposals.

RESOLUTION 7

ISO/TC 43/SC2 resolves that the following working groups ISO/TC 43/SC2/WG 1 "Plumbing noise" and ISO/TC 43/SC2/WG 6 "Measurement of sound insulation of suspended ceilings" shall be disbanded.

RESOLUTION 8

ISO/TC 43/SC2 supports the new work item dealing with "Measurements of flanking transmission in the laboratory and the field" as suggested in document 43/2N349. It, therefore, requests the Secretariat to take appropriate steps for inclusion of this work item in the programme of work of ISO/TC 43. The documents cited in Resolution No. 5 summarized the responses to a questionnaire concerning the implementation of ISO 140 Part 1 through Part 8. ISO 140 has to do with measurement of sound transmission loss and impact sound transmission both in the laboratory and in the field.

Document 43/2N349 (cited in Resolution No. 8) is the report of a study group on laboratories with flanking transmission.

SHORT COURSES

MARCH

MEASUREMENT SYSTEMS ENGINEERING
Dates: March 10-14, 1986
Place: Phoenix, Arizona
MEASUREMENT SYSTEMS DYNAMICS
Dates: March 17-21, 1986
Place: Phoenix, Arizona
Objective: Electrical measurements of mechanical and thermal quantities are presented through the new and unique "Unified Approach to the Engineering of Measurement Systems." Test requestors, designers, theoretical analysts, managers and experimental groups are the audience for which these programs have been designed. Cost-effective, valid data in the field and in the laboratory, are emphasized. Not only how to do that job, but how to tell when it's been done right.

Contact: Peter K. Stein, Director, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603; (602) 947-6333.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION
Dates: March 10-14, 1986
Place: Washington, DC
Dates: May 12-16, 1986
Place: Detroit, Michigan
Dates: June 2-6, 1986
Place: Santa Barbara, California
Dates: August 18-22, 1986
Place: Santa Barbara, California
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

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

MACHINERY DIAGNOSTICS
Dates: March 11-14, 1986
Place: San Francisco, California
Dates: March 17-21, 1986
Place: Carson City, Nevada
Dates: April 8-11, 1986
Place: Atlanta, Georgia
Dates: May 5-9, 1986
Place: Carson City, Nevada
Dates: June 16-20, 1986
Place: Carson City, Nevada
Dates: June 24-27, 1986
Place: Denver, Colorado
Objective: This seminar instructs rotating machinery users on transducer fundamentals, the use of basic diagnostic techniques, and interpreting industry-accepted vibration data formats to diagnose common rotating machinery malfunctions. The seminar includes class demonstrations, case histories, and a hands-on workshop that allows participants to diagnose malfunctions on demonstrator rotor systems.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 - 800-227-5514, Ext. 9682.

EXPLOSIVE SHOCKS IN AIR
Dates: March 17-21, 1986
Place: Monterey, CA
Objective: This course presents the theoretical and practical aspects of blast and shock waves generated by explosions in air and of their damage capability. Major topics covered in the course include the nature of explosions, thermodynamics of explosions, the shock front, reflected shocks, blast waves, explosion overpressures, scaling laws, dynamic blast loads on structures and structural response to blast loading. The course is intended for engineers and scientists requiring a solid foundation in the subject area. It has been designed as an introductory course and is therefore ideally suited to those new to the area.

Contact: Computational Mechanics Associates, P.O. Box 11314, Baltimore, MD 21239 - (301) 435-1411.

APRIL

FUNDAMENTAL ASPECTS OF HYPERVELOCITY IMPACT AND SHAPED-CHARGE PHENOMENA

Dates: April 7-11, 1986
Place: Baltimore, MD
Objective: The course is designed for novices in the field of hypervelocity impact. It will provide a basic introduction to theoretical and experimental aspects of hypervelocity impact, including shaped-charge phenomena. Major topics to be covered include: physics of explosives; fundamentals of shaped-charges; explosive/metal interaction; analytical penetration and hole growth models; experimental techniques in hypervelocity impact studies; computational aspects of hypervelocity impact and shaped-charges.

Contact: Computational Mechanics Associates, P.O. Box 11314, Baltimore, MD 21239 - (301) 435-1411.

MACHINERY MONITORING

Dates: April 22-24, 1986
Place: Philadelphia, Pennsylvania
Dates: May 20-22, 1986
Place: Chicago, Illinois
Dates: June 10-12, 1986
Place: Anaheim, California
Objective: The seminar focuses on the principles of vibration measurement for rotating machinery monitoring. Subjects covered in the seminar include troubleshooting, calibration and maintenance of monitoring systems, and the applications and installation of displacement, velocity, and acceleration transducers.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 -800-227-5514, Ext. 9682.

DYNAMIC BALANCING

Dates: April 23-24, 1986
June 18-19, 1986
Place: Columbus, Ohio
Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single, two and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels, etc., with emphasis on reducing costs and improving quality in balancing operations.

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

MACHINERY VIBRATION ANALYSIS II

Dates: April 28 - May 2, 1986
Place: Syria, Virginia
Objective: The objective of this course is to expose participants to advanced techniques of vibration analysis using single-and dual-channel FFT analyzers. These techniques include analysis of spectrum, time, frequency, and orbital domain; modal analysis; coherence, frequency response functions, and synchronous time averaging; and amplitude, phase, and frequency modulation. Data processing procedures are reviewed. All techniques are illustrated with examples and case histories of industrial machinery. Instrumentation necessary to implement the techniques is available for use by participants during informal workshops; taped data from actual industrial machinery are used during these workshops.

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

MAY

ROTATING MACHINERY VIBRATIONS

Dates: May 19-21, 1986
Place: Orlando, Florida
Objective: This course provides participants with an understanding of the principles and practices of rotating machinery vibrations and the application of these principles to practical problems. Some of the topics to be discussed are: theory of applied vibration engineering applied to rotating machinery; vibrational stresses and component fatigue; engineering instrumentation measurements; test data acquisition and diagnosis; fundamentals of rotor dynamics theory; bearing static and dynamic properties; system analysis; blading analysis; life estimation; practical rotor blading-bearing

dynamics examples and case histories; rotor balancing theory; balancing of rotors in bearings; rotor signature analysis and diagnosis; and rotor-bearing failure prevention.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, Il 60514 - (312) 654-2254.

APPLIED VIBRATION ENGINEERING
Dates: May 19-21, 1986
Place: Orlando, Florida
Objective: This intensive course is designed for specialists, engineers and scientists involved with design against vibration or solving of existing vibration problems. This course provides participants with an understanding of the principles of vibration and the application of these principles to practical problems of vibration reduction or isolation. Some of the topics to be discussed are: fundamentals of vibration engineering; component vibration stresses and fatigue; instrumentation and measurement engineering; test data acquisition and diagnosis; applied spectrum analysis techniques; spectral analysis techniques for preventive maintenance; signal analysis for machinery diagnostics; random vibrations and processes; spectral density functions; modal analysis using graphic CRT display; damping and stiffness techniques for vibration control; sensor techniques for machinery diagnostics; transient response concepts and test procedures; field application of modal analysis for large systems; several sessions on case histories in vibration engineering; applied vibration engineering state-of-the-art.

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

VIBRATION DAMPING TECHNOLOGY
Dates: May 19-23, 1986
Place: Reno, Nevada
Dates: July 14-17, 1986
Place: Montreal, Canada
Dates: September 15-19, 1986
Place: Dayton, Ohio
Dates: January, 1987
Place: Clearwater, Florida
Objective: Basics of theory and application of viscoelastic and other damping techniques for vibration control. The courses will concentrate on behavior of damping materials and their effect on response of damped systems, linear and nonlinear, and emphasize learning through small group exercises. Attendance will be strictly limited to ensure individual attention.

Contact: David I. Jones, Damping Technology Information Services, Box 565, Centerville Branch USPO, Dayton, OH 45459-9998 - (513) 434-6893.

JUNE

VIBRATION CONTROL
Dates: June 9-13, 1986
Place: San Diego, CA
Objective: Participants in this course should leave with an understanding of the options available for vibration control, including general design considerations and such control techniques as isolation and damping. Lectures provide a sound review of vibration theory and develop the principles of vibration isolation and damping as they apply to particular design problems. Examples and case histories are used to illustrate design approaches; participants can solve problems during workshops.

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

JULY

ROTOR DYNAMICS
Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors,

bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

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

ADVANCED TECHNIQUES FOR NOISE CONTROL

Dates: July 17-19, 1986
Place: Cambridge, Massachusetts
Objective: Among the topics to be covered are modern instrumentation for noise control, modal analysis, sound intensity applications, active techniques for noise control, structural and vibration transmission, and airport noise and monitoring systems.

Contact: Institute of Noise Control Engineering, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603.

AUGUST

MACHINERY VIBRATION ANALYSIS I

Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Dates: November 11-14, 1986
Place: Chicago, Illinois
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

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

VIBRATIONS OF RECIPROCATING MACHINERY

Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

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

SEPTEMBER

MODAL TESTING OF MACHINES AND STRUCTURES

Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods

for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

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

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

SYMPOSIUM ON DYNAMIC BEHAVIOR OF COMPOSITE MATERIALS, COMPONENTS, AND STRUCTURES
June 8-12, 1986
New Orleans, Louisiana

The Symposium on Dynamic Behavior of Composite Materials, Components, and Structures will be held at the 1986 Spring Meeting of the Society for Experimental Mechanics (SEM), June 8-12, 1986 in New Orleans, Louisiana. The symposium is co-sponsored by the SEM Composite Materials Committee and the SEM Modal Analysis/Dynamic Systems Committee.

Twelve invited papers are to be presented on topics such as an overview of recent research, dynamic behavior of composites in machinery, modal analysis of composite structures, damping characteristics of new polymer matrix and metal matrix composites, aeroelastic behavior of composite aircraft wings, delamination of composite laminates under impact, damage characterization with dynamic measurements, and rate sensitivity of energy absorbing composites.

For further information contact: R.F. Gibson, Mechanical Engineering Dept., University of Idaho, Moscow, ID 83843 - (208) 885-7432.

INTER-NOISE 86
July 21-23, 1986
Cambridge, Massachusetts

Two hundred and fifty technical papers are expected to be presented in six parallel sessions at INTER-NOISE 86, the 1986 International Conference on Noise Control Engineering. The theme of INTER-NOISE 86, to be held July 21-23, 1986 on the campus of the Massachusetts Institute of Technology in Cambridge, Massachusetts, will be "Progress in Noise Control." A major exhibition of materials and equipment for noise control will be held in conjunction with the three-day conference.

INTER-NOISE 86 will immediately precede the International Congress on Acoustics which is being held in Toronto, Canada.

For further information contact: Mrs. Gayle Fitzgerald, INTER-NOISE 86 Conference Secretariat, Office of Special Events, Massachusetts Institute of Technology, Room 7-111, Cambridge, MA 02139.

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

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

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

Institution of Mechanical Engineers publications are available in U.S.: SAE Customer Service, Dept. 676, 400 Commonwealth Drive, Warrendale, PA 15096, by quoting the SAE-MEP number.

When ordering, the pertinent order number should always be included, not the **DIGEST** abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

86-272
An Analytical Investigation of Dynamic Coupling in Nonlinear, Geared Rotor Systems
J.W. David
Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 170 pp (1984), DA8500906

KEY WORDS: Rotors, Gears, Coupled response, Harmonic balance method

This study addresses the topic of dynamic response of geared rotor systems. The effects of second-order coupling terms (dynamic coupling) in the disk equations of motion on the predicted response of geared rotor systems are investigated. The equations of motion for a rigid disk attached to a rotating shaft are derived. Two test problems having large nonlinearities are solved by the harmonic-balance technique. The results compare well with numerical solutions.

86-273
An Improved Technique for Testing Helicopter Rotor-Pylon Aeromechanical Stability Using Measured Rotor Dynamic Impedance Characteristics
R.L. Bielawa
Rensselaer Polytechnic Inst., Troy, NY
Vertica, 9 (2), pp 181-197 (1985), 8 figs, 3 tables, 17 refs

KEY WORDS: Helicopter rotors, Model testing, Resonant frequencies, Frequency domain method

The rationale for and theoretical basis of an improved technique for model testing the aeromechanical stability of rotor-pylon coupled rotorcraft systems are presented. This improved technique is based on the a priori ability to measure experimentally the dynamic impedance characteristics of the isolated (model) rotor in the frequency domain and makes use of the multivariable Nyquist stability criterion. The technique would be especially useful for evaluating helicopter ground and air resonance characteristics of rotorcraft subject to wide variation in pylon characteristics. An especially important and new feature of this test technique is the ability to make quantitative stability assessments of the coupled rotor-pylon system, over and above the quantitative stability assessment afforded by the Nyquist criterion. over and above the quantitative stability assessment afforded by the Nyquist criterion.

86-274
Influence of an Axial Torque on the Dynamic Behavior of Rotors in Bending
R. Dufour, J. Der Hagopian, M. Lalanne
Laboratoire de Mecanique des Structures, U.A. C.N.R.S. 862, Villeurbanne, France
Shock Vib. Bull., #55, Part 3, pp 27-35, June 1985, 10 figs, 4 tables, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Rotors, Axial excitation, Torque

It is necessary to predict with great accuracy the dynamic behavior of rotating machinery components at the design stage. This paper focuses on the secondary effect on the dynamic characteristics of rotors in bending, introduced by axial torque. The influence of a constant and a harmonic exciting torque is studied experimentally and theoretically.

86-275
Nonlinear Rotordynamics Analysis
W.B. Day
Auburn Univ., Auburn, AL
Rept. No. NASA-CR-171425, 38 pp (Mar 1985), N85-22364/2/GAR

KEY WORDS: Rotors, Nonlinear theories

The special nonlinearities of the Jeffcott equations in rotordynamics are examined. The immediate application of this analysis is directed toward understanding the excessive vibrations recorded in the LOX pump of the SSME during hot firing ground testing. Deadband, side force and rubbing are three possible sources of inducing nonlinearity in the Jeffcott equations. The present analysis initially reduces these problems to the same mathematical description. A special frequency, named the nonlinear natural frequency is defined and used to develop the solutions of the nonlinear Jeffcott equations as asymptotic expansions.

86-276
Structural Response of a Rotating Bladed Disk to Rotor Whirl
E.F. Crawley
Massachusetts Inst. of Tech., Cambridge, MA
Rept. No. NASA-CR-175605, 140 pp (Apr 1985), N85-22391/5/GAR

KEY WORDS: Rotors, Bladed disks, Whirling

A set of high speed rotating whirl experiments were performed in the vacuum of the MIT Blowdown Compressor Facility on the MIT aeroelastic rotor, which is structurally typical of a modern high bypass ratio turbofan stage. These tests identified the natural frequencies of whirl of the rotor system by forcing its response using an electromagnetic shaker whirl excitation system.

86-277
Stiffness and Damping Effects on Torsional Vibration in Motor Vehicle Drive Shafts (Einfluss der Steifigkeit und Dämpfung auf die Torsionsschwingungen der Wellen eines Kraftfahrzeuggetriebes)
G. Nitescu
Konstruktion, 37 (3), pp 105-108 (Mar 1985), 5 figs, 5 refs (In German)

KEY WORDS: Shafts, Stiffness effects, Damping effects, Torsional vibrations

Torsional vibrations of shafts are investigated. After the modeling of the drive, a vibration equation is formulated. From the solution of the differential equation of vibration the effect of stiffness and damping on the decrease of negative effect of torsional vibrations is determined.

86-278
Spin Pit Test of Bladed Disk with Blade Platform Friction Dampers
R.J. Dominic
Univ. of Dayton, Dayton, OH
Shock Vib. Bull., #55, Part 1, pp 71-79, June 1985, 16 figs, 8 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Bladed disks, Coulomb friction, Experimental data, Flexural vibrations, Vibration dampers

A turbine blade friction damping study is performed for a high speed bladed disk of the high pressure fuel turbopump of the space shuttle main engine. The experimental study involved spin pit testing of an instrumented bladed disk assembly. It was performed to evaluate the effectiveness and operational characteristics of blade platform friction dampers designed to limit damaging resonance vibrations of the turbine blades in their lower order flexural vibration modes. The test program is described and test results are presented.

86-279
Dynamic Shear Stress Analysis of Discs Subjected to Variable Rotations
S. Amada
Ship Res. Inst., Tokyo, Japan
Bull. JSME, 28 (240), pp 1029-1034 (June 1985), 13 figs, 13 refs

KEY WORDS: Disks

Dynamic circumferential displacements and shear stresses are analyzed for a hollow disc which rotates at variable speeds, and the inner face of which is fixed on a rigid shaft. The problem is solved by using the Laplace transform and Cauchy's integral theorem. The ratio of the maximum dynamic and quasi-static stresses, and the period of the cyclically changing stresses are obtained.

RECIPROCATING MACHINES

86-280
Computer Predictions and Experimental Tests of Exhaust Noise in a Single Cylinder Internal Combustion Engine
G. Ferrari, R. Castelli
Polytechnic of Milan, Milan, Italy
Noise Control Engrg. J., 24 (2), pp 50-56 (Mar/Apr 1985), 9 figs, 25 refs

KEY WORDS: Internal combustion engines, Exhaust systems, Noise prediction

A theoretical and experimental approach to the investigation of the gas-dynamic noise characteristics of the internal combustion engine exhaust system is described. For a one-dimensional, unsteady, non-adiabatic, and viscous flow, numerical solutions are obtained using the concept of characteristics; the radiated exhaust noise is then determined by assuming monopole radiation from the tailpipe outlet. Good agreement with experiments has been achieved in the calculation of both noise level and pressure-time histories for some basic exhaust systems.

86-281
Finite-Element Utilization in the Acoustical Improvement of Structure-Borne Noise of Large Industrial Machines
A.K. Al-Sabeeh
Ph.D. Thesis, North Carolina State Univ. at Raleigh, 278 pp (1983), DA8500221

KEY WORDS: Presses, Structure borne noise, Noise reduction, Finite element technique

The structure-borne noise of two punch presses is investigated by a theoretical approach based on the finite-element technique. The objective of this study is to identify the noise radiating frequency modes of large amplitude associated with components of the press structure in order to identify possible press modifications to reduce the overall noise level.

POWER TRANSMISSION SYSTEMS

86-282
Vibration and Noise of Power Transmission System Including Gears (Effect of Torque Fluctuation Caused by Gas Pressure Variation on the Torsional Vibration of Oil Injection Type Screw Compressor
N. Tanaka, Y. Nakamura, M. Fujiwara, T. Matsunaga
Hitachi, Ltd., Ibaraki, 300 Japan
Trans. JSME No. 458 (Mar 31, 1983)

KEY WORDS: Power transmission systems, Compressors, Torsional vibrations, Gears

A calculation of torque fluctuations, a measurement of torsionial vibration and a measurement of dynamic transmission error in oil injection type screw compressors are presented. The torsional vibration and the dynamic transmission error are measured using pulse generating gears, phase shift detectors and FFT analyzer.

86-283
Bond Graph Modeling and Computer Simulation of Automotive Torque Converters
D. Hrovat, W.E. Tobler
Ford Motor Co., Dearborn, MI
J. Franklin Inst., 319 (1/2), pp 93-114 (Jan/Feb 1985), 12 figs, 1 table, 14 refs

KEY WORDS: Mathematical models, Bond graph technique, Computerized simulation, Mechanical drives

A derivation of a set of four first-order nonlinear differential equations describing torque converter dynamics is given, along with the corresponding bond graph representation. The bond graph consists of an inertia-field and modulated gyrators which couple mechanical and hydraulic ports. Examples of static torque converter model validation and complete, dynamic model usage in the design of shift quality controllers for discrete ratio electronic transmissions are included.

ELECTROMECHANICAL SYSTEMS

86-284
A Bond Graph Computer Model to Simulate Vacuum Cleaner Dynamics for Design Purposes
J.A.M. Remmerswaal, H.B. Pacejka
Delft Univ. of Technology, Delft, The Netherlands
J. Franklin Inst., 319 (1/2), pp 83-92 (Jan/Feb 1985), 14 figs, 4 refs

KEY WORDS: Household appliances, Mathematical models, Computerized simulation, Bond graph technique

A relatively new method is developed to model the dynamic structure of such products as consumer durables which only implicitly makes use of mathematics: the bond graph method. The method is applied to investigate the dynamic behavior of vacuum cleaners. With this model a simulation of important deflections and reaction forces is performed to predict critical values.. The results show very good agreement with experimental data.

STRUCTURAL SYSTEMS

BRIDGES

86-285
Seismic Response Characteristics of Meloland Road Overpass during 1979 Imperial Valley Earthquake
S.D. Werner, M.B. Levine, J.L. Beck
Agbabian Associates, El Segundo, CA
Rept. No. AA-R-8222-5603, NSF/ENG-85006, 264 pp (Mar 1985) PB85-196293/GAR

KEY WORDS: Bridges, Seismic response, Experimental data

A two-span reinforced concrete bridge survived very strong shaking during the 1979 Imperial Valley earthquake with virtually no damage. This shaking triggered a total of 26 strong motion accelerometers located on or near the bridge, providing the most extensive array of earthquake response measurements yet obtained for bridges in the United States. This report describes work directed toward using these data to gain insights that can enhance future design, analysis, and instrumentation of bridges in an earthquake environment.

BUILDINGS

86-286
Automated Building Design Review Using BLAST. (Building Loads Analysis and System Thermodynamics)
J. Amber, D.J. Leverenz, D.L. Herron
Construction Engrg. Res. Lab., (Army), Champaign, IL
Rept. No. CERL-TR-E-85/03, 45 pp (Jan 1985), AD-A151 707/7/GAR

KEY WORDS: Computer programs, Buildings, Design techniques

This document describes a method for using the Building Loads Analysis and System Thermodynamics (BLAST) energy simulation computer program to review the energy effectiveness of the new Army facility designs. This review method covers both aspects of new Army's energy criteria: prescriptive energy standards and facility energy design budgets. The method compares the energy criteria with information contained in a BLAST output deck. This deck contains most of the information needed to review a new design for compliance with energy criteria.

86-287
Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings: The Methodology (Revised)
R.D. Ewing, A.W. Johnson, J.C. Kariotis
ABK, El Segundo, CA
Rept. No. ABK-TR-8, NSF/CEE-84054, 196 pp (Jan 1984), PB85-194371/GAR

KEY WORDS: Buildings, Masonry, Seismic response

A methodology for the mitigation of seismic hazards in existing unreinforced masonry (URM) buildings is presented. Attention is focused on selection of the seismic risk zone, and on design spectra for seismic hazard reduction. A procedure for field surveys of existing URM buildings is recommended and the response of existing structural systems to earthquakes is considered.

86-288
Earthquake Induced Motion Environments in Framed Buildings
A. Longinow, R.R. Robinson, J. Mohammadi
Illinois Institute of Technology, Chicago, IL
Shock Vib. Bull., #55, Part 2, pp 101-122, June 1985, 21 figs, 7 tables, 14 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC

KEY WORDS: Multistory buildings, Seismic response

Motions induced at various floor levels of high- and low- rise steel-framed buildings when subjected to an earthquake are examined. Three unbraced steel-framed buildings with heights of 24- 12- and 4-stories are modeled and analyzed when subjected to horizontal and vertical ground motions. Results include absolute horizontal and vertical displacement-time histories and response spectra curves for selected floor levels. Also included are seismic forces, i.e., moments, shears and axial forces induced in the columns of the three buildings during the dynamic response.

86-289

Stochastic Seismic Response Analysis of Hysteretic MDF Structures Using Mean Response Spectra

Jinren Jiang, Qinnian Lu

EEEV, 4 (4), pp 1-13 (1984), CSTA 624-84.98

KEY WORDS: Multistory buildings, Seismic response, Stochastic processes, Multidegree of freedom systems

Based on equivalent linearization and a mean response spectrum method for random vibration which has been extended to a non-stationary input case, an approximate method for calculating the stochastic seismic response of a hysteretic MDF structure is proposed.

86-290

Wind Induced Motion of Tall Buildings

A.G. Tallin

Ph.D. Thesis, The Johns Hopkins Univ., 128 pp (1984), DA8501683

KEY WORDS: Multistory buildings, Wind-induced excitation

The dynamic response of light and/or flexible modern tall buildings due to wind forces is analyzed, and studies are performed to identify those parameters that are most significant in determining structural motion. Expressions for the total rms displacement and acceleration experienced at any location in a tall building are developed using random vibration theory. Force records from wind tunnel experiments performed on a model of a tall building in an urban exposure boundary layer are analyzed using a two-channel FFT analyzer.

TOWERS

86-291

Acrosswind Response of Towers and Stacks of Circular Cross-Section

Chii-Ming Cheng

Ph.D. Thesis, Univ. of Houston, 273 pp (1984), DA8428111

KEY WORDS: Towers, Chimneys, Fluid-induced excitation, Wind-induced excitation

The wake-induced acrosswind force and associated dynamic acrosswind behavior of circular cross-section structures were investigated. The turbulent boundary layers, simulated by the combined action of an upstsream barrier, spires, and floor roughness elements, were similar to the atmospheric boundary layers developed over typical open terrain and urban areas. A simple investigation was carried out to observe the effect of aspect ratio on the acrosswind force. The acrosswind response measurements were taken using a series of base-pivoted aeroelastic models.

86-292

Analysis of Damped Twin Towers

C.W. White

Martin Marietta Denver Aerospace, Denver, CO

Shock Vib. Bull., #55, Part 1, pp 119-130, June 1985, 12 figs, 2 tables, 4 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Towers, Modal strain energy method, Viscoelastic damping, Spacecraft

A procedure used to design two viscoelastically damped 60-ft tall generic test towers is presented. It describes how the modal strain energy approach was used to identify favorable locations in these towers for viscoelastic structural members and for discrete viscoelastic damper mechanisms. The use of standard viscoelastic material property data to design the discrete dampers is illustrated.

FOUNDATIONS

86-293

A Two-Dimensional Non-Linear Static and Dynamic Response Analysis of Soil Structures

R. Siddharthan

Ph.D. Thesis, The Univ. of British Columbia (Canada), (1984)

KEY WORDS: Soil-structure interaction

A method of analysis in two-dimensions to predict static and dynamic response of soil structures, including soil-structure interaction is presented. The static and dynamic analyses can be performed in either effective or total stress mode or a combination of both modes. The predictive capability of the new method of analysis is verified by comparing the recorded porewater pressure and accelerations of two centrifuged models subjected to simulated earthquakes, to those computed by the new method.

86-294
Probabilistic Evaluation of Predicted Soil Behavior Under Cyclic Loading
S.U. Ejezie
Ph.D. Thesis, Carnegie-Mellon Univ., 294 pp (1984), DA8425814

KEY WORDS: Clays, Soils, Cyclic loading, Probability theory, Reliability

The presently used models of clay soil behavior under cyclic loading have been assessed using the principles of probability theory and reliability analysis to determine their relative accuracies. This was accomplished using sufficiently representative data from reputable sources. The actual probability distributions of the response parameters were established and incorporated into the analysis to achieve optimum accuracy. The results obtained reveal that most of the models are associated with appreciable error in their present forms, which renders them unsuitable for general applications. The error has been identified to stem from the original methods of formulation of the models.

HARBORS AND DAMS

86-295
EAGD-84: A Computer Program for Earthquake Analysis of Concrete Gravity Dams
G. Fenves, A.K. Chopra
Univ. of California, Richmond, CA
Rept. No. UCB/EERC-84/11, NSF/CEE-84022, 99 pp (Aug 1984), PB85-193613/GA

KEY WORDS: Dams, Concrete, Seismic analysis, Computer programs

This report documents the use of the computer program EAGD-84 which implements a general analytical procedure for the evaluation of the earthquake response of concrete gravity dams, including the effects of dam-water-foundation rock interaction and of materials such as alluvium and sediments, at the bottom of reservoirs. The development of an appropriate idealization of the system is discussed, the required input data to the computer program are described, the output is explained, and the response results from a sample analysis are presented.

ROADS AND TRACKS

86-296
A Systems Approach to the Characterization of Rough Ground
R.F. Harrison, J.K. Hammond
Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 99 (3), pp 437-447 (Apr 8, 1985), 5 figs, 1 table, 16 refs

KEY WORDS: Surface roughness, Road roughness, Maximum entropy spectral analysis

A Novel method for modeling rough surfaces as the output of linear filters operating on white noise in the spatial domain is proposed. These systems models may then be utilized in certain analytical methods to calculate the non-stationary response of vehicles moving on rough ground with variable velocity. Either time variable covariance or evolutionary spectra of response may be obtained by the method.

PRESSURE VESSELS

86-297
Seismic Sloshing of Reactor Tank with Internals
D.C. Ma, J. Gvildys, Y.W. Chang
Argonne National Lab., Argonne, IL
Rept. No. CONF-850410-12, 7 pp (1985), DE85002747/GAR

KEY WORDS: Nuclear reactor components, Seismic analysis, Sloshing

Of interest in the reactor design is the magnitude of the hydrodynamic pressure acting on the internal components and the maximum wave height of the free-surface when coolant sloshes. A new seismic analysis methodology which calculates the sloshing loads on submerged components is presented. Results of a study performed on the sloshing of a reactor tank with many in-tank components are also discussed.

POWER PLANTS

86-298
Methodology to Evaluate the Site Standard Seismic Motion for a Nuclear Facility
W.A. Soares
Minas Gerais Univ., Belo Horizonte, Brazil
Rept. No. INIS-BR-164, 298 pp (Mar 1983), DE85780572/GAR (In Portuguese)

KEY WORDS: Nuclear reactors, Seismic response

An overall view of the subjects involved in the determination of the site standard seismic motion to a nuclear facility is presented. The main topics discussed are: basic principles of seismic instrumentation; dynamic and spectral concepts; design earthquakes definitions; fundamentals of seismology; empirical curves developed from prior seismic data; available methodologies and recommended procedures to evaluate the site standard seismic motion.

86-299
Three-Dimensional Fluid-Structure Coupling in Transient Analysis
R.F. Kulak
Argonne National Lab., Argonne, IL
Computers Struc., 21 (3), pp 529-542 (1985), 28 figs, 16 refs

KEY WORDS: Fluid-structure interaction, Nuclear reactor safety

The numerical simulation of nonlinear, transient fluid-structure interactions (FSI) is a current area of concern by researchers in various fields, including the field of nuclear reactor safety. This paper primarily discusses the formulation used in an algorithm that couples three-dimensional hydrodynamic and structural domains. Both the fluid and structure are discretized using finite elements. The semi-discretized equations of motion are solved using an explicit temporal integrator. Results for several problems are presented and these include a comparison between analytical results for a FSI problem and numerical predictions.

86-300
Axial Flow Induced Vibration of Nuclear Power Plant Components
Joo Hyun Baik
Ph.D. Thesis, Univ. of Michigan, 213 pp (1984), DA8502758

KEY WORDS: Nuclear power plants, Fluid-induced excitation, Tube arrays, Axial excitation

This work examines the vibrations caused by axial turbulent flow of long slender beam-like nuclear power plant components, such as tubes in a steam generator or fuel rods in a nuclear reactor, taking into account the hydrodynamic interaction among them. To accommodate probabilistic vibration analysis, a mathematical model for non-homogeneous cross spectral density of fluctuating wall-pressure caused by flow spoilers such as grid assembly in a reactor and support plate in a steam generator is developed. It is shown that the root-mean-square values of rod displacement calculated with this model agree well with measured values.

VEHICLE SYSTEMS

GROUND VEHICLES

86-301
Modelling Complex Vehicle Systems Using Bond Graphs
H.B. Pacejka
Delft Univ. of Technology, Delft, The Netherlands
J. Franklin Inst., 319 (1/2), pp 67-81 (Jan/Feb 1985), 14 figs, 5 refs

KEY WORDS: Ground vehicles, Mathematical models, Bond graph technique

To improve the performance of vehicles on the road, theoretical studies are needed which make use of dynamic models. This paper directs the attention to the use of the bond graph technique as an aid in modeling the physical system. Specific problems which may arise when the graph is prepared for the actual simulation phase are discussed.

86-302
The Effects of Operational Parameters on Vehicle Directional Responses

I.N. Sutantra
Ph.D. Thesis, The Univ. of Wisconsin-Madison, 402 pp (1984), DA8500704

KEY WORDS: Ground vehicles, Tires, Ride dynamics

This study deals with a computer simulation study of the effects of operational parameters, such as load, load distribution, height of center of gravity, speed, tire pressure, tire construction, tire wear, tire coefficient of friction, tire blow out, and wet road conditions, on vehicle directional response. New response terms are introduced in order to study the possibility of loss of control either due to too-small vehicle responses (too-large vehicle responses) or due to confusing vehicle responses.

86-303
Approximating Dynamic Response in Small Arrays Using Polynomial Parameterizations and Response Surface Methodology
K.P., Jr. White, H.C., III Gabler, W.D. Pilkey
Univ. of Virginia, Charlottesville, VA
Shock Vib. Bull., #55, Part 3, pp 167-173, June 1985, 4 figs, 14 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Collision research (automotive), Data processing, Approximation methods

A method for deriving an approximate algebraic model which defines the performance of a dynamic system as a function of its response parameters is described. The method extracts essential response information from large amounts of test data or simulation output and stores this information in a single, small, two-dimensional array. This data compression provides for highly efficient storage of essential information in a form which is especially convenient for subsequent use in analysis, experimentation, model validation, or design optimization.

86-304
Impact Studies of a 1/3-Scale Model of an Air Cushion Vehicle
R.H. Daugherty
NASA Langley Res. Ctr., Hampton, VA
Rept. No. L-15916, NASA-TM-86360, 24 pp (Apr 1985), N85-23757/6/GAR

KEY WORDS: Surface effect machines, Impact tests, Model testing, Experimental data

An experimental investigation was conducted to determine the effects of various parameters of the impact performance of a 1/3-scale dynamic model of an air cushion vehicle. Impact response was determined by measuring the maximum values of variables, including sidelobe, front lobe, and cavity pressures, normal acceleration, pitch and roll angles, and vertical displacement during impact, for various combinations of drop height, initial pitch and roll angles, and forward speed.

86-305
Operational Noise Data for the LACV-30 Air Cushion Vehicle
P. Schomer
Construction Engrg. Res. Lab. (Army), Champaign, IL
Rept. No. CERL-TR-N-85/04, 25 pp (Mar 1985), AD-A154 063/2/GAR

KEY WORDS: Ground effect machines, Experimental data, Noise measurement

Operational data for LACV-30 air cushion vehicle were gathered and developed into sound exposure level vs. distance curves. Although the Army classifies the LACV-30 as an amphibious vehicle, an examination of its noise characteristics and operations showed it most closely resembles a helicopter. Thus the methodology for gathering rotary wing aircraft data was used. Measurements of LACV-30's passby runs over water at various distances and speeds were similar in concept to flyover and flyby measurements for helicopters, and the land maneuver measurements corresponded most nearly to a helicopter's hover measurements.

SHIPS

86-306
Seakeeping and Vibration Tests of the Coast Guard 110 Foot Surface Effect Ship SEA BIRD Class (WSES)
T.J. Coe
Coast Guard Res. and Dev. Ctr., Groton, CT
Rept. No. CGR/DC-16/84, USCG-D-32-84, 57 pp (Sept 1984), AD-A154 150/7/GAR

KEY WORDS: Surface effect machines, Vibration tests, Ships

Seakeeping and vertical acceleration tests were performed on the U.S. Coast Guard 110 ft surface effect ships USCGC SHEARWATER and USCGC SEA HAWK. Roll, pitch and heave motions were recorded and later analyzed. All motions were averaged by highest one tenth and highest one third single amplitudes. Vertical accelerations were further analyzed using ISO standards to determine the human response and fatigue limits relative to high frequency (1.8 Hz) heave motions encountered.

86-307
Further Studies on Liquid Sloshing
Y.K. Lou, M.C. Wu, C.K. Lee
Texas A & M Univ., College Station, TX
Rept. No. COE-277, MA-RD-760-85009, 228 pp (Mar 1985), PB85-198695/GAR

KEY WORDS: Tanker ships, Sloshing, Resonant frequencies

Sloshing is especially of concern for LNG Carriers and large oil tankers because of their tank size and geometrical configurations and the likelihood of near-resonant excitation of the contained liquid. When a tank is under multi-degree-of-freedom excitations the phase relationships among the excitations might have a significant effect on sloshing loads. An analytical solution is obtained for liquid sloshing under combined excitations with phase difference. A series of physical model tests has also been conducted to investigate the effects of the phase angle on liquid sloshing loads for tanks under combined roll and sway and roll and heave excitations.

86-308
Measurement of Ship Hydrodynamic Coefficients in Maneuvering from Simple Trials during Regular Operations
M.A. Abkowitz
Massachusetts Inst. of Tech., Cambridge, MA
Rept. No. MA-RD-760-84026, 72 pp (Nov 1984), PB85-197952/GAR

KEY WORDS: Ships, Hydrodynamic coefficients, System identification techniques

Previous research had demonstrated that the hydrodynamic coefficients in the equations of motion simulating ship maneuvering can be measured (identified), by the application of system identification techniques to ship motion measurements taken during special maneuvering trials of the ship. The preferred goal of the present project was to determine whether the hydrodynamic coefficients of a ship can be identified from simple trials conducted during a regular voyage using only instrumentation already on board.

86-309
Static and Dynamic Analysis for Side Column Structure of Gondolas
Wenbi Zhang
J. China Railway Soc., 6 (4), pp 1-13 (1984), CSTA No. 625.1-84.29

KEY WORDS: Cargo ships, Fluid-filled containers, Finite element techniques

The dynamic pressure exerted by bulk freight on the side walls of gondolas is analyzed. Considering the liquid-like property of bulk freight under the action of the given lateral vibration acceleration, a formula for solving the dynamic lateral pressure of bulk freight by the finite element method is derived from the Laplace equation and distribution rule of the lateral pressure along the height of the side wall is obtained.

86-310
A Finite Element Method of Riser Frequency Domain Analysis
A. Ertas
Ph.D. Thesis, Texas A & M Univ., 151 pp (1984), DA8504662

KEY WORDS: Marine risers, Finite element technique, Wave forces, Fluid-induced excitation

The linearized and nonlinear motion response of the riser to regular waves without current and regular waves with current is described. The linearized frequency domain technique and nonlinear time domain analysis are discussed and compared. The finite element method is used for performing dynamic analysis of a two dimensional riser structure subjected to forces generated by wave and current. For dynamic analysis, time histories of the displacements are generated through mode superposition technique. For the frequency domain analysis an improved linearization technique is developed and applied to the hydrodynamic drag term. Accuracy, advantageous, disadvantageous, applications and limitations of this technique are discussed.

AIRCRAFT

86-311

Vibrational Analysis in Aerodynamics. 1972-July 1985 (Citations from the International Aerospace Abstracts Data Base)

NTIS, Springfield, VA
205 pp (July 1985), PB85-863967/GAR

KEY WORDS: Aircraft vibration, Spacecraft, Aerodynamic loads, Bibliographies

This bibliography contains 248 citations concerning design and performance relative to aerodynamic vibration. Torsion blade flutter; vibration generated by rudders, rotor blades, panels and air foils; vortex shedding; load control; and helicopter gust response flutter are among the topics discussed. Aircraft vibrational analyses by means of analog computer simulation, autoflight control systems, and structural dynamics of aircraft for flight vehicle vibration control and reduction are included.

86-312

Vibrational Analysis in Aerodynamics. 1970-July 1985 (Citations from the Engineering Index Data Base)

NTIS, Springfield, VA
137 pp (July 1985), PB85-864049/GAR

KEY WORDS: Aircraft vibration, Spacecraft, Aerodynamic loads, Bibliographies

This bibliography contains 187 citations concerning aerodynamic, aircraft and spacecraft generated vibration. Structural design flutter in air cushion vehicles; helicopter blade flutter; bending-torsion flutter at supersonic, subsonic and transonic speeds; wake induced wing flutter; stalled and unstalled flutter, and panel flutter are among the conditions discussed relative to such analysis techniques as finite element analysis. Ground vibration test results, space vehicle automated design, and calculation of critical flutter speeds for fixed wing aircraft are included with respect to vibrational suppression performance.

86-313

Airworthiness Flight Test Program of an Aircraft Equipment Fairing

V.R. Miller, T.P. Severyn
Flight Dynamics Lab., AF Wright Aeronautical Labs., Wright-Patterson AFB, OH
Shock Vib. Bull., #55, Part 2, pp 69-75, June 1985, 7 figs, 1 table, 4 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Aircraft, Structural modification techniques, Aerodynamics characteristics

Results of an airworthiness flight test program of an aircraft equipment fairing are presented. The objective of the tests was to insure the airworthiness of the aircraft with the installed fairing. The tests were conducted to determine the structural integrity of the modifications and their effects on the aircraft handling qualities. The tests were extended to allow more detailed data acquisition and analysis due to the problems encountered with flow separation, aerodynamic buffeting and noise-induced fatigue. Rigid inspection requirements were levied after each flight to detect any structural damage.

86-314

Passive Damping - Sonic Fatigue - and the KC-135

P.A. Graf, M.L. Drake, M.P. Bouchard, R.J. Dominic
Univ. of Dayton Res. Inst., Dayton, OH
Shock Vib. Bull., #55, Part 1, pp 89-102, June 1985, 25 figs, 1 table, 5 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Acoustic fatigue, Aircraft, Takeoff

High noise levels occurring during maximum-thrust takeoff have caused sonic fatigue cracking of the aft fuselage skin and stringers of the KC-135A aircraft. A detailed description of a program to solve this problem through the design and evaluation of a passive damping system for the aft fuselage of the KC-135A is presented.

86-315

Air Bag Restraint System

D.L. Lorch
Dept. of Navy, Washington, DC
U.S. PATENT-4 508 294, 6 pp (Apr 2, 1985)

KEY WORDS: Air bags (safety restraint systems), Ejection seats

An air bag restraint system is disclosed for protecting an occupant in a seat during ejection from a vehicle, particularly an aircraft.

86-316
Bifurcation Theory Applied to Aircraft Motions
W.H. Hui, M. Tobak
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. REPT-85171, NASA-TM-86704, 17 pp (Mar 1985), N85-23705/5/GAR

KEY WORDS: Aircraft, Stability, Bifurcation theory

Bifurcation theory is used to analyze the nonlinear dynamic stability characteristics of single-degree-of-freedom motions of an aircraft or a flap about a trim position. The bifurcation theory analysis reveals that when the bifurcation parameter, e.g., the angle of attack, is increased beyond a critical value at which the aerodynamic damping vanishes,a new solution representing finite-amplitude periodic motion bifurcates from the previously stable steady motion. The sign of a simple criterion, cast in terms of aerodynamic properties, determines whether the bifurcating solution is stable (supercritical) or unstable (subcritical).

86-317
Recent Transonic Unsteady Pressure Measurements at the NASA Langley Research Center
M.C. Sandford, R.H. Ricketts, R.W. Hess
NASA Langley Res. Ctr., Hampton, VA
Rept. No. PAPER-85-23, NASA-TM-86408, 21 pp (Apr 1985), N85-23710/5/GAR

KEY WORDS: Aircraft wings, Aerodynamic loads

Four semispan wing model configurations were studied in a transonic dynamics tunnel. The unsteady pressure studies of the four models are described and some typical results for each model are presented. Comparison of selected experimental data with analytical results also are included.

86-318
Triaxial Vibration System
W.D. Everett, T.M. Helfrich
Pacific Missile Test Ctr., Point Mugu, CA
Shock Vib. Bull., #55, Part 2, pp 1-15, June 1985, 11 figs, 2 tables, 8 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Test facilities, Wing stores, Helicopters

During the reliability tests of external stores the Pacific Missile Test Center has been successful in reproducing the in-service vibration experienced by the store when carried on a high performance jet aircraft. In attempting to increase test capability to include stores carried on helicopters and other low speed platforms and to maintain a triaxial vibration capability, a test facility is being developed that will test a 500 pound store in the 0 to 500 Hertz frequency range with a stroke of 2 inches double amplitude. A description of the device, an overview of the effort to date, an analytical investigation of the motion, and an evaluation test plan that has been developed for a thorough evaluation of the device is presented.

86-319
Recent Developments in the Dynamics of Advanced Rotor Systems
W. Johnson
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. A-85089, NASA-TM-86669, 117 pp (Mar 1985), N85-24320/2/GAR

KEY WORDS: Helicopter rotors, Aircraft vibration, Vibration control

The problems that were encountered in the dynamics of advanced rotor systems are described. The basic dynamic problems of rotors are discussed: aeroelastic stability, rotor and airframe loads, and aircraft vibration. Advanced topics that are the subject of current research are described: vibration control, dynamic upflow, finite element analyses, and composite materials. The dynamics of various rotorcraft configurations are considered: hingeless rotors, bearingless rotors, rotors with circulation control, coupled rotor/engine dynamics, articulated rotors, and tilting proprotor aircraft.

MISSILES AND SPACECRAFT

86-320
Damping Models for Flexible Communications Satellites by Substructural Damping Synthesis

P.C. Hughes
Univ. of Toronto, Downsview, Ontario, Canada
Rept. No. UTIAS-287, 62 pp (Jan 1985), N85-23868/1/GAR

KEY WORDS: Spacecraft, Damping coefficients, Substructuring methods

Most modern spacecraft are structurally flexible and, moreover, these spacecraft can naturally and profitably be analyzed as a collection of attached substructures (solar array panels, antennas, thermal radiators, etc.). Various models are combined for substructural energy dissipation so that an overall damping model for the spacecraft results. Four such substructural damping models are discussed, two of which are shown to produce the same results. Such a synthesis procedure proves valuable when substructural damping data is known, either from ground tests or detailed analysis.

86-321

An Update of Spacecraft Dynamic Environments Induced by Ground Transportation

M.R. O'Connell
California Inst. of Technology, Pasadena, CA
Shock Vib. Bull., #55, Part 2, pp 77-85, June 1985, 8 figs, 2 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Spacecraft, Transportation effects

An update to the JPL spacecraft transportation dynamic environments data base has been developed based on data from recent transportation of spacecrafts. Vibration levels are significantly lower than those measured in 1966, while the shock response spectra are nearly the same. JPL groundshipping criteria and shipping practices, which have been very successful in preventing damage, are also summarized.

86-322

Application of the ITD Algorithm to Landsat Transient Responses

R.R. Kauffman
General Electric Co., Philadelphia, PA
Shock Vib. Bull., #55, Part 3, pp 81-89, June 1985, 5 figs, 2 tables, 6 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Spacecraft, Modal damping, Time domain method

Frequency, damping, and three degree-of-freedom mode shapes were estimated from data transmitted from the orbitting Landsat-4 and Landsat-5 earth observation spacecraft. The data was comprised of three channels of time history data corresponding to orthogonal rotations of the spacecraft. The data was processed using the Ibrahim time domain technique.

86-323

Time-Domain Response Envelope for Structural Dynamic Systems

Jay-Chung Chen, M. Trubert, J.A. Garba
California Inst. of Technology, Pasadena, CA
J. Spacecraft Rockets, 22 (4), pp 442-449 (July/Aug 1985), 11 figs, 1 table, 10 refs

KEY WORDS: Spacecraft, Transient response, Time domain method

A transient envelope solution method is developed for payload structural systems. This method requires that the external forcing functions are decomposed into a quasistatic and dynamic parts. The amplitude of the peak envelope and the corresponding varying frequencies for the generalized forcing functions are required for obtaining the response envelopes. The proposed method is applied to a spacecraft structural system and the results are in good agreement with the exact solution.

86-324

Design of Integrally Damped Spacecraft Panels

C.V. Stahle, J.A. Staley
Valley Forge Space Ctr., Philadelphia, PA
Shock Vib. Bull., #55, Part 1, pp 103-108, June 1985, 12 figs, 1 table, 11 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC).

KEY WORDS: Equipment mounts, Spacecraft equipment response, Vibration damping, Acoustic absorption

The results of preliminary design and analysis studies of damped spacecraft equipment mounting panels are presented. Increased vibroacoustic reliability and reduced program development costs can be achieved by controlling spacecraft equipment vibration during launch. To reduce the significant number of anomalies which occur shortly after launch, component vibration requirements have been increased to provide larger margins. This has resulted in a large number of vibroacoustic test failures during qualification and acceptance tests. A $40 million cost saving is estimated using the OCTAVE code if the equipment vibration environment is reduced 50 percent for an operational satellite system using MIL-STD-1540 test program.

86-325
Incorporating Control into the Optimal Structural Design of Large Flexible Space Structures
T.V. Muckenthaler
Air Force Inst. of Tech., Wright-Patterson AFB, OH
Rept. No. AFIT/GA/AA/84D-7, 139 pp (Dec 1984), AD-A152 858/7/GAR

KEY WORDS: Spacecraft, Optimum control theory, Design techniques, Computer progams

An eigenspace optimization approach is used to incorporate optimal control into the structural design process for large flexible space structures. The equations of motion for an uncontrolled system are developed by deriving the kinetic and potential energy for the system and then using assumed modes to discretize the energies. These expressions are then linearized, the Lagrangian formed, and Lagrange equations written for the system. An existing optimal control law is incorporated to form the equations of motion for the controlled system. A parameter optimization technique is used to minimize the mass of the Draper/RPL configuration model involving eigenspace optimization. A computer algorithm is developed that effectively optimizes a global structural parameter vector to minimize the mass of the model, while constraining specified eigenvalues.

86-326
Passive Load Control Dampers
D.M. Eckblad, P.J. Schirmer
Boeing Aerospace Co., Seattle, WA
Shock Vib. Bull., #55, Part 1, pp 131-138, June 1985, 18 figs, 2 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Missiles, Underground structures, Nuclear explosion effects, Shock isolation, Dampers

The need to accommodate greater nuclear groundshock threats for a larger and heavier missile/canister within an existing underground site has led to a unique damper requirement which is satisfied using the passive load control damper. The design approach to develop this passive load control damper is described. Details in modeling the passive load control damper valve dynamics are given. Dynamic analysis is compared with various levels of tests, showing good correlation.

86-327
Ultra-High-Velocity Impacts Utilizing a Rocket Sled and an Explosively Accelerated Flyer Plate
R.A. Benham, W.R. Kampfe
Sandia National Labs.
Shock Vib. Bull., #55, Part 2, pp 51-56, June 1985, 12 figs, 5 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Reentry vehicles, Impact tests

Well-controlled impacts of reentry vehicle nose tips with relatively thick targets at controlled inclination and at velocities above 14,000 fps can now be obtained using a newly developed testing method. The instrumented nose tip is mounted on a rocket sled and is accelerated to a velocity of more than 6000 fps. An explosively accelerated flyer plate (target) is driven toward the sled, at the proper angular orientation, at velocities of more than 8000 fps. Impact of the target and nose tip occurs at the combined velocities. This method has been demonstrated in two experiments, with total test costs a fraction of that of the rocket flight test.

86-328
Low Order Dynamic Models of Indian Remote Sensing Satellite
M. Sambasiva Rao, B.G. Prakash, M.S.S. Prabhu
ISRO Satellite Ctr., Bangalore 560 017, India
Shock Vib. Bull., #55, Part 3, pp 129-153, June 1985, 10 figs, 6 tables, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Launch vehicles, Spacecraft, Mathematical models, Coupled response

Simple low order equivalent dynamic models of Indian Remote Sensing Satellite (IRS) are gener-

ated. The models consist of physical elements like springs, beams, etc., with lumped masses. Two decoupled models, one in longitudinal and the other in lateral direction, are generated representing the dynamic characteristics of the satellite adequately in the low frequency range of 0-100 Hzs. A building-block approach is followed in systematically constructing the models.

86-329
Water Impact Testing of a Filament Wound Case
A.A. Schmidt, D.A. Kross, R.T. Keefe
NASA/Marshall Space Flight Ctr., Huntsville, AL
Shock Vib. Bull., #55, Part 2, pp 57-67, June 1985, 23 figs, 3 tables, 1 ref (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Booster rockets, Space shuttles, Impact tests

A lightweight filament wound case (FWC) solid rocket booster is being developed by NASA to increase the payload capability of the Space Shuttle. Tests were conducted on a quarter scale FWC model to measure cavity collapse pressure distributions, deflected shape and the effects of end conditions and pressure scaling.

86-330
Ignition/Duct Overpressure Induced by Space Shuttle Solid Rocket Motor Ignition
H. Ikawa, F.S. Laspesa
Rockwell Intl., Downey, CA
J. Spacecraft Rockets, 22 (4), pp 481-488 (July/Aug 1985), 16 figs, 9 refs

KEY WORDS: Space shuttles, Launching response

An analytical methodology, with a propagating solid rocket motor (SRM) exhaust front as a perturbation pressure wave generator, is developed to enhance understanding of the ignition/duct overpressure (IOP/DOP) induced during the Space Shuttle liftoff. Waveform, amplitude, and low-frequency responses of IOP/DOP are simulated.

86-331
Vibroacoustic Study of the NASA Goddard Space Flight Center OSS-1 Payload
Y.A. Lee, W. Henricks
Lockheed Missiles and Space Co., Inc., Sunnyvale, CA
Rept. No. LMSC-D980796, NASA-CR-175320, 37 pp (Jan 1985), N85-22465/7/GAR

KEY WORDS: Space shuttles, Testing techniques

A comparative evaluation of shuttle liftoff and ground test random response data obtained from the pallet payload flown in the cargo bay of STS-3 is presented. The study was initiated to evaluate the possibility that the payload flight vibration response can exceed that which occurred during ground test, when the ground test acoustic excitation is normalized to the flight acoustic environment.

86-332
Shuttle Payload Bay Dynamic Environments: Summary and Conclusion Report for STS Flights 1-5 and 9
M. O'Connell, J. Garba, D. Kern
Jet Propulsion Lab., Pasadena, CA
Rept. No. JPL-PUB-84-88, NASA-CR-175656, 166 pp (Dec 1, 1984), N85-23896/A/GAR

KEY WORDS: Space shuttles, Experimental data, Vibration measurement, Noise measurement

The vibration, acoustic and low frequency loads data from the first five shuttle flights are presented. The engineering analysis of that data is also presented. Vibroacoustic data from STS-9 are also presented representing the only data taken on a large payload. Payload dynamic environment predictions developed by the participation of various NASA and industrial centers are presented along with a comparison of analytical loads methodology predictions with flight data, including a brief description of the methodologies employed in developing those predictions for payloads.

BIOLOGICAL SYSTEMS

HUMAN

86-333
Research on the Effect of Noise at Different Times of Day: Models, Methods and Findings

J.M. Fields
Bionetics Corp., Hampton, VA
Rept. No. NASA-CR-3888, 83 pp (Apr 1985), N85-23375/7/GAR

KEY WORDS: Noise tolerance, Human response

Social surveys of residents' responses to noise at different times of day are reviewed. The research findings are classified according to the type of time of day reaction model, the type of time of day weight calculated and the method which is used to estimate the weight. Challenges to common assumptions in nighttime response models are evaluated. All existing social survey results in which averages of nighttime responses were plotted by nighttime noise levels are reproduced.

86-334
Influence of Road Noise on Riding Comfort
J.C. Young
Transport and Road Res. Lab., Crowthorne, UK
Rept. No. TRRL/LR-1128, 27 pp (1984), PB85-182640/GAR

KEY WORDS: Traffic noise, Noise generation, Road roughness, Human response

Experiments are reported involving 14 subject exposed to noise from 7 types of road surfacing. The subjects, chosen after audiometric tests, each received pre-recorded road noise from various types of road surfacings as they travelled over surfaces of known unevenness, in a medium-sized car. The method of paired comparisons was used to examine the annoyance caused by road noise. A rating scale was used to assess both annoyance and overall riding comfort.

86-335
Vibration Nuisance from Road Traffic - Results of a 50 Site Survey
G. R. Watts
Transport and Road Res. Lab., Crowthorne, UK
Rept. No. TRRL/LR-1119, 37 pp (1984), PB85-182541/GAR

KEY WORDS: Traffic-induced vibrations, Traffic noise, Human response

Vibration nuisance in residential properties caused by road traffic is investigated. The subjective data was obtained by interviewing approximately 30 people at each of 50 residential locations. 18-hour noise exposure measures were found to be more closely associated with the site median vibration and noise nuisance ratings than window vibration or traffic flow levels. The Leq dB(A) level was the noise measure most closely associated with subjective site median vibration nuisance ratings, accounting for about half the variance in the median ratings.

86-336
Community Survey of Helicopter Noise Annoyance Conducted Under Controlled Noise Exposure Conditions
J.M. Fields, C.A. Powell
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-86400, 188 pp (Mar 1985), N85-23374/0/GAR

KEY WORDS: Helicopter noise, Human response

Reactions to low numbers of helicopter noise events (less than 50 per day) were studied in a community setting. Community residents were repeatedly interviewed about daily noise annoyance reactions on days when helicopter noise exposures were, without the residents' knowledge, controlled. The effects of maximum noise level and number of noise events on helicopter noise annoyance are consistent with the principles contained in LEQ-based noise indices. The effect of the duration of noise events is also consistent with LEQ-based indices.

86-337
Aviation Noise Effects
J.S. Newman, K.R. Beattie
Federal Aviation Admn., Washington, DC
Rept. No. FAA-EE-85-2, 117 pp (Mar 1985), AD-A154 319/8/GAR

KEY WORDS: Aircraft noise, Human response

This report summarizes the effects of aviation noise in many areas, ranging from human annoyance to impact on real estate values. It also synthesizes the findings of literature on several topics. Included in the literature were many original studies carried out under FAA and other Federal funding over the past two decades. Efforts have been made to present the critical finding and conclusions of pertinent research, providing, when possible, a bottom line conclusion, criterion or perspective. Issues related to aviation noise are highlighted, and current policy is presented.

86-338
Sound Measurements at Ultrasonic Industrial Plants and a Comparison with Criteria for Prevention of Hazardous Health Conditions (Geräuschmessungen an industriellen Ultraschallanlagen und Vergleich mit Beurteilungskriterien zur...)
K. Körpert, R. Vanek
Allgemeine Unfallversicherungsanstalt, Hauptstelle fur Berufskrankheitenbekampfung, Vienna, Austria
Acustica, 58 (1), pp 48-56 (June 1985), 8 figs, 4 tables, 19 refs (In German)

KEY WORDS: Noise measurement, Ultrasonic techniques, Industrial facilities, Human response

Ultrasound cleaning, welding and drilling devices are increasingly used in industry and therefore the question arises how to set sound exposure limits to avoid hearing damage as well as unpleasant subjective effects. The sound measurement data of a set of ultrasound devices are analyzed and compared with known criteria. The conclusion is that the AU-weighted sound pressure level seems to be best suited for practical application.

86-339
Noise Radiated from Forging Presses
E. Doege, G. Wischmann
Univ. of Hannover, Fed. Rep. Germany
Noise Control Engrg. J., 24 (2), pp 44-48 (Mar/Apr 1985), 7 figs, 6 refs

KEY WORDS: Industrial facilities, Forging machinery, Noise generation, Noise measurement, Human response

Sledge hammers and forging presses with their equipment- and impact-noise impulses are the sources of the extremely high noise levels in forging factories. Noise measurements near 42 screw and crank presses and their workshops describe the emission and the noise stress experienced by forging workers.

86-340
Acoustic Noise Associated with the MOD-1 Wind Turbine: Its Source, Impact, and Control
N.D. Kelley, H.E. McKenna, R.R. Hemphill, C.L. Etter
Solar Energy Res. Inst., Golden, CO
Rept. No. SERI/TR-635-1166, 262 pp (Feb 1985), DE85002947/GAR

KEY WORDS: Wind turbines, Noise generation, Human response

This report summarizes extensive research conducted to establish the origin and possible amelioration of acoustic disturbances associated with the operation of the DOE/NASA MOD-1 wind turbine installed in 1979 near Boone, North Carolina. Results have shown that the source of this acoustic annoyance was the transient, unsteady aerodynamic lift imparted to the turbine blades as they passed through the lee wakes of the large, cylindrical tower supports. Several techniques for reducing the abrupt, unsteady blade load transients were researched and are discussed.

86-341
Hand-Arm Vibration
The 4th Intl. Symp. Helsinki, Finland, May 6-8, 1985. Spons. by the Sci. Committee on Health Effects of Physical Environmental Factors of the Intl. Commission on Occupational Health

KEY WORDS: Human hand, Human response, Vibratory tools

The purpose of the symposium was to clarify risks associated with power tools, to examine exposure limits and design goals for future tools, to improve measurement techniques, and to stimulate further research. Sessions held were on diagnosis and treatment of vibration syndrome; epidemiological studies of exposure to vibration; power tool vibration studies and industrial processes involving exposure to vibration; models of the hand-arm system; compounding effects of vibration induced disorders; medical and legal implications of exposure to vibration. The proceedings containing selected papers will be published as supplement of Scandinvaian Journal of Work, Environment and Health during 1986.

86-342
Subjective Reactions to Whole-Body Vibration of Short Duration
A. Kjellberg, B.-O. Wikström

National Board of Occupational Safety and Health, S-17184 Solna, Sweden
J. Sound Vib., 99 (3), pp 415-424 (Apr 8, 1985), 3 figs, 1 table, 10 refs

KEY WORDS: Vibration excitation, Human response

An important problem in the evaluation of whole-body vibration is how shocks are to be included in a comprehensive measure of the vibration load on man. This calls for knowledge of how the effect of the vibration changes as a function of its duration. This was the purpose of three experiments in which subjects were exposed to vertical sinusoidal vibration of varying duration. The vibrations were each presented together with a vibration of the same frequency but with a constant duration. The subjects task was to adjust one of the vibrations until both gave rise to the same discomfort towards the end of the vibration.

86-343
Model Evaluation of Spinal Injury Likelihood for Various Ejection System Parameter Variations
E. Privitzer
Air Force Aerospace Medical Res. Lab., Wright-Patterson Air Force Base, OH
Shock Vib. Bull., #55, Part 3, pp 99-116, June 1985, 11 figs, 31 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC

KEY WORDS: Human spine, Head (anatomy), Impact response, Ejection seats, Mathematical models

The head-spine model (HSM), a discrete element model of the human head-spine structure, is described. This model was developed to provide a mathematical means for the investigation of three-dimensional head-spine structure dynamic response and injury likelihood in impact environments, and to serve as a design tool for the evaluation of crewmember-ejection system impact interactions. Results are presented from a study which involved the use of the HSM to evaluate the effects of variations in certain ejection system parameters on head-spine structure ejection response and injury likelihood.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

86-344
Vibration Control of Multi-Degree of Freedom System by Dynamic Absorbers (1st Report, On the Design Method for Dynamic Absorber)
K. Seto, K. Iwanami, Y. Takita
The National Defense Academy, Yokosuka, Japan
Trans. JSME No. 458 (Dec 28, 1983)

KEY WORDS: Dynamic absorbers, Vibration control, Multi-degree of freedom systems

To control the mechanical vibration of a multi-degree of freedom system, this paper proposes the practical application of dynamic absorbers and a new approach to their design. The principal objective of the design method proposed here is to exactly estimate equivalent masses and their locations in each vibration mode, after decoupling the vibration system in modal domain. The effectiveness of the design method is demonstrated by controlling the undamped vibration of a three degree of freedom system using three absorbers.

86-345
Vibration Control of Multi-Degree of Freedom System by Dynamic Absorbers (2nd Report, On the Design of the Dynamic Absorber by the Transfer Matrix Method)
K. Seto
The National Defense Academy, Yokosuka, Japan
Trans. JSME No. 458 (Jan 5, 1984)

KEY WORDS: Dynamic absorbers, Vibration control, Beams

To confirm the availability of the design method for dynamic absorbers of multi-degree of freedom systems, this paper shows that the first three resonances of a cantilever beam structure with negligible internal damping can be suppressed effectively by three dynamic absorbers which are designed using the method. The suitable locations to install each dynamic absorber and the equivalent masses at these locations are estimated by applying the transfer matrix method. After forming a complex transfer matrix for the dynamic absorber, the complex transfer matrix method to calculate the frequency response of the beam structure with three dynamic absorbers is shown.

86-346
Optimum Vibration Control of Rigid Body Supported by Four Active Isolators
Y. Iwata, Y. Okada
Tokyo Metropolitan Univ., Tokyo, Japan
Trans. JSME No. 458 (Jan 5, 1984)

KEY WORDS: Active isolation, Ground vehicles, Active vibration control

The optimum vibration control of a multi-dimensional vibration system as in the case of a transportation vehicle is considered impossible if the control makes use of only passive elements, such as a spring and damper. This paper proposes a scheme to realize an optimum vibration isolation system with employment of active elements which control the pneumatic pressure of the air springs. The design principle is to calculate the optimum feedback transfer functions minimizing the accelerations of vertical, rolling and pitching modes within the predetermined stroke of the air springs when the system is given a stationery random vibration.

86-347
Transient Response of Unidirectional Vibration Isolators with Many Degrees of Freedom
A.F. Vakakis, S.A. Paipetis
Univ. of Patras, Patras, Greece
J. Sound Vib., 99 (4), pp 557-562 (Apr 22, 1985), 4 figs, 2 tables, 5 refs

KEY WORDS: Vibration isolators, Elastomers, Damping effects, Laplace transformation

Following a procedure developed by the authors for the investigation of the dynamic behaviour of an n-degree-of-freedom linear elastic system with damping, the corresponding transient response is dealt with. The procedure is based on a class of polynomials depending on the mechanical properties of the system and the Laplace transformation is applied. As an example, a four-degree-of-freedom is examined.

86-348
Response of a Symmetric Self-Damped Pneumatic Shock Isolator to an Acceleration Pulse
M.S. Hundal, D.J. Fitzmorris
Univ. of Vermont, Burlington, VT
Shock Vib. Bull., #55, Part 1, pp 139-154, June 1985, 11 figs, 3 tables, 14 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC

KEY WORDS: Shock isolators, Pneumatic dampers

Pneumatic damping offers several advantages in shock and vibration applications including cleanliness, light weight and few moving parts. Large deflections of pneumatic shock absorbers make their behavior nonlinear and thus difficult to analyze. This paper details the analysis and response of a symmetric pneumatic absorber with orifice damping. With proper design such an absorber can provide a response to a shock pulse similar to that of a (theoretically) linear absorber. Results are given in the form of graphs and empirical formulas which can be used for design.

86-349
Nonlinear Random Vibration of the Vehicle Suspended with Oil-Pneumatic Spring
Yaoqun Lin, Dechang Xi
Acta Armamentarii, (1), pp 17-25 (1985), CSTA No. 623.4-85.03

KEY WORDS: Suspension systems (vehicles), Pneumatic springs

Vibration of a vehicle suspended with oil-pneumatic springs is investigated, simplified as a two-degree nonlinear system subjected to a stationary random road excitation. The MSRs of the displacement, velocity and acceleration of the vehicle vibration are given.

BLADES

86-350
A Simple Method of Estimating the Fatigue Life of Stochastically Excited Blades (Ein einfaches Modell zur Abschätzung der Lebensdauer von stochastisch angeregten Schaufeln)
H. Bloemhof
Sonnhaldenstrasse 3, CH-8904 Aesch
MTZ Motortech. Z., 46 (6), pp 235-237 (June 1985), 7 figs, 4 refs (In German)

KEY WORDS: Blades, Stochastic processes, Fatigue life, Probability density function

Based on the vibration characteristics of a blade stochastically excited in one natural mode, the probability density function of the vibration's peak values is discussed. It is shown how this function is related to the rms value of the vibration signal.

86-351
Factors Affecting the Fatigue Life of Turbine Blades and an Assessment of Their Accuracy
N.F. Rieger
Stress Technology Inc., Rochester, NY
Shock Vib. Bull., #55, Part 1, pp 51-69, June 1985, 18 figs, 2 tables, 5 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Rotor blades (turbomachinery), Fatigue life

Factors which influence the fatigue life of turbomachine blades are identified, and the current state of knowledge in each area is discussed. Estimates are presented for the probable accuracy to which blade excitation, damping, material properties, and life history data can presently be determined for a given geometry and operating conditions. The influence of errors in these input data estimates on the resulting accuracy of predicted values for blade life is estimated using linear theory. Recent advances which lead to improved estimates of cumulative damage life are discussed.

86-352
Aerodynamic Damping of Oscillating Cascades — Computation and Experiment (Aerodynamische Schaufeldämpfung — Rechnung und Experiment)
H.E. Gallus, H. Holtmann, W. Knauf
MTZ Motortech. Z., 46 (6), pp 225-231 (June 1985) 13 figs, 7 refs (In German)

KEY WORDS: Cascades, Rotor blades (turbomachinery), Aerodynamic damping

A method for computing two-dimensional, unsteady, subsonic, inviscid, compressible flow through oscillating cascades of turbomachinery blades and related experimental investigations are presented. Nonlinear Eulerian equations are solved for time-dependent blade positions using a combined method: for interior points, the Warming/Beam algorithm has been implemented, while the boundary conditions are computed using a bicharacteristic method. The unsteady computation grid is generated once per time step using the Thompson, Thames and Mastin method.

86-353
Characteristics of Natural Frequencies of Steam Turbine Blades (3rd Report, Vibration of Bound Blades on Entire Disk Circumference)
M. Shiga
Hitachi Ltd., Ibaraki, Japan
Bull. JSME, 28 (240), pp 1196-1203 (June 1985) 7 figs, 2 tables, 4 refs

KEY WORDS: Bladed disks, Turbine blades, Natural frequencies

To avoid resonance of steam turbine blades during operation, it is necessary to establish a prediction method for the natural frequencies of blades. A calculation method of the natural frequencies is developed for structures with blades bound on the entire disk circumference. The relationship between the natural frequencies of all bound blades and those of a bound group consisting of several blades, and variations of the natural frequencies according to variation in blade dimensions are discussed.

86-354
Response of a Wind Turbine Blade to Seismic and Turbulent Wind Excitations
Rex Chin-Yih Hong
Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 179 pp (1984) DA8502178

KEY WORDS: Turbine blades, Wind turbines, Wind-induced excitation, Turbulence, Seismic excitation

The dynamic behavior of a wind turbine blade under seismic and turbulent wind excitations is investigated. A procedure is developed in which the Markov process theory and Ito's stochastic differential equation are used to obtain equations for statistical moments of blade response variables. Such equations then can be used to determine certain moment stability conditions for any given set of parameters, and moment responses if the system is stable.

86-355
Cyclic Structural Analyses of Anisotropic Turbine Blades for Reusable Space Propulsion Systems
J.M. Manderscheid, A. Kaufman
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2534, NASA-TM-86990, 13 pp (Apr 12, 1985), Presented at 1985 Jannaf Propulsion Mtg., San Diego, CA, Apr 9-12, 1985, N85-24339/2/GAR

KEY WORDS: Turbine blades, Cyclic loading, Fatigue life

Turbine blades for reusable space propulsion systems are subject to severe thermomechanical loading cycles that result in large inelastic strains and very short lives. These components require the use of anisotropic high-temperature alloys to meet the safety and durability requirements of such systems. To assess the effects on blade life of material anisotropy, cyclic structural analyses are being performed for the first stage high-pressure fuel turbopump blade of the space shuttle main engine. The blade alloy is directionally solidified MAR-M 246 alloy. The analyses are based on a typical test stand engine cycle.

86-356
Wind Tunnel Investigation of Dynamic Stall of an NACA 0018 Airfoil Oscillating in Pitch (Etude en Soufflerie du Decrochage Aerodynamique d'un Profil NACA 0018 Oscillant en Tangage)
R.H. Wickens
National Aeronautical Establishment, Ottawa, Ontario, Canada
Rept. No. NAE-AN-27, NRC-24262, 71 pp (Feb 1985) AD-A154 717/3/GAR

KEY WORDS: Turbine blades, Aerodynamic loads, Experimental data

The purpose of the test was to simulate the dynamic aerodynamic behavior of a vertical axis wind turbine blade section at the equatorial plane under the dynamic stall conditions which may occur at low ratios of tip speed to wind speed. Measurements were made of wing surface pressure time histories at various chordwise locations, during a complete cycle of oscillation.

86-357
Influences of Difference in Blade Natural Frequency and Damping on Fan Resonant Amplitudes (Analysis for Engine Order Resonances)
N. Hagiwara, T. Suzuyama, H. Ishi, T. Kohno
Hitachi Ltd., Tsuchiura, Japan
Trans. JSME No. 458 (Jan 5, 1984)

KEY WORDS: Blades, Fans, Natural frequencies, Damping effects, Resonant response

Influence of difference in natural frequencies and damping of axial fans on resonant amplitudes of engine orders are reported. The analytical results reveal several new characteristics of vibration.

86-358
Estimating Unsteady Aerodynamic Forces on a Cascade in a Three-Dimensional Turbulence Field
T. Norman, W. Johnson
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. A-85166, NASA-TM-86701, 31 pp (Mar 1985) N85-23704/8/GAR

KEY WORDS: Cascades, Vanes, Aerodynamic loads, Turbulence

An analytical method has been developed to estimate the unsteady aerodynamic forces caused by flow field turbulence on a wind tunnel turning vane cascade system (vane set). This method approximates dynamic lift and drag by linearly perturbing the appropriate steady state force equations, assuming that the dynamic loads are due only to free stream turbulence and that this turbulence is homogeneous, isotropic, and Gaussian. Correlation and unsteady aerodynamic effects are also incorporated into the analytical model.

86-359
Factors Influencing Rotor Aerodynamics In Hover and Forward Flight
R.H. Miller
Massachusetts Inst. of Technology, Cambridge, MA
Vertica, 9 (2), pp 155-164 (1985) 12 figs, 22 refs

KEY WORDS: Helicopters, Propeller blades, Vortex-induced vibration, Helicopter rotors

The aerodynamic characteristics of rotors are heavily influenced by blade vortex interactions, both in hover and in forward flight. In addition to geometrical considerations, the nature of the vortex, including its roll-up characteristics, must be specified for reasonably accurate aerodynamic analyses. This paper discusses techniques recently developed for treating these problems. Analytically derived blade loads at forward speeds are examined and compared with test results.

86-360
A Comparison with Theory of Peak-to-Peak Sound Level for a Model Helicopter Rotor Generating Blade Slap at Low Tip Speeds
R.R. Fontana, J.E., Jr. Hubbard
Massachusetts Inst. of Technology, Cambridge, MA
Vertica, 9 (2), pp 101-125 (1985) 21 figs, 1 table, 42 refs

KEY WORDS: Helicopters, Propeller blades, Noise measurement

Mini-tuft and smoke flow visualization techniques have been developed for the investigation of model helicopter rotor blade vortex interaction noise at low tip speeds. These techniques allow the parameters required for calculation of the blade vortex interaction noise using the Widnall-Wolf model to be determined. The measured acoustics are compared with the predicted acoustics for each test condition.

86-361
Design and Development of a Dynamically Scaled Model AH-64 Main Rotor
F.K. Straub, R.A. Johnston, R.E. Head, H.L. Kelley
Hughes Helicopters, Inc., Culver City, CA
Vertica, 9 (2), pp 165-180 (1985) 14 figs, 5 tables, 7 refs

KEY WORDS: Helicopter rotors, Propeller blades, Model testing, Experimental data

A 27% dynamically scaled model of the AH-64 Apache advanced attack helicopter has been designed and developed. The 13-ft-diameter model has undergone a series of performance tests in a research center wind tunnel where full-scale flight conditions were simulated. These tests will provide a better understanding of the current Apache rotor and, together with testing of advanced rotor blade designs, will suggest potential improvements in the blade design for the AH-64 Apache.

86-362
Application of Floquet Theory to Helicopter Blade Flapping Stability
J.K. March
Air Force Inst. of Tech., Wright-Patterson AFB, OH
Rept. No. AFIT/GAE/AA/84D-13, 212 pp (Dec 1984) AD-A154 460/0/GAR

KEY WORDS: Helicopters, Propeller blades, Stability, Floquet theory

The flapping stability of a helicopter rotor blade in forward flight is explored. The equations of motion for the flapping motion of the blade are converted from nonlinear differential equations with periodic coefficients to linear periodic differential equations through the assumption of a rigid blade where the elastic flapping deflections are negligible as compared to the rigid body flapping rotations about the flapping hinge. The stability of the homogenous part of the flapping motion linearized periodic differential equations is examined through the application of Floquet theory.

86-363
Periodic Control of the Individual-Blade-Control Helicopter Rotor
R.M., Jr. McKillip
M.I.T., Cambridge, MA 02139
Vertica, 9 (2), pp 199-225 (1985), 18 figs, 25 refs

KEY WORDS: Propeller blades, Helicopters, Active vibration control

This paper describes the results of an investigation into methods of controller design for linear periodic systems utilizing an extension of modern control methods. Trends present in the selection of various cost functions are outlined, and closed-loop controller results are demonstrated for two cases: first, on an analog computer simulation of the rigid out of plane flapping dynamics of a single rotor blade, and second, on a 4 ft diameter single-bladed model helicopter rotor in the M.I.T. 5 x 7 subsonic wind tunnel, both for various high levels of advance ratio.

86-364
Oscillating Airfoils and Their Wake
W. Send
NASA, Washington, DC

Rept. No. NASA-TM-77831, 17 pp (Apr 1985), N85-23701/4/GAR

KEY WORDS: Propeller blades, Airfoils

The unsteady phenomena in the wake of an oscillating wing or rotor blade are examined theoretically using the Prandtl approximation of the vortex-transport equation. A mathematical model is developed and applied to such problems as the effect of winglets on the performance of fixed wings and the possibility of employing similar designs in rotor blades.. Model predictions for several profiles are compared with published and experimental measurements. Graphs and diagrams are provided.

86-365

Rotor Blade Flap-Lag Stability and Response in Forward Flight in Turbulent Flows

Ting-Nung B. Shiau

Ph.D. Thesis, Univ. of Illinois, Urbana-Champaign, 178 pp (1984), DA8502297

KEY WORDS: Helicopters, Propeller blades, Turbulence

The effect of random air turbulence on the coupled flap-lag motion of a helicopter rotor blade in forward flight is investigated. By assuming white noise turbulence and applying a special case of the stochastic averaging procedure, equations are developed which describe the stochastic first and second moments of the perturbations in flap and lead-lag angles due to turbulence. The stability of multibladed rotors in the presence of turbulence is investigated using the example of a three-bladed rotor.

BEARINGS

86-366

On the Static Running Accuracy of Ball Bearings

H. Tamura, E.H. Gad, T. Kondou, T. Ayabe

Zagazig Univ., Zagazig, Egypt

Bull. JSME, 28 (240), pp 1240-1246 (June 1985), 6 figs, 13 refs

KEY WORDS: Ball bearings

The quasi-static vibratory analysis of a rotor supported by ball bearings is presented. The system is an ideal ball bearing in which the inner ring moves in the radial plane with two degrees of freedom under a constant radial load. The motion of the inner ring center due to ball revolution, which has been known as the Perret-Meldau problem since the 1905's, is analyzed in detail. The results show that the inner ring motion has complicated features and changes drastically with the design and operating conditions.

GEARS

86-367

Jump Phenomena in Gear System to Random Excitation

K. Sato, S. Yamamoto, O. Kamada, N. Takatsu

Utsunomiya Univ., Utsunomiya, Japan

Bull. JSME, 28 (240), pp 1271-1278 (June 1985), 15 figs, 11 refs

KEY WORDS: Gears, Random excitation, Jump phenomena

The occurrence of jump phenomena in gear systems to random excitation are investigated theoretically considering the transmission error as a stochastic process. The occurrence is examined from the standpoint of mean square value, and is investigated about the probability density function in simplified form.

86-368

An Integrated Gear System Dynamics Analysis Over a Broad Frequency Range

L.K.H. Lu, W.B. Rockwood, P.C. Warner, R.G. DeJong

Westinghouse Electric Corp., Sunnyvale, CA

Shock Vib. Bull., #55, Part 3, pp 1-11, June 1985, 17 figs, 14 refs (55th Symp. Shock Vib., Dayton, OH Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Gears, Marine engines

An integrated analytical scheme for Marine Gear System Dynamics is presented in this paper. The work is divided into three parts: gear excitation source prediction, response calculation in the low frequency range, and average response estimation in the high frequency range.

86-369
Coupled Torsional-Flexural Vibration of a Geared Shaft System Using Finite Element Analysis
S.V. Neriya, R.B. Bhat, T.S. Sankar
Concordia Univ., Montreal, Quebec H3G 1M8, Canada
Shock Vib. Bull., #55, Part 3, pp 13-25, June 1985, 9 figs, 3 tables, 4 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Gears, Torsional vibrations, Flexural vibrations, Coupled response

The coupled torsional-flexural vibration due to unbalance and geometrical eccentricity in the gears is studied. The coupling action is identified through the analysis of the gear motion and this effect is included in the finite element model of the system.. The free vibration problem is solved to obtain the natural frequencies and mode shapes. The response spectra for various parametric combinations are presented and discussed.

FASTENERS

86-370
Static and Cyclic Behavior of Semi-Rigid Steel Beam-Column Connections
A. Azizinamini, J.H. Bradburn, J.B. Radziminski
South Carolina Univ., Columbia, SC
Rept. No. NSF/ENG-85003, 234 pp (Mar 1985), PB85-194363/GAR

KEY WORDS: Joints, Beam-columns, Steel, Cyclic loading

Results are presented of a study undertaken to investigate the behavior of semi-rigid beam-to-column connections subjected to static and cyclic loadings. Tests were conducted on bolted connections comprised of top and seat beam flange angles and double web angles to evaluate cyclic performance under constant amplitude, and variable amplitude displacements and to determine moment-rotation behavior under static loading. From the constant amplitude cyclic tests, linear log-log equations were established. Empirical relationships established by the tests were applied to a linear cumulative damage model and the results of several variable amplitude block cyclic tests are compared with damage summations predicted by the model.

STRUCTURAL COMPONENTS

STRINGS AND ROPES

86-371
On Damping Properties of a Plucked String
M. Nakai, Y. Kitano
Kyoto Univ., Kyoto, Japan
Bull. JSME, 28 (240), pp 1188-1195 (June 1985) 14 figs, 9 refs

KEY WORDS: Strings, Damping coefficients, Musical instruments

A plucked string of musical instrument damps abnormally at specific frequencies. In order to investigate this phenomenon called dead point, the damping of a plucked string supported at two points on a simply supported beam was measured.

BARS AND RODS

86-372
In-Plane Impulse Response of a Curved Bar with Varying Cross-Section
K. Suzuki, Y. Miyashita, T. Kosawada, S. Takahashi
Yamagata Univ., Yonezawa, Japan
Bull. JSME, 28 (240), pp 1097-1104 (June 1985) 8 figs, 2 tables, 14 refs

KEY WORDS: Bars, Impulse response, Variable cross section

The dynamic response of a plane curved bar with varying cross-section is analyzed under a dynamic load working towards the center of curvature of the bar. As numerical examples, time responses of displacements and bending moment are found for a symmetric semi-elliptic arc bar with varying cross-section and clamped ends subjected to a step concentrated impact load. The time responses are compared with those for a static load.

86-373
Rate Effects in Lateral Compression, for an Energy-Absorbing Unit of Crossed Layers of Wooden Bars

N.K. Gupta, W. Johnson
Indian Inst. of Technology, Delhi, Hauz Khas, New Delhi, India
Intl. J. Impact Engrg., 3 (2), pp 121-136 (1985) 11 figs, 3 tables, 10 refs

KEY WORDS: Bars, Wood, Energy absorption

Experimental results concerning the rate of loading of orthogonally crossed layers of wooden bars subject to lateral compression by flat platens in an Instron machine, and by low velocity impact in a drop hammer, are presented. The behavior of a two-crossed bar basic unit is described, and the influence of rate of testing and moisture content of the wood on its load-compression characteristic is discussed.

86-374
A General Model of the Dynamics of Moving and Rotating Rods
A. Rosen, O. Rand
Israel Inst. of Technology, Haifa, Israel
Computers Struc., 21 (3), pp 543-561 (1985) 8 figs, 22 refs

KEY WORDS: Rods, Rotating structures, Translational response

A general and accurate model of a curved rod that rotates and moves in a linear motion is presented. The inertia loads are accurate and a matrix notation is used throughout the whole derivation of these loads. Motions are described at the point of attachment of the rod in cases where the rod is not moving freely in space. The equations of motion, their derivation and solution are described in detail. Capabilities of the model are presented by solving representative examples.

86-375
A Theory for a Vibrating Circular Rod Damping in a Two-Phase Bubbly Fluid (Bubbly Fluid Configuration)
O. Kohgo, F. Hara
Tokyo Univ. of Science, Tokyo, Japan
Trans. JSME, No. 458 (Jan 5, 1984)

KEY WORDS: Rods, Damping coefficients, Submerged structures

A theoretical analysis of a damping ratio for a vibrating circular rod in a two-phase air-water bubbly fluid is presented, showing a good agreement between theoretical and experimental results.

BEAMS

86-376
Optimal Design of Elastic Beams with Segmentwise Constant Height in the Case of Dynamic Loading
Ü. Lepik
Tartu State Univ., Tartu, Estonian SSR
Intl. J. Impact Engrg., 3 (2), pp 77-91 (1985) 1 fig, 5 tables, 4 refs

KEY WORDS: Beams, Elastic properties, Impact response, Optimum design

A shape optimization method for elastic beams with segmentwise constant height is proposed. The ends of the beam are simply supported, clamped or free. Two problems are discussed: a beam loaded by lateral pressure and a beam struck by an attached mass.

86-377
Some Observations on the Dynamic Equations of Prismatic Members in Compression
W.H. Wittrick
The Old Forge, Ebrington, Chipping Campden, Gloucestershire, UK
Intl. J. Mech. Sci., 27 (6), pp 375-382 (1985) 3 figs, 8 refs

KEY WORDS: Beams, Prismatic bodies, Vlasov theory, Timoshenko theory,

The dynamic equations governing the longitudinal and the coupled transverse and torsional deformations of uniformly compressed elastic prismatic members are discussed. It is shown that if they are properly formulated, the modes of buckling of members with their ends simply supported and, where appropriate, free to warp are precisely the same as the modes of vibration, and that for each mode there is a very simple relation between the critical compressive stress and the natural frequency.

86-378
Comparison of Dynamic Torsion Theories for Beams of Elliptical Cross-Section

N.G. Stephen
Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 100 (1), pp 1-6 (May 8, 1985) 1 fig, 17 refs

KEY WORDS: Beams, Torsional response

A comparison between several dynamic torsion theories for beams of noncircular cross-section and their predicted torsional wave first branch dispersion characteristics is made with some recently published exact data for elliptical cross-section beams of various eccentricities.

86-379
Non-Linear Forced Oscillation of a Beam Coupled to an Actuator via Hertzian Contact
M.D. Bryant
North Carolina State Univ., Raleigh, NC
J. Sound Vib., 99 (3), pp 403-414 (Apr 8, 1985) 3 figs, 18 refs

KEY WORDS: Beams, Forced vibrations, Hertzian contact, Fourier series, Harmonic balance method

Forced harmonic oscillation of a system involving a piezoelectric actuator coupled via Hertzian contact to an elastic beam is modeled. Hertzian nonlinearities are replaced by an asymptotic series, and the resulting system of equations are solved by using complex Fourier series and harmonic balance techniques. The complex coefficients of the complex Fourier series are evaluated recursively, and the resulting complex solution is used to obtain approximate real solutions.

86-380
Transient Response in Flexure to General Uni-Directional Loads of Variable Cross-Section Beam with Concentrated Tip Inertias Immersed in a Fluid
K. Nagaya
Gunma Univ., Kiryu, Gunma, Japan
J. Sound Vib., 99 (3), pp 361-378 (Apr 8, 1985) 10 figs, 3 tables, 12 refs

KEY WORDS: Beams, Variable cross section, Submerged structures, Transient response, Fluid-induced excitation

A method is presented for solving problems of transient response in flexure due to general unidirectional dynamic loads of beams of variable cross section with tip inertias. An elastodynamic theory which includes effects of continuous mass and rigidity of the beam has been applied. The theoretical results given in this paper are applicable to problems of dynamic response due to arbitrary loads varying with time of beams of arbitrary shape with concentrated tip inertias. Numerical calculations have been carried out for two cases: a uniform beam with a tip inertia and a non-uniform beam (a truncated cone) with a tip inertia. Both are immersed in a fluid and subjected to large waves such as conoidal waves.

86-381
Vibration and Stability of Elastically Supported Multi-Span Beams under Conservative and Non-Conservative Loads
S. Chonan, M. Sasaki
Tohoku Univ., Sendai, Japan
J. Sound Vib., 99 (4), pp 545-556 (Apr 22, 1985) 10 figs, 7 refs

KEY WORDS: Beams, Elastic supports, Timoshenko theory, Natural frequencies

This paper deals with the vibration and stability of multi-span beams elastically supported against translation and rotation at several intermediate points as well as both ends. The beam is subjected to an axial or tangential load at the ends. The problem is studied on the basis of the Timoshenko beam theory. The influence of the support stiffness on the natural frequencies and the divergence and flutter instability loads are studied in detail.

86-382
Coupled Flexural, Longitudinal and Shear Wave Motion in Two-and Three-Layered Damped Beams
D.J. Mead, S. Markus
Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 99 (4), pp 501-519 (Apr 22, 1985) 6 figs, 2 tables, 10 refs

KEY WORDS: Beams, Layered materials, Ceramics, Wave propagation

It is shown how a ceramic layer attached to a two-layered (elastic/viscoelastic) beam alters the wave propagation mechanism in the beam. The ceramic layer is assumed to possess mass but not longitudinal stiffness. Shear deformation, rotatory, longitudinal and transverse inertia forces are all included in the analysis. The equations of motion of the layered beam are derived by using the virtual work principle. Relevant dispersion curves for an infinite beam are presented and discussed, and are compared with dispersion curves obtained from a number of simplified theories.

86-383
Modal Hierarchical Timoshenko Beam Finite Elements
A.W. Lees, D.L. Thomas
Central Electricity Generating Board, Bristol, UK
J. Sound Vib., 99 (4), pp 455-461 (Apr 22, 1985), 1 fig, 4 tables, 14 refs

KEY WORDS: Beams, Finite element technique, Modal analysis, Timoshenko theory

The hierarchical Timoshenko beam finite element is transformed into modal coordinates. The degrees of freedom of the new element are the deflection and cross section rotation at the two nodes together with an arbitrary number of coefficients of the elements clamped-clamped modes. Hence only two degrees of freedom are made continuous at an element boundary, permitting incorporation into user-oriented programs. Examples illustrating the use and accuracy of the element are given.

86-384
Spline-Based Rayleigh-Ritz Methods for the Approximation of the Natural Modes of Vibration for Flexible Beams with Tip Bodies
I.G. Rosen
NASA Langley Res. Ctr., Hampton, VA
Rept. No. ICASE-85-22, NASA-CR-172566, 33 pp (Mar 1985), N85-23100/9/GAR

KEY WORDS: Beams, Mass-beam systems, Rayleigh-Ritz method, Spline technique

Rayleigh-Ritz methods for the approximation of the natural modes for a class of vibration problems involving flexible beams with tip bodies using subspaces of piecewise polynomial spline functions are developed. An abstract operator theoretic formulation of the eigenvalue problem is derived and spectral properties investigated. The existing theory for spline-based Rayleigh-Ritz methods applied to elliptic differential operators and the approximation properties of interpolatory splines are used to argue convergence and establish rates of convergence.

86-385
Time Domain Mathematical Modeling of Elastic Instabilities and Large Elastic-Plastic Deflections
R.P. Brooks
Franklin Res. Ctr., Philadelphia, PA
Shock Vib. Bull., #55, Part 3, pp 117-128, June 1985, 20 figs, 3 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Beams, Time domain method, Mathematical models, Dynamic buckling

Mathematical modeling and computational techniques, based on an explicit time integration scheme, are presented for the calculation of elastic instabilities and large elastic-plastic deflections of beam elements. The equations are formulated to facilitate their introduction into time-domain computer programs. The simple models presented demonstrate the phenomena of Euler, angle and lateral buckling, as well as plastic-buckling with strain-rate effects.

86-386
Dynamic Impact of an Elastically Supported Beam — Large Area Contact
L.M. Keer, J.C. Lee
Northwestern Univ., Evanston, IL
Intl. J. Engrg. Sci., 23 (10), pp 987-997 (1985), 10 figs, 7 refs

KEY WORDS: Beams, Elastic supports, Impact response

The dynamic contact problem of a rigid, smooth striker impacting an elastically supported beam is solved. Use is made of the superposition of an elastic layer solution together with an elementary beam theory solution that incorporates the dynamic effects The problem is formulated in such a manner as to require the solution of a Volterra integral equation for each time increment. Numerical results are presented for various parameters.

CYLINDERS

86-387
Investigation of the Aerodynamic Forces on Bluff Bodies at High Reynolds Numbers
G. Schewe
Deutsche Forschungs- und Versuchsanstalt fuer Luft-und Raumfahrt e.v., Fed. Rep. Germany
Rept. No. DFVLR-MITT-84-19, ESA-TT-914, ISSN-176-7739, 33 pp (Nov 1984), N85-23727/9/-GAR

KEY WORDS: Circular cylinders, Aerodynamic loads

Steady and unsteady forces acting on a circular cylinder, a square-section cylinder and an H-profile were investigated in a pressurized wind tunnel. The forces were measured by a piezo-multicomponent balance, with a large dynamic range, low interference and a high natural frequency. The Reynolds number range between 20,000 and 7 million is investigated with the same circular cylinder and balance by varying flow velocity and air density.

FRAMES AND ARCHES

86-388
Optimal Shakedown Design of Frames by Linear Programming
M. Domaszewski, E.M. Samp-Staniskawska
Universite de Technologie de Compiegne, Compiegne, France
Computers Struc., 21 (3), pp 379-385 (1985), 9 figs, 20 refs

KEY WORDS: Framed structures, Cyclic loading, Shakedown theorem

A mathematical model of flexural framed structures subjected to cyclic loadings is presented, and the problem of minimum-weight shakedown design of these structures is formulated as a pair of dual linear programming problems. Such a formulation reflects the duality between static and kinematic theorems of shakedown theory.

86-389
Seismic Reliability Analysis of Rigid Frame Structures
C.A. Tzavelis
Ph.D. Thesis, Columbia Univ., 95 pp (1984), DA8427488

KEY WORDS: Framed structures, Seismic analysis, Reliability

A reliability analysis method is developed for plane rigid frame structures, with shear walls in all or some of their wall openings, subjected to horizontal in-plane earthquake ground accelerations. The structural reliability is measured in terms of the probability that, through the structure's lifetime, its response will not violate a set of performance criteria selected to represent a safe state of structural behavior.

86-390
Dynamic and Acoustic Analysis of Hammer Frames
M.M. Nigm, M.M. Sadek
ASME Paper No. 84-WA/NCA-16

KEY WORDS: Frames, Hammers, Modal analysis, Finite element technique, Helmholtz integral method

The dynamic and acoustic characteristics of the frame of a hydraulically assisted hammer are investigated using finite-element modal analysis and numerical solution of the Helmholtz integral equation.

PANELS

86-391
Effect of Sound-Absorptive Facings on the Sound Transmission Through Panels
A. Trochidis
Univ. of Thessaloniki, Thessaloniki, Greece
J. Acoust. Soc. Amer., 78 (3), pp 942-945 (Sept 1985), 4 figs, 6 refs

KEY WORDS: Panels, Acoustic absorption, Sound waves, Sound transmission

The effect of sound-absorptive facings on the airborne-sound transmission of panels is discussed. The response of a simple model, consisting of an infinite elastic plate with an attached sound-absorptive facing, to acoustical excitation is calculated. Numerical calculations of the transmission loss, carried out for typical examples, show the influence of the main parameters involved.

86-392
Vibration and Damping Analysis of Curved Sandwich Panel with Viscoelastic Core
J. Vaswani, N.T. Asnani, B.C. Nakra
I.I.T. Delhi-110016, India
Shock Vib. Bull., #55, Part 1, pp 155-166, June 1985, 8 figs, 2 tables, 7 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Panels, Sandwich structures, Viscoelastic core-containing media, Resonant frequencies

Equations of motion for flexural vibrations of a curved sandwich panel, consisting of elastic face layers sandwiching a viscoelastic core, have been derived considering extension and bending deformations in the face layers and shear deformation in the core layer, using variational principles. A solution for a panel with simply supported edges is taken in series summation form and the correspondence principle of linear viscoelasticity is applied for evaluating the resonant frequencies and associated system loss factors.

86-393
Unsteady Analysis of Rotor Blade Tip Flow
B. Maskey, B.M. Rao
Analytical Methods, Inc., Redmond, WA
Rept. No. AMI-8412, NASA-CR-3868, 57 pp (May 1985), N85-25202/1/GAR

KEY WORDS: Panels, Aircraft wings, Propeller blades, Aerodynamic loads, Computer programs

The development of the VSAERO-TS and VSAERO-H computer programs for calculating the unsteady aerodynamic characteristics of arbitrarily shaped wings oscillating in pitch is presented. The effect of several wake parameters on chordwise pressure distribution in VSAERO-TS is given and the convergence characteristics of both programs are discussed.

86-394
Structural Response of Panels Subjected to Shock Loading
R. Houlston, J.E. Slater
Defence Res. Establishment, Suffield, Ralston, Alberta, Canada
Shock Vib. Bull., #55, Part 2, pp 149-163, June 1985, 34 figs, 3 tables, 8 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Panels, Shock response, Ships, Fluid-structure interaction

In combat operations, warships could be subjected to air blast and underwater shock loads capable of causing significant local damage. As part of a vulnerability and survivability study, the prediction and measurement of the structural response of ship panels to free field air-blast explosions is explored. Experiments with steel plates and a full scale stiffened panel are described in detail. Finite element modeling results are presented with a detailed correlation to experiment.

PLATES

86-395
Acoustic Damping, Radiation and Impedance of Plain Plates Under Axial Loading (Schalldämmung, Abstrahlung und Impedanz von ebenen Platten mit axialer Belastung)
J. Czuchaj
Institut fur Technische Akustik, TU Berlin
Acustica, 58 (1), pp 27-38 (June 1985), 14 figs, 1 table, 6 refs (In German)

KEY WORDS: Plates, Sound waves, Acoustic absorption, Acoustic impedance

The influence of an axial load (tension and compression) on the acoustic properties of plates is investigated theoretically and experimentally. Starting from the bending wave equation of plates with axial loading the bending-wave number, the bending-wave phase velocity and the frequency of the limiting coincidence are calculated. In addition formulas for the transmission loss, and the sound radiation as well as the impedance of point-driven infinite plates are derived.

86-396
Transverse Vibrations of an Elliptic Plate with Variable Thickness

B. Singh, D.K. Tyagi
Univ. of Roorkee, Roorkee 247667, India
J. Sound Vib., 99 (3), pp 379-391 (Apr 8, 1985), 6 figs, 6 tables, 6 refs

KEY WORDS: Plates, Natural frequencies, Flexural vibrations, Variable cross section, Galerkin method

Galerkin's method has been used to obtain the frequencies of symmetric transverse vibrations of an elliptic plate with clamped edges and variable thickness. The procedure can be used to generate a sequence of approximations which may be truncated when the required number of frequencies have converged to the desired accuracy. The results for an elliptic plate with uniform thickness, circular plate with parabolically varying thickness and a circular plate with uniform thickness have been obtained as special cases.

86-397
Fundamental Frequency of Vibration of Thin Elastic Plates Elastically Supported Along Internal Segments
R.H. Gutierrez, P.A.A. Laura
Inst. of Applied Mechanics, Puerto Belgrano Naval Base, Argentina
Appl. Acoust., 18 (5), pp 325-336 (1985), 6 tables, 6 refs

KEY WORDS: Rectangular plates, Circular plates, Elastic supports, Fundamental frequencies

The title problem is approximately solved in a unified manner in the case of rectangular and circular plates elastically restrained against rotation along the boundary. Polynomial coordinate functions and a variational approach are used in order to obtain an approximate frequency equation.

86-398
Dynamic and Static Analysis of Skew Sandwich Plates
S.S.F. Ng, D.K.Y. Lam
Univ. of Ottawa, Ottawa, Ontario, Canada
J. Sound Vib., 99 (3), pp 393-401 (Apr 8, 1985), 4 figs, 3 tables, 16 refs

KEY WORDS: Plates, Sandwich structures, Flexural vibrations, Finite element technique

A finite element displacement model is presented for the dynamic and static analysis of clamped and simply supported skew sandwich plates. The geometric admissibility conditions of the principle of minimum total potential energy are satisfied by representing the assumed displacement pattern by a polynomial function. For static analysis, the sandwich plate is assumed to be uniformly loaded although point loads can be handled with very little modification in the computer program. For the dynamic analysis, results are presented for free flexural vibrations of skew sandwich plates with different plate aspect ratios, angles of skew and core rigidities.

86-399
Axisymmetric Vibrations of Layered Annular Plates with Linear Variation in Thickness
N. Sankaranarayanan, K. Chandrasekaran, G. Ramaiyan
Anna Univ., Madras-600025, India
J. Sound Vib., 99 (3), pp 351-360 (Apr 8, 1985), 7 figs, 2 tables, 11 refs

KEY WORDS: Annular plates, Layered materials, Variable cross section, Energy methods, Rayleigh-Ritz method

Free vibrations of laminated annular plates with a linear variation in thickness in the radial direction are analyzed. An energy method based on the Rayleigh-Ritz technique is used for the analysis. Displacement functions which are polynomials in the radial coordinate are assumed. The resulting generalized eigenvalue problem is solved by a simultaneous iteration technique.

86-400
Soft-Spring Nonlinear Vibrations of Antisymmetrically Laminated Rectangular Plates
D. Hui
Ohio State Univ., Columbus, OH
Intl. J. Mech. Sci., 27 (6), pp 397-408 (1985), 6 figs, 30 refs

KEY WORDS: Rectangular plates, Layered materials, Geometric imperfection effects, Nonlinear response

This paper deals with the effects of initial geometric imperfections and in-plane boundary conditions on the large-amplitude vibration behavior of angle- and cross-ply rectangular thin plates. It is found that the presence of imperfection amplitudes of the order of only half the total laminated-plate thickness may significantly raise the vibration frequencies, and change the large-amplitude vibration behavior from the well known hard-spring to soft-spring behavior.

86-401
On the Field Experiences of Undex Testing for a Stiffened Flat Plate Model
T.R. Rentz, Y.S. Shin
Naval Postgraduate School, Monterey, CA
Shock Vib. Bull., #55, Part 2, pp 173-191, June 1985, 14 figs, 15 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Stiffened plates, Underwater explosions, Experimental data, Computer programs

An experimental investigation into the underwater shock-induced responses of a stiffened flat plate has been conducted. An air-backed flat plate with externally machined rectangular stiffeners and a clamped boundary condition was subjected to a shock wave loading by an eight pound TNT charge detonated underwater. The plate was instrumented to measure transient strains. The test structure acceleration and free field pressures were also measured.

86-402
Vibrations of Skew Plates Immersed in Water
G. Muthuveerappan, N. Ganesan, M.A. Veluswami
Indian Inst. of Tech., Madras 600 036, India
Computers Struc., 21 (3), pp 479-491 (1985), 6 figs, 6 tables, 8 refs

KEY WORDS: Skew plates, Submerged structures, Natural frequencies

Two skew prism fluid elements are developed for the study of vibrations of skew plates immersed in water. Their aspect ratios, thickness ratios and boundary conditions are discussed and the influence of skew angles on the vibration of skew plates is investigated.

86-403
Vibrations of Twisted Cantilever Plates — A Comparison of Theoretical Results
R.E. Kielb, A.W. Leissa, J.C. MacBain
NASA Lewis Res. Ctr., Cleveland, OH
Intl. J. Numer. Methods Engrg., 21 (8), pp 1365-1380 (Aug 1985), 11 figs, 3 tables, 24 refs

KEY WORDS: Cantilever plates, Rotor blades (turbomachinery), Vibration prediction

Numerical results were obtained for a set of 20 different twisted plates having various aspect ratios, thickness ratios and pretwist angles. Nineteen distinct theoretical methods were employed, 15 using finite elements, two using shell theory, and two using beam theory. The numerical results obtained showed considerable disagreement. Analytical methods used are described.

86-404
A Finite Element-Equivalent Energy Linearization Technique for the Analysis of Nonlinear Plate Vibration
M.A.E. Ghabrial, R.K. Miller, L.C., Jr. Wellford
Univ. of Southern California, Los Angeles, CA
Intl. J. Numer. Methods Engrg., 21 (8), pp 1499-1520 (Aug 1985), 20 figs, 18 refs

KEY WORDS: Circular plates, Finite element technique, Equivalent linearization method

A simplified technique for the dynamic analysis of geometrically nonlinear plate structures is developed. The essence of this technique is the construction of a linear substitute of the nonlinear problem. The linear substitute problem is derived from an equivalence criterion which involves balancing the energies of the linear substitute model and the nonlinear model over one period of oscillation. The linearized equations are discretized by a finite element method, and solutions at different amplitudes are obtained numerically by an incremental-iterative scheme.

86-405
Static and Dynamic Analysis of Stiffened Plates
R.S. Srinivasan, V. Thiruvenkatachari
Indian Inst. of Technology, Madras 600 036, India
Computers Struc., 21 (3), pp 395-403 (1985), 10 figs, 4 tables, 9 refs

KEY WORDS: Stiffened plates, Natural frequencies

A method for the static and dynamic analysis of eccentrically stiffened annular sector plates is presented. The plate is clamped on all edges. The integral equation technique is adopted for the solution. In the static analysis the deflection and stresses at center and the stresses at the edges are obtained and are presented graphically. The natural frequencies of stiffened clamped plates are also obtained for plates with different sector angles.

86-406
Nonlinear Transient Responses of Initially Stressed Composite Plates
J.K. Chen, C.T. Sun
Purdue Univ., West Lafayette, IN
Computers Struc., 21 (3), pp 513-520 (1985), 11 figs, 24 refs

KEY WORDS: Plates, Composite structures, Finite element technique, Prestressed structures

The nonlinear transient response of initially stressed composite plates is investigated using the finite element method. A nine-node isoparametric quadrilateral element is developed to model laminated plates under initial deformation and initial stress according to the Mindlin plate theory and von Karman large deflection assumptions. In the time integration, the Newmark constant acceleration method in conjunction with an efficient and accurate iteration scheme is used. Numerical results for deflections and bending moments for isotropic and laminated plates are obtained.

86-407
Response of Flat Plate Concrete Structures to Lateral Loading
H. Akiyama
Ph.D. Thesis, Univ. of Washington (1984)

KEY WORDS: Plates, Seismic response, Concrete

A beam analogy model is developed for predictions of the response of flat plate concrete structures to lateral loads. The results of a comprehensive series of slab-column subassemblage tests were used for development of that model.

86-408
Elasto-Plastic Blast Response of Rectangular Plates
D.Z. Yankelevsky
Israel Inst. of Technology, Haifa, Israel 32000
Intl. J. Impact Engrg., 3 (2), pp 107-119 (1985), 7 figs, 2 tables, 10 refs

KEY WORDS: Rectangular plates, Blast response

A new model to analyze the dynamic large deformation response of elasto-plastic rectangular plates is presented. The plate is modeled with rigid segments interconnected by hinge lines which yield a roof-shaped displacement field. The model may be used to calculate the midsection time history of bending moments and membrane forces, stress and strain distributions, displacement, velocity and acceleration as well as the dynamic reactions and the permanent displacement.

SHELLS

86-409
Dynamic Response of Shells and Plates Subjected to Variable Magnitude Traveling Loads
R. Shankaran
Ph.D. Thesis, The Univ. of Akron, 318 pp (1985), DA8500860

KEY WORDS: Shells, Plates, Moving loads, Viscoelastic properties

The dynamic response of structures subjected to variable magnitude traveling loads is investigated. Shells and plates are used as typical structures. Two cases are considered: one in which the load traverses open trajectories, as in the case of a load moving along an infinite shell or plate strip, and the other in which the load moves in a closed trajectory, as around a shell of revolution. The study focuses on the effect of traveling load variability on viscoelastic type structural behavior.

86-410
Comparative Solutions for a Punch Problem of an Elastic Sphere Encapsulated in an Elastic Shell
Y. Sarig, R.W. Little, L.J. Segerlind
Inst. of Agricultural Engrg., ARO, The Volcani Center, Bet Dagan, Israel
Intl. J. Impact Engrg., 3 (2), pp 93-105 (1985), 7 figs, 1 table, 22 refs

KEY WORDS: Spherical shells, Concentric structures, Impact response

Two potential methods are proposed for analyzing the deformation of an elastic sphere encapsulated in an elastic shell and subjected to punch loading. Numerical evaluation of both models showed that the results are comparable. The Boussinesq method is a more rigorous mathematical approach and offers a better insight into the actual behavior of the domain under given boundary conditions. Its utilization is limited to well defined geometrics because of the complexity involved. The finite element method is capable of handling irregular shapes but requires large computer memory for an exact solution.

86-411
Vibration Characteristics of Hexagonal Radial Rib and Hoop Platforms
W.K. Belvin
NASA Langley Res. Ctr., Hampton, VA
J. Spacecraft Rockets, 22 (4), pp 450-456 (July/Aug 1985), 17 figs, 4 tables, 6 refs

KEY WORDS: Antennas, Spacecraft platforms, Reinforced structures

The modes of vibration of planar radial rib and hoop hexagonal platforms have been characterized by both experiment and analysis. The sensitivity of mode shapes and frequencies to cable stiffness and preload is presented. Primary vibration modes of the radial rib platform involve beam bending. Vibration modes of the hoop platform exhibit beam bending, frame bending, and torsion.

86-412
Non-Stationary Random Vibration of an Elastic Circular Cylindrical Liquid Storage Tank Due to a Simulated Earthquake Excitation
M. Sakata, K. Kimura, M. Utsumi
Tokyo Inst. of Technology, Ookayama, Meguro-ku, Tokyo, Japan
Trans. JSME No. 458 (Jan 5, 1984)

KEY WORDS: Storage tanks, Random vibrations, Seismic response, Earthquake response

The nonstationary response of an elastic circular cylindrical tank partially filled with a liquid to a simulated earthquake excitation is investigated. The earthquake acceleration is modeled as an amplitude modulated non-white random process and the mean and standard deviation responses of liquid surface displacement and tank wall deformation are analyzed by the moment equation approach. The nonlinearity of liquid surface oscillation is considered in the response analysis to a long period earthquake excitation.

RINGS

86-413
Finite Element Method for In-Plane Vibrations of Rotating Timoshenko Rings and Sectors
K. Singh, B.P. Singh
Indian Inst. of Technology, Kanpur, India
Intl. J. Numer. Methods Engrg., 21 (8), pp 1521-1533 (Aug 1985), 5 figs, 6 tables, 12 refs

KEY WORDS: Rings, Timoshenko theory, Finite element technique

A simple and logical finite element formulation is presented for the analysis of rings and sectors, with Timoshenko effects. The elemental properties are derived from the governing differential equation of motion using the Galerkin method. A quintic polynomial, satisfying the compatibility of derivatives up to second order, is used for the ring finite element. The efficiency of the formulation is illustrated by numerical results.

PIPES AND TUBES

86-414
Industrial Jet Noise: Coanda Nozzles
P. Li, N.A. Halliwell
Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 99 (4), pp 475-491 (Apr 22, 1985), 15 figs, 4 tables, 9 refs

KEY WORDS: Nozzles, Coanda effect, Jet noise, Noise reduction

The performance of Coanda-type nozzles is examined in detail and an index rating for nozzle performance is introduced. Results show that far field stagnation pressure distributions are Gaussian and similar in all cases. Noise reduction and thrust efficiency are shown to be closely related to the design geometry of the central body of the nozzle. Performance is based on four fundamental characteristics.

86-415
The Prediction of Flow-Induced Noise in Heat Exchanger Tube Arrays
J.A. Fitzpatrick
Dublin Univ., Dublin 2, Ireland
J. Sound Vib., 99 (3), pp 425-435 (Apr 8, 1985), 5 figs, 21 refs

KEY WORDS: Tube arrays, Heat exchangers, Fluid-induced excitation, Noise generation

A number of methods for the prediction of flow-induced acoustic standing waves in heat exchangers are recommended in the literature. The merits of the techniques for predicting resonance are compared, with use of data from four independent sources, and a method for estimating the limit conditions for avoidance of resonance is recommended. The parameters for estimating the damping capacity of a tube bank are examined and shown to have limitations. A modified damping criterion is suggested and appears to correlate existing data well.

86-416
Heat Exchanger Tube Vibrations. 1970-May 1985 (Citations from the Engineering Index Data Base)
NTIS, Springfield, VA
109 pp (May 1985), PB85-861201/GAR

KEY WORDS: Heat exchangers, Tubes, Computerized simulation, fluid-induced excitation, Bibliographies

This bibliography contains 154 citations concerning design, fabrication, and vibration studies of heat exchanger tubes. Basic excitation mechanisms of tube vibrations, effects of heat exchanger configurations, preoperational testing of tubes, and vibration detection techniques are discussed. Model studies and computer simulation techniques are presented.

86-417
Dynamic Stability of a Spinning Tube Conveying a Flowing Fluid
G.A. Benedetti
Sandia National Labs., Livermore, GA
Rept. No. SAND-84-8703, 34 pp (Feb 1985), DE85007583/GAR

KEY WORDS: Tubes, Fluid-filled containers, Fluid-induced excitation, Beams, Cables

The dynamic stability of a spinning tube through which an incompressible fluid is flowing is examined. The tube can be considered as either a hollow beam or as a hollow cable. The analytical results can be applied to spinning or stationary tubes through which fluids are transferred. The coupled partial differential equations are determined for the lateral motion of a spinning Bernoulli-Euler beam or a spinning cable carrying an incompressible flowing fluid.

86-418
The Use of Modal Analysis Concepts in the Simulation of Pipeline Transients
M. Lebrun
Universite Claude Bernard Lyon I, Villeurbanne Cedex, France
J. Franklin Inst., 319 (1/2), pp 137-156 (Jan/Feb 1985), 15 figs, 9 refs

KEY WORDS: Pipelines, Modal analysis, Bond graph technique

The bond graph technique is used to build up a finite-order representation of a hydraulic network whose distributed character is inherent to the system. The network model is set from the bond graphs of each line which resulted from a modal approximation. The problems of the causalities imposed by the subsystems linked to the network are presented and a technique using pressure and flow duality is suggested.

86-419
Dynamic Transient Forces Induced by Valve Opening in Steam Piping
M. Mikasinovic
Ontario Hydro, Toronto, Canada
Heating/Piping/Air Cond., 57 (10), pp 71-74 (Oct 1985), 6 figs, 1 table, 4 refs

KEY WORDS: Pipelines, Steam hammer, Transient response

A method is presented to avoid steam hammer to compute dynamic loadings imposed on piping runs between elbows.

86-420
Seismic Analysis of Buried Pipeline Networks
Ming-Ping Chung

Ph.D. Thesis, Arizona State Univ., 406 pp (1984), DA8501317

KEY WORDS: Pipelines, Underground structures, Seismic analysis

There is a long history of damage to underground pipelines due to earthquakes. An up-to-date overview of over 100 technical papers in the area of experimental and field observations is provided. Important soil parameters which control the damage behavior of the pipelines have been identified. It is concluded that more experimental and field data are needed before seismic resistant design regulations for the pipelines can be realistically formulated.

DUCTS

86-421
The Time-Dependent Finite Difference Procedure for Propagation of Sound in a Non-Uniform Lined Duct — a Comparison with Experiments
A. Cabelli, R.F. LaFontaine, I.C. Shepherd
Commonwealth Scientific and Industrial Res. Organization, Melbourne, Australia
J. Sound Vib., 100 (1), pp 35-40 (May 8, 1985), 3 figs, 14 refs

KEY WORDS: Ducts, Acoustic linings, Sound waves, Wave propagation, Finite difference technique

A time-dependent finite difference procedure is developed for the calculation of acoustic fields which incorporate finite impedance and rigid wall boundaries. A numerical mapping technique is invoked to transform the solution domain into a rectangular geometry and the procedure is used to solve for frequencies where cross modes can propagate in the straight sections of duct. Numerical results are corroborated with experiments.

86-422
Procedure for Design of Ducts to Reduce Propeller Cavitation and Vibrations
J.K. Chen, S. Tsakonas
Stevens Inst. of Tech., Hoboken, NJ
Rept. No. MA-RD-760-85007, 304 pp (Sept 1984), PB85-197895/GAR

KEY WORDS: Ducts, Shrouds, Propellers, Design techniques, Vibration control

This study extends and improves the current propeller ducts design procedure, which substantially reduces selected spatial harmonics of any given ship model nominal wake and thus homogenizes the inflow field to the enshrouded propeller. This fact will constitute the most important factor in the study of the ducted-propeller problem since by controlling and homogenizing the propeller inflow field, vibratory characteristics of the system will be minimized and the intermittent blade cavitation will be reduced substantially. Three schemes have been studied in the attempt to ameliorate the inflow field.

86-423
Active Noise Reduction Systems in Ducts
J. Tichy, G.E. Warnaka, L.A. Poole
ASME Paper No. 84-WA/NCA-15

KEY WORDS: Ducts, Sound waves, Wave propagation, Noise reduction

Fundamentals of the theory of sound propagation inducts with perfectly reflecting walls relevant to noise reduction systems is summarized.

BUILDING COMPONENTS

86-424
Modelling of Reinforced Concrete Members for Seismic-Response Analysis
S.A. Kaba
Ph.D. Thesis, Univ. of California, Berkeley, CA, 202 pp (1984), DA8427002

KEY WORDS: Structural members, Concrete, Seismic response

An interactive analysis program suited for micro-computers developed to analyze structural steel, reinforced concrete, and prestressed concrete sections subjected to axial load and uniaxial bending moments is described. The theoretical background for the program, the solution strategies used and their limitations, and the types of analyses for which the program is suited are discussed.

86-425
Airborne Sound Transmission Loss Characteristics of Wood-Frame Construction
F.F. Rudder
Forest Products Lab., Madison, WI
Rept. No. FSGTR-FPL-43, 30 pp (Mar 1985), AD-A154 174/7/GAR

KEY WORDS: Framed structures, Wood, Sound transmission loss

This report summarizes the available data on the airborne sound transmission loss properties of wood-frame construction and evaluates the methods for predicting the airborne sound transmission loss. The first part of the report comprises a summary of sound transmission loss data for wood-frame interior walls and floor-ceiling construction. The second part of the report presents the prediction of the sound transmission loss of wood-frame construction. Appropriate calculation methods are described both for single-panel and for double-panel construction with sound absorption material in the cavity.

ELECTRIC COMPONENTS

CONTROLS (SWITCHES, CIRCUIT BREAKERS)

86-426
Bond Graph Models for Electromagnetic Actuators
D. Karnopp
Univ. of California, Davis, CA
J. Franklin Inst., 319 (1/2), pp 173-181 (Jan/Feb 1985), 5 figs, 6 refs

KEY WORDS: Actuators, Bond graph technique

Rotary and linear electromechanical actuators are often used as the effectors for controlled systems and they often are important contributors to the dynamic response of the complete system. A generalized bond graph model for such actuators is developed which represents the three major types of forces or torques generated when coils, low reluctance elements and permanent magnets interact. A wide variety of actuators can be modeled by versions of the basic bond graph which is simplifiable when some effects are negligible.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

86-427
Simple and Effective Acoustic Emission Source Location System
M. Barksy, N.N. Hsu
National Bureau of Standards (NEL), Gaithersburg, MD
Materials Evaluation, 43 (1), pp 108-110 (Jan 1985), PB85-186971

KEY WORDS: Acoustic emission, Noise source identification

A simple acoustic emission (AE) source location system has been designed, constructed, and demonstrated. It will indicate the approximate location of an AE source inside a square area at a fast rate. The system requires no computer support, is totally self contained, and can be built with inexpensive, readily available integrated circuits.

86-428
Complete Mapping of Ultrasonic Fields from Optically Measured Data in a Single Cross-Section
R. Reibold, F. Holzer
Physikalisch-Technische Bundesanstalt, Braunschweig, Fed. Rep. Germany
Acustica, 58 (1), pp 11-16 (June 1985), 7 figs, 5 refs

KEY WORDS: Sound waves, Measurement techniques

A method is described by which the pressure amplitude and phase values at any point in a continuous wave ultrasonic beam can be determined, by measuring the pressure distribution in an arbitrary cross-section of the beam with the light diffraction tomography method and by calculating the propagation of the corresponding angular spectrum.

86-429
Ultrasonic Power Measurement by Means of Radiation Force (Ultraschall-Leistungsmessung mit Hilfe der Schallstrahlungskraft)

K. Beissner
Mitteilung aus der Physikalisch-Technischen Bundesanstalt, Braunschweig, Fed. Rep. Germany
Acustica, 58 (1), pp 17-26 (June 1985), 6 figs, 36 refs (In German)

KEY WORDS: Sound waves, Wave radiation, Measuring instruments

The acoustic radiation force measurement is one of the most important methods of investigating ultrasonic fields in fluids. Besides its immediate purpose of determining the ultrasonic power, it often serves as a means of calibrating other measurement methods and as the ultimate basis for the quantitative evaluation of ultrasonic fields. A comprehensive discussion of various aspects of the radiation force measurement, based on experimental and theoretical research during recent years, is presented.

86-430
An Evaluation of the Kirchhoff Approximation for Acoustic Plane Wave Reflection Coefficients from a Sinusoidal Boundary
D.F. McCammon
Ph.D. Thesis, Pennsylvania State Univ., 155 pp (1984) DA8429110

KEY WORDS: Sound waves, Wave reflection, Approximation methods

The Kirchhoff approximation has been frequently applied in the solution of the Helmholtz integral equation for problems involving acoustic scattering from rough surfaces; however, an evaluation of the range of effectiveness of this approximation has never been made. In this thesis, an exact solution to scattering from a general periodic surface is applied to a sinusoidal surface to facilitate a study of the behavior of the Kirchhoff approximation. A series solution to the Helmholtz integral equation for an arbitrary surface is also formulated on the sinusoid, and a proof of the convergence of the series is demonstrated.

86-431
A Procedure for Explicit Determination of Acoustical Shape Design by the Finite Element Method
R.J. Bernhard
ASME Paper No. 84-WA/NCA-13

KEY WORDS: Acoustic properties, Finite element technique

A method is presented for decomposing the original acoustic finite element matrices into matrices which may be multiplied by shape change variables to develop a model of the revised geometry without redefinition of the input data.

86-432
On the Applications of the BIE Method in Studies of Acoustic Radiation from Vibrating Structures
J.K. Jiang, M.G. Prasad
ASME Paper No. 84-WA/NCA-12

KEY WORDS: Sound waves, Wave propagation, Boundary value problems

The applications of the boundary integral equation method for studies on acoustical fields of various vibrating structures are described.

86-433
A Simple Chart for the Estimation of the Attenuation by a Wedge Diffraction
Z. Maekawa, S. Osaki
Kobe Univ., Rokko, Nada, Kobe, Japan
Appl. Acoust., 18 (5), pp 337-354 (1985), 9 figs, 6 refs

KEY WORDS: Sound waves, Wave diffraction, Wedges

A simple method of estimating the effect of a wedge angle on the sound attenuation achieved by diffraction with a wedge is described. The effect is defined as the difference between the attenuation brought about by the wedge and that due to a virtual thin barrier with the same Fresnel number, related to the source-receiver geometry. A single, reasonably accurate chart is derived from the exact solution by means of parametric studies, carried out with the aid of a computer under restricted conditions.

86-434
Penetration of Sound from a Point Source into a Rigid Porous Medium
T.L. Richards, K. Attenborough, N.W. Heap, A.P. Watson
The Open Univ., Milton Keynes MK7 6AA, UK
J. Acoust. Soc. Amer., 78 (3), pp 956-963 (Sept 1985) 7 figs, 17 refs

KEY WORDS: Sound waves, Wave transmission, Porous materials, Point source excitation

A method of steepest-descents integration suitable for use when a pole may approach near to one of the saddle points in the complex plane of integration is applied to the problem of predicting the field, resulting from a point source near to the interface between two semi-infinite media. It has been shown that is possible to obtain asymptotic approximations for the field above or below the interface to any desired degree of accuracy, in a way that is more straightforward and less algebraically cumbersome than that which is employed when using the subtraction of the pole technique. The measured data are compared with theoretical predictions.

86-435

Diffraction of Acoustic Plane Waves: A Time-Domain Analysis

H. Lasota
Technical Univ. of Gdansk, Gdansk, Poland

J. Acoust. Soc. Amer., 78 (3), pp 1086-1092 (Sept 1985), 4 figs, 27 refs

KEY WORDS: Sound waves, Wave diffraction, Time domain method

A time-domain approach to some fundamental problems of plane-wave diffraction and radiation is developed for the three classical cases of boundary conditions. The contributions of the simple and double sources (monopoles and dipoles) distributed on the wave front are regarded separately, this analysis enabling a closer look to be taken at the plane-wave forward-only propagation mechanisms. The result emphasizes the young-Rubinowicz interpretation of diffraction phenomena, the edge wave being a special case of the aperture wave.

86-436

The Effect of Kapitza Resistance and Attenuation on Second-Sound Resonators in Liquid Helium II

R.J. Atkin, N. Fox
Univ. of Sheffield, Sheffield S10 2TN, UK

J. Sound Vib., 99 (4), pp 493-499 (Apr 22, 1985), 11 refs

KEY WORDS: Sound waves, Wave attenuation, Resonant response

The resonance characteristics of second-sound waves in liquid helium II are analyzed by using standard acoustical techniques. The effects of dissipation, Kapitza resistance and thermal capacity of the heater are assessed. In typical experimental situations the resonant frequency shift due to these effects is likely to be negligible.

86-437

Wave-Wave Interactions, Microseisms, and Infrasonic Ambient Noise in the Ocean

A.C. Kibblewhite, K.C. Ewans
Univ. of Auckland, Auckland, New Zealand

J. Acoust. Soc. Amer., 78 (3), pp 981-994 (Sept 1985), 9 figs, 45 refs

KEY WORDS: Underwater sound, Wind-induced excitation

Underwater ambient noise is known to be wind dependent. Several mechanisms have been proposed to explain the nature of the transfer of energy from the wind to the acoustic noise field. Examples include wind and wave turbulence and nonlinear interactions between surface waves. This study examines these wind-related mechanisms at the low end of the acoustic spectrum.

86-438

Water-Borne Sound Insertion Loss of a Planar Compliant-Tube Array

M.C. Junger
Cambridge Acoustical Associates, Inc., Cambridge, MA

J. Acoust. Soc. Amer., 78 (3), pp 1010-1012 (Sept 1985), 2 figs, 4 refs

KEY WORDS: Underwater sound, Sound insertion noise, Tube arrays, Lumped parameter method

This lumped-parameter analysis models the compliant-tube array as a homogeneous fluid layer, thin in terms of wavelengths, whose bulk modulus and thickness match those of the tube array. For closely packed arrays, the results are in good agreement with those of the rigorous, numerical solution. For sparse arrays, the lumped-parameter model fails near and above the fundamental tube resonance frequency because it does not account for accession to inertia.

86-439

Sensitivity of Underwater Sound Transmissions to Sound-Speed Profile Selection

P. Bilazarian
Ph.D. Thesis, Rensselaer Polytechnic Inst., 124 pp (1984), DA8500939

KEY WORDS: Sound waves, Underwater sound

The sensitivity of oceanic sound transmissions to the choice of a sound-speed profile is analyzed using ray theory. The profile may be any one from a collection of depth-dependent, single-minimum profiles which can be used to model a deep-ocean sound channel. Several configurations are considered with fixed source and receiver, separated by less than about 50 km, so that different types of ray propagation can occur. Given a specified profile, procedures are prescribed for constructing a simpler profile, for which all important acoustic quantities are either identical or negligibly different. The construction methods are easy to apply, have physical interpretations, and identify the critical aspects of profile data which influence transmissions.

86-440

Normal Mode Cycle Distance and Beam Displacement, Time Delay, etc., for Low (non-WKB) Frequencies

R.A. Koch, J.B. Lindberg
Univ. of Texas, Austin, TX
J. Acoust. Soc. Amer., 78 (3), pp 995-1002 (Sept 1985) 1 fig, 13 refs

KEY WORDS: Underwater sound, Wave propagation, Normal modes

Formulation of the impedance boundary condition normal mode identification algorithm is used to develop the relationship between the normal mode and geometric ray quantities for low frequency, where previous analyses, employing WKB or other high-frequency approximations, may not be valid. The result shows that mode normalization is not uniquely related a priori to a mathematically meaningful horizontal wave-number derivative of mode number. A suggestion for constructing from this result an optimal eigenvalue predictor for numerical eigenmode calculations is discussed.

86-441

Normal Mode Measurements and Remote Sensing of Sea-Bottom Sound Velocity and Attenuation in Shallow Water

Ji-xun Zhou
Inst. of Acoustics, Academia Sinica, Beijing, People's Rep. of China
J. Acoust. Soc. Amer., 78 (3), pp 1003-1009 (Sept 1985) 9 figs, 1 table, 17 refs

KEY WORDS: Underwater sound, Sound waves, Wave attenuation, Normal modes

The dispersion analysis of explosive signals and measurements of individual mode attenuation in the Yellow Sea are reported. By adjusting input parameters of a normal mode computer program and making the calculated results coincide with field data, the compressional wave velocity and attenuation in the sediment for the frequency range of 80-800 Hz is simultaneously deduced. The sea-bottom velocity, attenuation, and its frequency dependence, probed from two sea areas with a different depth and sound velocity profile in the summer and the winter, are very close. The errors due to the change of environmental parameters are discussed.

86-442

Acoustical Impedance Models for Outdoor Ground Surfaces

K. Attenborough
The Open Univ., Milton Keynes, UK
J. Sound Vib., 99 (4), pp 521-544 (Apr 22, 1985) 18 figs, 2 tables, 26 refs

KEY WORDS: Acoustic impedance, Ground surface, Porous materials, Soils

A theory which predicts the acoustical characteristics of rigid porous materials in terms of four physical parameters is used to provide impedance versus frequency models for various types of ground surface. It is found possible to obtain tolerable agreement with measurements of surface normal impedance for grass-covered ground, bare ground and layered forest floor when measured values of flow resistivity and porosity and estimated values of the other two parameters are used. The agreement with measured acoustical data is shown to be superior to that obtainable with the single-parameter, semi-empirical model that is widely used to predict ground effect even when the single parameter is adjusted for best-fit.

86-443

Classification of Soils Based on Acoustic Impedance, Air Flow Resistivity, and Other Physical Soil Parameters

M.J.M. Martens, L.A.M. van der Heijden, H.H.J. Walthaus, W.J.J.M. van Rens
Catholic Univ. of Nijmegen, The Netherlands
J. Acoust. Soc. Amer., 78 (3), pp 970-980 (Sept 1985) 13 figs, 3 tables, 26 refs

KEY WORDS: Soils, Acoustic impedance, Ground surface, Experimental data

Measurements are presented that can be used to test theories that predict acoustical characteristics of outdoor surfaces. The specific acoustic impedances of forest soils, grass-covered surfaces, and bare sandy soils have been measured in situ using an inclined track method. Best-fit effective flow resistivities have also been deduced from the acoustical measurements. For grass-covered and forest soils the soil stratification has been determined and measurements have been carried out to determine the acoustical significance of the different layers. Physical soil parameters have also been measured, including porosity; water, air, and solid matter content; soil texture; and directly measured air flow resistivity.

86-444
Design of a Test Facility for Transmission Loss Measurement
G. Papanikolaou, A. Trochides
Univ. of Thessaloniki, Thessaloniki, Greece
Appl. Acoust., 18 (5), pp 315-323 (1985) 9 figs, 2 refs

KEY WORDS: Test facilities, Sound transmission loss, Walls

The design, construction and performance of a test facility for transmission loss measurement are described. A series of measurements concerning the performance of the test facility are presented and discussed.

86-445
A New Methodological Trial on Probabilistic Prediction of Road Traffic Noise Based on the Grouping Model of Poisson-Type Traffic-Flow
M. Ohta, K. Nakamura, N. Nakasako
Hiroshima Univ., Higashi-Hiroshima, Japan
Acustica, 58 (1), pp 39-47 (June 1985) 4 figs, 1 table, 7 refs

KEY WORDS: Traffic noise, Noise prediction

A probabilistic prediction method for road traffic noise, a grouping model of traffic flow based on an exponentially distributed vehicles model, is introduced. The effect of grouping traffic flow on the probability distribution form and its various types of statistics for road-traffic noise is discussed.

86-446
Studies on Impact Sound (Second Report, Mechanism of Sound Generation)
T. Igarashi, T. Aimoto
Technological Univ. of Nagaoka, Nagaoka, Niigata, Japan
Bull. JSME, 28 (240), pp 1247-1254 (June 1985) 14 figs, 2 tables, 8 refs

KEY WORDS: Impact noise, Noise generation

The mechanism of the impact sound generation of a ball colliding against a plate is investigated. The pulse-like contact force occurring between the ball and the plate, vibration of the plate, and impact sounds at positions near and far from the plate surface were measured simultaneously.

86-447
Image Method Prediction of Industrial Hall Noise Levels — A New Algorithm
G.R. Lemire, J. Nicolas
Universite de Sherbrooke, Sherbrooke, Quebec, Canada
Noise Control Engrg. J., 24 (2), pp 58-67 (Mar/Apr 1985) 13 figs, 2 tables, 20 refs

KEY WORDS: Noise prediction, Industrial facilities

The image method is often used to predict sound levels within enclosures. One of the drawbacks of this method is the lengthy computation time involved. This paper describes the basis of a new algorithm which permits the researcher optimum use of this computation time. This method also enables one to take into account a rough estimate of the source directivity and the extra sound attenuation due to the obstacle effect produced by the surrounding machines or reflectors. The new algorithm is applied to a weaving shed.

86-448
Construction Noise Standards and the Draft Singapore Code

R.B.W. Heng, B.V.A. Rao
National Univ. of Singapore, Singapore 0511
Appl. Acoust., 18 (5), pp 337-354 (1985) 9 tables, 30 refs

KEY WORDS: Standards and codes, Construction industry, Noise generation

A code of practice for the control of noise from construction and demolition sites in Singapore has been proposed. The code has been proposed in response to growing public concern over the noise problem caused at construction and demolition sites springing up all over the country. The country's warm climate, necessitating open windows, and its generally built up nature, have contributed to the seriousness of the situation.

86-449
Industrial Noise Control: Architectural and Environmental Aspects. 1975-May 1985 (Citations from the INSPEC; Information Services for the Physics and Engineering Communities Data Base)
NTIS, Springfield, VA
196 pp (May 1985), PB85-859338/GAR

KEY WORDS: Noise control, Industrial facilities, Bibliographies

This bibliography contains 260 citations concerning architectural and engineering acoustics associated with noise control in industrial environments. Important sources of industrial noise and the level of exposure by workers to noise are examined. Methods for active attenuation of noise, that is, the cancelling of a noise by the addition of further noise is examined. Both absorptive and non-absorptive noise control methods are presented.

SHOCK EXCITATION

86-450
Non-Linear Approximation of Weakly Compressible Fluids in Fluid-Structure Interaction Problems
H. Neishlos
National Inst. for Aeronautics and Systems Technology, Pretoria, South Africa
Intl. J. Engrg. Sci., 23 (10), pp 1031-1036 (1985), 8 refs

KEY WORDS: Fluid-structure interaction, Shock wave propagation

A model for shock propagation in one-dimensional weakly compressible fluids is developed by assuming, for any instant, a step function for the fluid density. The resulting set of equations is reduced to a single first order ordinary differential equation for the density. Under simple assumptions this approach results in a novel nonlinear interactive approximation for the fluid pressure on the structure's surface.

86-451
Analysis of Cavitation Caused by Shock Wave Interaction with a Restrained Mass
R.T. Handleton
David Taylor Naval Ship Res. and Dev. Ctr., Portsmouth, VA
Shock Vib. Bull., #55, Part 2, pp 193-203, June 1985, 7 figs, 4 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Underwater shock waves, Cavitation

A method for obtaining the motion of a restrained mass loaded by an underwater shock wave is developed through an analysis of the opening and closing of cavitation at the mass. Without making energy assumptions beforehand, the derived motion of the mass is used to calculate the fraction of the incident shock wave energy absorbed by the restraint over a range of parameters. The energy study provides a basis for judgments of the fraction of incident energy absorbed by a yielding surface.

86-452
A New Approach to the Derivation of the Impulse Response of a Rectangular Piston
G. Scarano, N. Denisenko, M. Matteucci, M. Pappalardo
Istituto di Acustica, Rome, Italy
J. Acoust. Soc. Amer., 78 (3), pp 1109-1113 (Sept 1985), 6 figs, 12 refs

KEY WORDS: Pistons, Impulse response

A spatial convolution approach is employed to derive an exact solution for the impulse response of a uniformly vibrating rectangular piston. While in the classical approach, the impulse response is regarded as a function of time for a fixed field point location, here the impulse response is regarded as a function of the spatial coordinates for a fixed time instant. The introduction of *line masses and the use of their integral proper*ties allow a simple derivation of the analytical expression of the impulse response.

86-453
Conversion Between Power Spectrum and Response Spectrum and Artificial Earthquakes
Jinren Jiang, Feng Hong
EEEV, 4 (3), pp 1-11 (1984) CSTA No. 624-84.91

KEY WORDS: Seismic response spectra, Monte Carlo method, Power spectra, Simulation

Methods of generating artificial earthquake accelerograms is reviewed, and an equivalent stationary approximate cumulative distribution of the maximum response to nonstationary random excitation is proposed. Comparison of the response spectrum of artificial accelerograms with the goal spectrum shows that the artificial accelerograms have sufficient accuracy and can be used for seismic response analysis and Monte Carlo simulations.

86-454
Aseismic Design Based on Random Vibration
Wei-Joe Sun
Ph.D. Thesis, Case Western Reserve Univ., 171 pp (1984) DA8503616

KEY WORDS: Seismic design, Random vibrations, Dams

Random vibration modal time history (RVMTH) analyses have been developed to compute evolutionary covariance matrices of responses of linear dynamic systems that can be coupled into modes and are excited by nonstationary, nonwhite, excitation. The output of such analyses includes covariance matrices of any response vector processes which contain rms values of responses and their time derivatives, and correlations between responses and time derivatives. South output is sufficient for computing mean outcrossing rates from which reliability estimates can be made. The RVMTH design methods are applied to linear plane frames and to plane strain, finite element models of dams.

86-455
Response of Confined Concrete Subjected to Earthquake Type Loadings
A. Fafitis
Ph.D. Thesis, Northwestern Univ., 511 pp (1984) DA8502368

KEY WORDS: Concrete, Seismic response

The concept of envelope curve is experimentally confirmed and extended to confined normal weight concrete as well as plain and confined light weight concrete. For slowly applied loading the envelope curve as defined by the monotonic curve may be exceeded. This observation limits the validity of the envelope concept, but it is not too severe for earthquake loadings. The proposed analytical expressions for the envelope curve are used to predict the behavior of large size columns with longitudinal and lateral reinforcement. The predictions compare favorably with experimental results.

86-456
Predicting Blast Induced Porewater Pressure Increases in Soil — A Review
W.A. Charlie, S.R. Abt
Colorado State Univ., Fort Collins, CO
Civil Engrg. for Practicing and Design Engrs., 4, pp 311-328 (1985) 1 fig, 4 tables, 58 refs

KEY WORDS: Blast excitation, Ground vibration, Soils

A review of explosive induced ground motions and the potential for fairly long porewater pressure increases and shear strength reductions in water saturated soils as a result of blast induced vibrations is presented. The information and references presented represent the state-of-the-art.

86-457
Characterization of Structural Response to Earthquake Motion
J.J.R.T. de Azevedo
Ph.D. Thesis, Stanford Univ., 239 pp (1984) DA8429491

KEY WORDS: Seismic response, Damage prediction, Earthquake damage

An additional earthquake ground motion severity characterization is examined. This characterization is based on the statistical properties of the accelerogram peaks and on the geophysical aspects of the seismic event. It incorporates information on the frequency content of the ground motion and is shown to be related to the duration of ground motion. The purpose is to bring an additional insight to the problem of ground motion characterization and help in reducing its uncertainty. Distance to the source and epicentral azimuth with respect to the fault line are shown to be the parameters that most influence the type of ground acceleration peak statistical distribution. The results are substantiated by observations of past seismic events.

86-458

Reduction of First Excursion Probability of Mechanical Systems under Earthquake Excitations by Inelastic Restoring Force-Deformation Relation

S. Aoki, K. Suzuki
Tokyo Metropolitan Univ., Tokyo, Japan

Bull. JSME, 28 (240), pp 1226-1232 (June 1985) 11 figs, 14 refs

KEY WORDS: Earthquake response, Mechanical systems, Nuclear power plants, Industrial facilities

Important mechanical systems installed in nuclear power plants and other industrial facilities must be designed to perform during and after destructive earthquake excitations. Reduction of the first excursion probability of such mechanical systems with inelastic restoring force-deformation relation is examined. Obtained results are examined by a theoretical technique using the equivalent linearization method. It is concluded that the first excursion probability of inelastic mechanical systems is less than that of elastic systems.

86-459

Shock Environment in a Civil Defense Blast Shelter

T.R. Slawson, S.C. Woodson, S.A. Kiger
US Army Engineer Waterways Experiment Station, Vicksburg, MS

Shock Vib. Bull., #55, Part 2, pp 95-100, June 1985, 13 figs, 1 table, 6 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Blast resistant structures, Shock tests, Experimental data

A series of 12 dynamic tests were conducted on 1/4-scale structural models of a civil defense blast shelter. The dynamic loading was generated using a high explosive simulation technique and simulated the overpressure from a large-yield nuclear detonation at peak overpressures ranging from approximately 0.23 MPa (34 psi) to 1.09 MPa (158 psi).

86-460

Reliability of Structures Subjected to Multiple Blast Loads

A. Longinow, J. Mohammadi, H.S. Napadensky
Illinois Institute of Technology, Chicago, IL

Shock Vib. Bull., #55, Part 2, pp 87-93, June 1985, 8 figs, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Hardened installations, Blast resistant structures, Reliability

The problems involved in predicting the response of structures when subjected to multiple blast loads are examined. The structure is modeled as a single degree of freedom system with a resistance function which provides for an approximate degradation in its strength. The method considers uncertainties in both structural and blast load parameters. A failure probability is computed after each blast. Individual failure probabilities are combined to yield the probability of collapse. The method of analysis is described and its application is illustrated by means of an example problem.

86-461

Structures to Resist the Effects of Accidental Explosions. Volume 6. Special Considerations in Explosive Facility Design

M. Dede, S. Lipvin-Schramm, N. Dobbs, J.P. Caltagirone
Ammann and Whitney, New York, NY

Rept. No. ARLCD-SP-84001-VOL-6, SBI-AD-E401 323, 237 pp (Apr 1985) AD-A154 275/2/GAR

KEY WORDS: Blast resistant structures, Design techniques, Explosion effects

Procedures for the design of blast-resistant structures other than above ground, cast-in-place concrete or structural steel structures, are presented, as well as the design of other miscellaneous blast-resistant components. The design of reinforced and nonreinforced masonry walls, precast elements both prestressed and conventionally reinforced, pre-engineered buildings, suppressive shielding, blast resistant windows, underground structures, earth covered, arch-type magazines, blast valves, and shock isolation systems are also included.

VIBRATION EXCITATION

86-462

On the Peak Factor of Stationary Gaussian Processes

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Belgonucleaire S.A., Brussels, Belgium

J. Sound Vib., 100 (1), pp 15-34 (May 8, 1985) 9 figs, 4 tables, 32 refs

KEY WORDS: Normal density functions, Probability density function, Approximation methods

New simple approximate formulae are introduced for the average and the standard deviation of the peak factor of stationary Gaussian processes. The formulae take into account the bandwidth of the process and are based on the assumption that the extreme point process is Markovian. Also presented are simulation results for various spectral shapes (response of the linear oscillator to a white noise, bimodal spectrum, and ideal bandpass process). These suggest that none of the currently available bandwidth parameters can represent accurately the overall effect of the spectral shape on the peak factor.

86-463

On Systems Having an Infinitely Dense Discrete Spectrum of Resonance Frequencies

D. Shilkrut, Z. Grünseit

Ben-Gurion Univ. of the Negev, Beersheva, Israel

J. Sound Vib., 100 (1), pp 7-13 (May 8, 1985) 4 figs, 1 table, 4 refs

KEY WORDS: Power spectral density, Periodic excitation

The infinitely dense spectrum of resonance frequencies arising from a periodic but nonharmonic excitation is presented. A physical reasoning for why systems may operate under such conditions is given based on the notions of an allowed value of amplitude of vibrations in a defined time interval of application of the excitation. The phenomenon is illustrated by a periodically moving force on one-dimensional systems.

86-464

First Passage Times for Combinations of Random Loads

P.A. Jacobs

Naval Postgraduate School, Monterey, CA

Rept. No. NPS55-85-2, 43 pp (Feb 1985) AD-A153 275/3/GAR

KEY WORDS: Random excitation

Structures are subject to changing loads from various sources. In many instances these loads fluctuate in time apparently random fashion. Models are considered for which the stress put on the structure by various loads simultaneously can be described by a regenerative process. Simulation results are given to assess the accuracy of using the asymptotic results to approximate the distribution.

86-465

Coupled Acoustic and Hydrodynamic Wave Instabilities

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Univ. of Alabama, Huntsville, AL

Joint Army-Navy-NASA-Air Force Combustion Mtg., Proc. 21st, Laurel, MD, Oct 1-4, 1984, Vol. 1, pp 129-137; Avail: Chemical Propulsion Information Agency, Laurel, MD 20707

KEY WORDS: Hydrodynamic excitation, Acoustic excitation, Coupled response

Theoretically, there exist an infinite number of frequencies for both acoustic and hydrodynamic oscillations. The purpose of this paper is to review the work on the combined action of acoustic and hydrodynamic frequencies at which instabilities may arise. The mathematical formulations for the theory and some simple numerical examples are demonstrated.

86-466

A Direct Method for Estimating Lower and Upper Bounds of the Fundamental Frequency

D. Jin, W.D. Pilkey, B.P. Wang, Y. Okada
Tsinghua Univ., Beijing, China
Shock Vib. Bull., #55, Part 3, pp 155-166, June 1985, 6 tables, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Fundamental frequencies

When studying or designing a vibrating system, it is useful to have a quick estimate of frequencies, especially the fundamental frequency. The lower and upper bounds of the fundamental frequency provide the approximation and range of this frequency. A direct method is presented to get the lower and upper bounds of a fundamental frequency. In contrast to currently used approaches, the lower and upper bounds can be obtained simultaneously by this method. The method is applicable to discrete and continuous systems.

86-467
Generalized Dynamic Analysis of Interactive Fluid-Structure Transient Response
J.E. Boisvert, B.E. Sandman
Naval Underwater Systems Ctr., Newport, RI
Shock Vib. Bull., #55, Part 2, pp 165-171, June 1985, 13 figs, 3 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Fluid-structure interaction, Submerged structures, Transient response

A generalized classical analytical method is formulated for the solution to the response of submerged structures excited by transient forces. The approach is directly applicable to numerous problems where transient structural response in the presence of a heavy fluid medium is of fundamental interest. The proposed methodology, which captures the complete spectral distribution of frequency and wavenumber, is capable of describing response to unlimited space-time waveforms of transient loading.

MECHANICAL PROPERTIES

DAMPING

86-468
Vibration Damping Materials. 1.
C. Pillot, P. Galy, D. Dideron, G.L. Wilson
Pennsylvania State Univ., University Park, PA
Rept. No. NSF/INT-83001, 427 pp (July 1983), PB85-180941/GAR

KEY WORDS: Material damping, Vibration damping

The text provides a compilation of the properties of a number of commercially available materials that may be used in vibration damping. The advantages of damping are reviewed, and the properties of materials are described, with special emphasis given to viscoelastic properties. The two most common damping techniques, sandwich coating and simple coating, are examined, and ways that the dynamic characteristics of damping materials may be measured are noted. Measurable data, including the excitation force, the displacement, and the frequency, are addressed. Finally, data are supplied concerning approximately 70 viscoelastic materials; information concerning the materials' viscoelastic properties and concerning their manufacturers are included.

86-469
Quantitative Comparison of Active and Passive Damping for Large Space Structures
F. Shen
Toronto Univ., Downsview, Ontario, Canada
Rept. No. UTIAS-TN-249, 78 pp (Feb 1985), N85-22524/1/GAR

KEY WORDS: Active damping, Viscoelastic damping, Spacecraft

A quantitative method for comparing active and passive damping according to weight and positivity criteria is outlined which assumes thruster actuators for active damping and viscoelastic material for passive damping. Each of these damping techniques is implemented by optimizing the damping performance against weight. The mobile communications satellite is used as a model to compare active and passive damping. The results show that, in general, active damping is much more weight-cost effective and possess better positivity qualities than passive damping.

86-470
Temperature Shift Effects on Complex Modulus
J.A. Eichenlaub, L.C. Rogers
Air Force Flight Dynamics Lab., Wright-Patterson Air Force Base, OH

Shock Vib. Bull., #55, Part 1, pp 85-88, June 1985, 8 figs, (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Material damping, Viscoelastic damping, Shear modulus, Temperature effects

The first step in using viscoelastic materials to control vibration is the accurate determination of the material properties. Since polymer properties exhibit a strong dependence on frequency and temperature, it is necessary to characterize samples over a wide range of temperatures and frequencies. This paper presents a method of defining the temperature shift parameter equation when the frequency range is inadequate to find it by inspection of the experimental data.

86-471
A Different View of Viscous Damping
P.J. Torvik, R.L. Bagley
Air Force Inst. of Technology, Wright-Patterson Air Force Base, OH
Shock Vib. Bull., #55, Part 1, pp 81-84, June 1985, 6 refs (55th Symp. Shock Vib., Dayton, OH, Oct. 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Viscous damping

This paper reviews the modeling and physics of a linear viscous damper.

86-472
A Different Approach to "Designed In" Passive Damping
M.L. Drake
Univ. of Dayton, Dayton, OH
Shock Vib. Bull., #55, Part 1, pp 109-117, June 1985, 13 figs, 3 tables, 16 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Material damping, Design techniques

Damping material vendors will soon be supplying damping materials in bulk form (sheets, rolls, uncured gum) to the structural system manufacturers. Since the damping materials will be required in bulk form, the possibility of ordering a custom formulated material exists. A method is demonstrated to develop the required damping material properties, discuss formulation changes usable to adjust the damping material properties, and discuss the benefits of such design procedures.

86-473
Impact Damper with Granular Materials (3rd Report, Indicial Response)
Y. Araki, Y. Yuhki, I. Yokomichi, Y. Jinnouchi
Kyushu Inst. of Technology, Kitakyushu, Japan
Bull. JSME, 28 (240), pp 1211-1217 (June 1985) 13 figs, 1 table, 6 refs

KEY WORDS: Impact dampers, Granular materials

A new type impact damper consists of a bed of granular materials moving in a container fixed to the primary vibrating system. The problem is to determine the characteristics of the impact damper for reducing the vibration of the system to a prescribed value. This report deals with the indicial response of the damper; i.e., the damping characteristics of free oscillations from an initial displacement of the vertical and horizontal vibrating system. Experimental models were tested and numerical analyses were made to find the damping characteristics for several values of mass ratio and clearance.

FATIGUE

86-474
Calculation of Fatigue-Stress Concentration Factors (Zur Berechnung von Kerbwirkungszahlen)
H. Dietmann
Konstruktion, 37 (2), pp 67-71 (Feb 1985) 2 figs, 4 tables, 27 refs (In German)

KEY WORDS: Structural members, Discontinuity-containing media, Fatigue life

Formulas for the most simple calculation of fatigue-stress concentration factors are developed, based on the available calculation method of Siebel and Petersen. These factors are required for the determination of strength of vibrating notched structural components.

86-475
Thermo-Mechanical Drive Components and Exhaust System Test Bench for Fatigue Testing under Operational Loading (Thermisch-mechanischer Aggregate- und Abgasanlagen-Prüfstand fur Betriebsfestigkeitsuntersuchungen)
H.-G. Holzheimer, H.J. Kolitsch
Automobiltech. Z., 87 (5), pp 227-229 (May 1985) 1 fig, 7 refs (In German)

KEY WORDS: Fatigue tests, Mechanical drives, Exhaust systems

Due to the ever increasing demand for qualitative and quantitative testing, a new engine driven exhaust system test bench has been developed. This test bench is designed for fatigue testing under operational load conditions and is capable of testing not only exhaust systems but also other drive components. The concept and constructive realization of the test bench are presented.

86-476
Investigation of Modes, Frequencies and Forced Response of a High Frequency Fatigue Test System
D.K. Rao, D.I.G. Jones
Air Force Materials Lab. (AFWAL/MLLN), Wright-Patterson AFB, OH
Shock Vib. Bull., #55, Part 2, pp 27-38, June 1985, 22 figs, 3 tables, 11 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Fatigue tests, Test facilities, Turbine blades, Bladed disks

A low cost, resonance based fatigue test system prototype, designed for studying the crack-growth rates of turbine or disc blade materials under the combined action of a high cycle fatigue load and low cycle fatigue load, has been fabricated. Theoretical and experimental analysis of the dynamic characteristics of this prototype structure are presented.

86-477
Initial Design and Testing of a Unique High Frequency Fatigue Test System
D.I.G. Jones
Wright-Patterson AFB, OH
Shock Vib. Bull., #55, Part 2, pp 17-26, June 1985, 19 figs, 1 table, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Fatigue tests, Test facilities, Crack propagation

The development of a high-frequency resonant fatigue test system for investigating crack initiation and propagation behavior in test specimens under combined low cycle and high cycle loading is described. The system offers significant advantages in low cost and simplicity. Initial dynamic response predictions for the prototype system are described, and comparisons with experimental measurements are presented.

86-478
Fatigue Damage and Small Crack Growth During Biaxial Loading
Chang-Tsan Hua
Ph.D. Thesis, Univ. of Illinois, Urbana-Champaign, 169 pp (1984) DA8502185

KEY WORDS: Fatigue life, Crack propagation

The progressive nature of fatigue damage under biaxial loading has been investigated. Experiments were performed on thin-wall tubular specimens of 1045 steel in tension, torsion, and combined tension-torsion loading. Two equivalent strain amplitudes, one in the high cycle fatigue region and one in the low cycle fatigue region were employed for all loading patterns. >The test program included constant amplitude loading and variable amplitude loading. Two types of variable loading patterns, step loading and block loading, were selected.

86-479
Fatigue Life, Fatigue Crack Propagation and Fracture Toughness Study of 7075 Aluminum Alloy Subjected to Thermomechanical Processing
Moon Hee Lee
Ph.D. Thesis, Oregon State Univ., 165 pp (1984) DA8500998

KEY WORDS: Fatigue life, Crack propagation, Aluminum, Temperature effects

Due to its high strength/weight ratio, 7075 aluminum alloy has been widely used as an aerospace material. However, it has relatively low fatigue strength and low fracture toughness in the T6 condition. Thermomechanical processing, including pre-cyclic loading and stretching at high and ambient temperatures, has been investigated with the aim of improving these properties.

86-480
A Fatigue Life Prediction Method for Tensile-Shear Spot Welds
Pei-Chung Wang
Ph.D. Thesis, Univ. of Illinois, Urbana-Champaign, 137 pp (1984) DA8502336

KEY WORDS: Fatigue life, Prediction techniques, Steel

An empirical three-stage initiation-propagation model has been developed which predicts the fatigue resistance of tensile-shear spot welds under constant amplitude loading test. The model consists of Stage I -- fatigue crack initiation and early growth, Stage II -- through sheet thickness crack propagation, and Stage III -- across sheet width crack propagation. The improvements of tensile-shear spot weld fatigue resistance through manipulation of geometry, residual stress and material property variables are discussed with the aid of the model.

86-481
Estimation of Corrosion Fatigue Lives Based on the Variations of the Crack Lengths Distributions During Stress Cycling
S. Ishihara, I. Maekawa, K. Shiozawa, K. Miyao
Toyama Univ., Toyama, Japan
Bull. JSME, 28 (240), pp 1015-1022 (June 1985) 8 figs, 2 tables, 16 refs

KEY WORDS: Fatigue life, Corrosion fatigue

A method of estimation of corrosion fatigue lives is proposed. The crack initiation, crack growth behavior and the variation of the distribution of crack lengths during corrosion fatigue process are taken into consideration in the method. Comparing the estimated results with experimental results, it is concluded that this method could estimate the corrosion fatigue lives with good accuracy.

86-482
Examination of the Threshold Condition for Propagation of Fatigue Cracks Using Slip-Initiation Phenomena (3rd Report, In the Case of Aged Cracked Specimen)
S. Kitaoka, M. Murata
Nagoya Univ., Nagoya, Japan
Bull. JSME, 28 (240), pp 1023-1028 (June 1985) 11 figs, 6 refs

KEY WORDS: Fatigue life, Crack propagation

The threshold condition for propagation of Mode I micro fatigue cracks in an aged cracked specimen made of carbon steel is investigated. Models for estimating the stress amplitude acting on the micro region near the crack tip are proposed applying the values mentioned above. The stress condition at the crack propagation threshold can be explained by a model.

86-483
Acoustic Emission Study of Fatigue Crack Extension Position in a Stress Cycle
Chul Jung Kim
Ph.D. Thesis, Northwestern Univ., 145 pp (1984) DA8502391

KEY WORDS: Acoustic emission, Fatigue life, Crack propagation

In recent fatigue crack propagation theories of Weertman, the position of the onset of fatigue crack extension in a stress cycle has been predicted. The acoustic emission technique was used to check this theory. The acoustic emission released during fatigue of the aluminum alloys 7050-T76 and 2024-T3, the steel alloys 4140 and 4340, 304 stainless steel, and maraging 300 steel was studied using center notched specimens which were subjected to a tension-tension sinusoidal load at room temperature in air environment at the frequency range of 10-20 Hz.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

86-484
Operational Test of Mechanical Drives Using the Period Measurement Method (Funktionsprüfung mechanischer Getriebe mit dem PDM-Verfahren)
J. Schmitt, U. Claussen
Konstruktion, 37 (3), pp 117-122 (Mar 1985) 9 figs, 1 table, 9 refs (In German)

KEY WORDS: Vibration measurement, Measurement techniques

The deflection, velocity, acceleration etc. of mechanical drives can be measured in real time and with high resolution by means of a period measurement method. The method is illustrated in measuring the dynamic characteristics of a gear drive and the drive of a thread rolling machine.

86-485
Special Function Response Methods in Analysis of Linear Systems
Qingzuan Du
J. China Railway Soc., 6 (4), pp 14-20 (1984) CSTA 625.1-84.30

KEY WORDS: Signal processing techniques, Time domain method, Frequency domain method

From the viewpoint of signal resolution, both the time domain analysis and the frequency domain analysis may be considered as the special function response methods of linear systems. In the gate function response approach, due to the fact that there is no relative time displacement between the elemental signals, the zero-state response of a linear system is expressed in the form of ordinary integration instead of convolution integration, thus the solution is effectively simplified.

86-486
Forced Structural Response Using Component Mode Synthesis
J.J. Allen, D.R. Martinez
Oklahoma State Univ., Stillwater, OK
Rept. No. SAND-83-1866, 40 pp (Mar 1985) DE85008479/GAR

KEY WORDS: Component mode synthesis

The effects of omitting constraint modes corresponding to applied loads in systems modeled with component mode synthesis are discussed. A method of correcting for the omitted constraint modes is also developed. A free component mode synthesis method is applied to a continuous model of an axial rod-spring system, and the effect of omitted constraint modes on the static, steady-state harmonic, and transient response is studied. The effect of omitted constraint modes on the transient response of an asymmetric beam is presented using the free and fixed component mode synthesis methods implemented in MSC/NASTRAN. A simple pinned truss finite element model is also studied.

86-487
Analytical Studies of Thickness-Extensional Trapped Energy Mode Resonators and Transducers
D.V. Shick
Ph.D. Thesis, Rensselaer Polytechnic Inst., 119 pp (1984) DA8500961

KEY WORDS: Piezoelectric transducers

Partially electroded PZT-7A plates undergoing free and forced thickness-extensional trapped energy mode vibrations are treated analytically. In each problem the solution consists of a sum of the dominant plate eigensolutions for shorted electrodes in the electroded region and for zero surface charge in the unelectroded region. The driven thickness solution is also included in the electroded region in the problems of forced vibrations.

86-488
Beam Steering of Electrically Segmented Piezoceramic Ultrasonic Transducers Using Normal Mode Coupling
H. Eslambolchi
Ph.D. Thesis, Univ. of California, San Diego, 189 pp (1984) DA8502488

KEY WORDS: Piezoelectric transducers

The theory of normal mode steering is developed, the dispersion curve is derived so the traveling wave velocities can be evaluated, and the effect of the mirror lobe due to the reflection from the edge boundary is analyzed. The theory is then verified by measurements on an experimental normal mode transducer which is compared with a companion staved or mechanically segmented transducer.

86-489
Displaying Acoustic Intensity in an Enclosed Volume Using Color Graphics
C.E. Spiekermann, C.J. Radcliffe
ASME Paper No. 84-WA/NCA-14

KEY WORDS: Acoustic intensity method, Graphic methods, Gross spectral method

This paper discusses using the cross-spectral method for measuring acoustic intensity to obtain three orthogonal vector components of the propagating wave component of the total acoustic response at several points in an enclosed volume.

86-490
Pattern Approval and Verification of Sound Level Meters (Zulassung und Eichung von Schallpegelmessern)
K. Brinkmann
Mitteilung aus der Physikalisch-Technischen Bundesanstalt, Braunschweig
Acustica, 58 (1), pp 2-10 (June 1985) 2 figs, 1 table, 13 refs (In German)

KEY WORDS: Sound level meters, Measuring instruments

A report is given on the scope and results of approval tests on comparison measurements carried out on sound level meters to guarantee uniformity of the technical tests executed upon verification. Information is provided about the nature and frequency of occurrence of the faults found in these tests and describes certain developments in this field to be anticipated in the near future.

DYNAMIC TESTS

86-491
Preliminary Investigation of the Dynamic Force-Calibration of a Magnetic Suspension and Balance System
M.J. Goodyer
Southeast Basins Inter-Agency Committee, Atlanta, GA
Rept. No. NASA-CR-172580, 14 pp (May 1985) N85-23808/7/GAR

KEY WORDS: Wind tunnel testing, Aerodynamic loads, Dynamic calibration

The aerodynamic forces and moments acting upon a magnetically suspended wind tunnel model are derived from calibrations of suspension electro magnet currents against known forces. As an alternative to the conventional calibration method of applying steady forces to the model, early experiences with dynamic calibration are outlined, that is a calibration obtained by oscillating a model in suspension and deriving a force/current relationship from its inertia force and the unsteady components of currents.

86-492
Design and Field Experience with the WES 10KBar Airblast and Soil Stress Gage
C.E. Joachim, C.R. Welch
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS
Shock Vib. Bull., #55, Part 2, pp 135-147, June 1985, 16 figs, 1 table (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Shock tests, Transducers, Measuring instruments, Seismic response

A family of shock transducers based on the classical load-cell geometry, i.e., the elastic compression of a column, is currently under development. The transducers include an airblast gage, a soil stress gage, and a soil-structure interface stress gage. These gages operate at considerably higher pressure ranges than previous elastic shock transducers. This paper describes the transducer development and presents some dynamic measurements produced from these gages.

86-493
A Decade of Reliability Testing Progress
R.N. Hancock
LTV Aerospace and Defense Co., Dallas, TX
Shock Vib. Bull., #55, Part 1, pp 29-41, June 1985, 9 figs, 5 tables, 12 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Reliability, Testing techniques

The problems in avionics reliability were described at the 45th Shock and Vibration Symposium, which was held at the Dayton Convention Center in 1974. The fundamental problem was that great numbers of design and workmanship defects were still present in equipment after it had been placed in field service. The thesis at the time was that the reliability testing (or laboratory testing in general) had been inadequate to disclose the defects.

86-494
CERT — Where We Have Been — Where We Are Going
A. Burkhard
Air Force Wright Aeronautical Labs., Wright-Patterson Air Force Base, OH
Shock Vib. Bull., #55, Part 1, pp 43-49, June 1985, 6 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Reliability, Testing techniques

The combined environment reliability test is described, including its development, progress, and accomplishments.

86-495
Pyrotechnic Shock Simulation Using the Controlled Response of a Resonating Bar Fixture
N.T. Davie
Sandia National Labs., Albuquerque, NM
Rept. No. SAND-85-118C, CONF-850450-2, 8 pp (1985) DE85006537/GAR

KEY WORDS: Testing techniques, Pyrotechnic shock environment

Test laboratories frequently simulate pyrotechnic shock by mounting test items on various bar or plate fixtures which are excited into resonance by mechanical impact. A method is described for controlling the longitudinal response of a bar fixture. This method ultimately provides a predictive means for controlling the shock spectrum shape produced by the simulated pyrotechnic shock. Control of the shock spectrum shape eliminates much of the trial and error usually required to tailor a shock test to satisfy the test requirement. A simple analytical model which describes the propagation and reflection of strain waves in the bar fixture is also derived.

86-496
D'Alembert Unfolding of Hopkinson Bar Airblast Data
H.G. White, C.R. Welch
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS
Shock Vib. Bull., #55, Part 2, pp 129-134, June 1985, 8 figs, 2 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Hopkinson bar technique, Testing techniques

Strain gaged Hopkinson bars are being used to make airblast impulse measurements in high pressure explosive environments. The data obtained are typically limited in time by the arrival of the reflected tensile wave from the dump end of the bar. A simple data unfolding procedure based on an elastic D'Alembert solution for stress waves in a bar is presented. Bar gage airblast data unfolded using this procedure and the impulse data from these records are also presented.

86-497
Development of a 3KBar Static Calibration Device
C.D., Jr. Little
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS
Shock Vib. Bull., #55, Part 2, pp 123-128, June 1985, 11 figs, 1 table (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Testing instrumentation, Calibrating

The definition of increasingly severe dynamic test environments from explosive loadings for defense and military structures has required pressure and stress measurements on the order of several kilobars. To facilitate these measurements a static fluid calibration device was developed which enables transducer calibration to the 3 kbar pressure level. The device is constructed of high-strength steels and is a totally self-contained unit, needing no further means of confinement. In addition to transfer calibration, the device provides a useful vehicle for experimental transducer verification through determination of nonlinear and hysteretic effects.

86-498
Assessment of Dynamic Test Methods for the Measurement of Fracture Toughness
R.A.W. Mines, C. Ruiz
Oxford Univ., UK
Rept. No. OUEL-1561/85, 74 pp (1984) PB85-182673/GAR

KEY WORDS: Testing techniques, Fracture properties

The instrumented impact test, using a pendulum or a pressure bar, has been shown to provide lower bounds to the static fracture toughness of steel. The investigation has raised a number of questions of a fundamental nature and suggested potentially fruitful lines for further work, in particular the development of dynamic calibration functions, the dynamic analysis of the complete pendulum/testing machine system in order to propose standards that will insure consistency between tests, the improvement of electronic filtering, the correlation between high strain rate mechanical properties and impact fracture toughness and the expansion of the data base in the elasto-plastic range, using an instrumented pendulum.

DIAGNOSTICS

86-499

Time Domain Modal Analysis of a Slotted Cylindrical Shell

W.Q. Feng, P.Q. Zhang, T.C. Huang
Univ. of Wisconsin, Madison, WI
Shock Vib. Bull., #55, Part 3, pp 67-79, June 1985, 6 figs, 2 tables, 3 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Diagnostic techniques, Cylindrical shells, Modal analysis, Time domain method

The modal parameters will change if a structure changes from being perfect to being defective. This paper investigates a cylindrical shell with a longitudinal slot by the time domain method. The 11 sets of mode vectors, all of them nearly real modes, are investigated and the modal shapes are plotted. When the slotted shell is compared with the original perfect shell, it is found that several new mode vectors are created for the slotted shell, and the characteristics of the kept modes, the modes shapes of the perfect shell which remain for the slotted shell, will also change.

BALANCING

86-500

Balancing of a Flexible Rotor by Driving Torque Excitation (Theoretical Consideration)

K. Ono
Tokyo Inst. of Technology, Tokyo, Japan
Trans. JSME No. 458 (May 30, 1983)

KEY WORDS: Modal balancing technique, Flexible rotors, Flexural vibrations, Torsional vibrations

A novel modal balancing method is presented by the excitation of driving torque at low rotational speed below its first critical speed. The bending and torsional vibrations are analyzed for a flexible rotor under the driving torque excitation. A measuring procedure for modal unbalance is also described.

86-501

Sensitivity Analysis of the Locations of the Balancing Planes of an Unbalanced Rotor-Bearing System Using Dynamic Condensation Technique

S. Ahuja, A.M. Sharan
Memorial Univ., St. John's, Newfoundland, Canada
Shock Vib. Bull., #55, Part 3, pp 37-55, June 1985, 17 figs, 13 tables, 9 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Balancing techniques, Dynamic condensation method, Rotors

An analytical procedure for the dynamic balancing of multi-rotor systems supported on fluid-film bearings is presented. The model is developed based on the finite element method which includes the effects of translational, and rotational inertia, and gyroscopic moments, using the consistent matrix approach in conjunction with the dynamic matrix reduction technique, the modal analysis, and the least-square balancing technique. The use of the matrix reduction technique for determining an equivalent reduced system for balancing, provides subsequent saving of computational time and space on the digital computer.

86-502

Development of a Multiplane Multispeed Balancing System for Turbine Systems

M.R. Martin
Mechanical Technology, Inc., Latham, NY
Rept. No. MTI-84TR39, NASA-CR-174750, 114 pp (July 19, 1984) N85-22400/4/GAR

KEY WORDS: Balancing machines, Turbines

A prototype high speed balancing system was developed for assembled gas turbine engine modules. The system permits fully assembled gas turbine modules to be operated and balanced at selected speeds up to full turbine speed. The balancing system is a complete stand-alone system providing all necessary lubrication and support hardware for full speed operation.

MONITORING

86-503
Structural Damage Detection by the System Identification Technique
J.C.S. Yang, T. Tsai, V. Pavlin, J. Chen
Univ. of Maryland, College Park, MD
Shock Vib. Bull., #55, Part 3, pp 57-66, June 1985, 6 figs, 6 tables, 17 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: System identification techniques, Failure detection, Fatigue life

The development of a technique with the potential to detect and track progressive fracture by observing changes in the identified system parameters -- mass, stiffness and damping matrix elements -- is described. The method, called the system identification technique, has two steps: a process of retrieving the eigenvalues and eigenvectors during a dynamic response phase and the determination of mass, stiffness and damping matrices from these values. The proposed technique was verified on cantilever beam continuous structure systems through finite element simulation and experimental studies.

86-504
Vibration Monitoring
J. Reason
Power, pp S-1 - S-12 (Sept 1985) 22 figs, 2 tables

KEY WORDS: Monitoring techniques, Rotating machinery, Vibration measurement, Data processing

A periodic vibration measurement and data handling program is described which defines the best time to overhaul rotating equipment for maximum availability at lowest cost.

86-505
Acoustic Emission/Flaw Relationship for In-Service Monitoring of Nuclear Pressure Vessels. Quarterly Report April 1984 - September 1984
P.H. Hutton, R.J. Kurtz
Battelle Pacific Northwest Labs., Richland, WA
Rept. No. PNL-5125-VOL-3-VOL-4, 27 pp (Mar 1985) NUREG/CR-3825-V3-V4/GAR

KEY WORDS: Monitoring techniques, Acoustic emission, Nuclear reactor components

Technical progress toward continuous acoustic emission monitoring of nuclear reactor pressure boundaries for flaw detection is described. A draft report of ZB-1 vessel test results was completed. Growth of machined flaws was detected by AE during both 65 degrees C and 285 degrees C testing. AE data was generally proportional to crack growth. A key result was clear detection of a natural crack in a fabrication weld by AE. Crack growth rates estimated from AE data compared well with measured crack growth rates. In service hydro test monitoring gave mixed results. Impending failure conditions are readily detectable.

86-506
Observation and Identification of Crack Growth Modes in Reactor Steels Using Acoustic Emission
R.H. Jones, P.H. Hutton, M.A. Friesel, S.M. Wolf
Battelle Pacific Northwest Labs., Richland, WA
Rept. No. PNL-SA-12656, CONF-8403152, 136 pp (Dec 1984) DE85006624/GAR

KEY WORDS: Monitoring techniques, Acoustic emission, Nuclear reactors, Steel, Crack propagation

This workshop was held to identify major technical issues in the quantitative correlation of acoustic emission with crack growth mode in reactor steels. The technological value of such a correlation is clear in terms of accepting acoustic emission as an on-line nondestructive probe of cracking in light-water reactor structural components and, as a consequence, in terms of increasing reactor availability and reliability. The value for materials science is clear as well as in terms of demonstrating the potential of a new in-situ nondestructive probe for characterizing microfracture events and possibly local deformation phenomena during mechanical testing, a capability not available with existing probes. The desired output from this workshop was a set of recommendations for the development of acoustic emission monitoring; these require expertise of both the technological and scientific communities.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

86-507

Application of Deformable Body Mean-Axis to Dynamics of Flexible Mechanical Systems

O.P. Agrawal

Ph.D. Thesis, Univ. of Illinois at Chicago, 205 pp (1984) DA8501232

KEY WORDS: Equations of motion, Elastic properties, Mechanical systems

A method for the dynamic analysis of flexible multi-body systems that undergo large geometric changes, is developed. The configuration of each elastic body is represented using two sets of generalized coordinates: reference generalized coordinates that define the location and orientation of a body reference frame, and the elastic generalized coordinates that define the elastic deformation of the finite element nodal points with respect to the body reference. A multirate integration method, whereby two different numerical integration algorithmns are employed to simultaneously solve the set of algebraic and differential equations is developed. Numerical examples are presented in order to demonstrate the validity of the theory developed.

86-508

Weighted Linearization Technique for Period Approximation in Large Amplitude Non-Linear Oscillations

V.P. Agrwal, H.H. Denman

Wayne State Univ., Detroit, MI 48202

J. Sound Vib., 99 (4), pp 463-473 (Apr 22, 1985) 7 figs, 6 refs

KEY WORDS: Approximation methods, Linearization methods

Period approximations for conservative, one-dimensional, nonlinear oscillating systems are considered. The approximation technique used is linearization of the nonlinear restoring function governing the system. The best large amplitude results are investigated, with use of linearization based on weight functions of the power type. The nonlinear functions examined are odd polynomials, sine, hyperbolic sine, tangent, and hyperbolic tangent.

86-509

Application of Ritz Vectors for Dynamic Analysis of Large Structures

R.R. Arnold, R.L. Citerley, M. Chargin, D. Galant

Anamet Labs., Inc., San Carlos, CA

Computers Struc., 21 (3), pp 461-467 (1985) 4 figs, 11 refs

KEY WORDS: Rayleigh-Ritz method, Modal superposition method

The use of an orthogonal set of specially selected Ritz vectors is shown to be very effective in reducing the cost of dynamic analysis by modal superposition. Several mechanical structures are examined, and the Ritz vector approach is compared to the classical eigenvector approach on the basis of cost, accuracy and elapsed analysis (throughput) time. Mathematical proof of the completeness of orthogonal Ritz vectors is provided for the case of a positive definite mass matrix and a symmetric stiffness matrix.

86-510

The Combination of Different Type Elements Using a Lagrangian Multiplier Technique for Static and Dynamic Structural Analysis

Pwu Tsai, Wen-Hwa Chen

National Tsing Hua Univ., Hsinchu, Taiwan, Republic of China

Computers Struc., 21 (3), pp 493-500 (1985) 13 figs, 1 table, 10 refs

KEY WORDS: Lagrange equations, Combined systems, Transient analysis

This paper extends the previous applications of the combination technique of axisymmetric solid and solid elements for three dimensional stress analysis to several other types of element combinations, such as plate-solid, axisymmetric plate-axisymmetric solid and beam-plane stress elements. Without using the multipoint constraint equations or transition elements, this technique is also intended to deal with eigenvalue and transient analysis of compound realistic structures. Several numerical examples are presented. Comparisons of calculated results and the referenced solutions show the high accuracy and advantages of this technique.

86-511

Substructure Synthesis Method for Time History Response Analysis (1st Report, Error Estimation in the Method in Which Coupling Effects are Constant During Time Step)

T. Fujikawa, E. Imanishi
Kobe Steel, Ltd., Kobe, Japan
Trans. JSME No. 458 (Jan 5, 1984)

KEY WORDS: Substructuring methods

A method is proposed to estimate the magnitude of error caused by approximation of the substructure synthesis method for the time history analysis where coupling effects are assumed as constant during each time step. Its accuracy is examined through calculations with several linear vibration models which are divided into subsystems and connected by springs.

86-512
On the Subharmonic Vibrations of Order 1/2 of a Nonlinear Vibrating System with a Duffing Type Restoring Characteristic (2nd Report, Case of Soft Spring)
Y. Tsuda, J. Inoue, H. Tamura, A. Sueoka
Ohita Univ., Ohita-shi, Japan
Bull. JSME, 28 (240), pp 1204-1210 (June 1985) 5 figs, 12 refs

KEY WORDS: Subharmonic oscillations, Harmonic balance method

The subharmonic oscillations of order 1/2 of a system with a Duffing type restoring characteristic are investigated making use of a harmonic balance method, under the condition that both the periodic exciting force (an unbalancing force) and the constant force (gravity) are operative. The restoring characteristic of this system is assumed to be a soft spring.

86-513
Stability and Dynamics of Elastic Structures and Fluid Flows
E.L. Reiss
Northwestern Univ., Evanston, IL
Rept. No. AFOSR-TR-85-369, 14 pp (Mar 1985) AD-A154 188/7/GAR

KEY WORDS: Asymptotic approximation, Perturbation theory, Stability, Elastic media

The main thrust of this research program has been the development and applications of asymptotic and perturbation methods for analyzing: the stability and dynamics of inelastic structures, fluid flow, and other nonlinear problems; and for problems of scattering of acoustic, electromagnetic and other waves.

86-514
Order Reduction of Multi-time Scale Systems Using Bond Graphs, the Reciprocal System and the Singular Perturbation Method
G. Dauphin-Tanguy, P. Borne, M. Lebrun
Institut Industriel du Nord, Villeneuve d'Ascq Cedex, France
J. Franklin Inst., 319 (1/2), pp 157-171 (Jan/Feb 1985) 12 figs, 11 refs

KEY WORDS: Reduction methods, Bond graph technique, Perturbation theory

The singular perturbation method applied to multi-time scale processes enables the reduction of dimensionality by considering only one part of the system --the slow or the fast part -- depending on the frequency domain of interest. The fast and slow dynamics of bond graph models can be estimated by determination of causal loop-gains. The notion of a reciprocal system which, with singular perturbation techniques, can obtain more accuracy on the fast time scale behavior of the system is defined.

86-515
Dynamics of a Class of Repeated Systems with Non-identical Elastic and Visco-elastic Interconnections — A Bond Graph Approach
B. Samanta, A. Mukherjee
Indian Inst. of Technology, Kharagpur, India
J. Franklin Inst., 319 (5), pp 473-497 (May 1985) 13 figs, 1 table, 9 refs

KEY WORDS: Bond graph technique, Periodic structures

Dynamics of a class of repeated systems, termed here "parallel" systems, are studied. A parallel system has been defined as one consisting of identical subsystems connected in a topologically identical manner where the parameters of interconnections may not be identical and they need not be restricted to the immediate neighborhood. The governing equations for such systems are derived in state-space form using bond graph techniques. An algorithm is established to decouple these otherwise coupled system equations so that the overall system dynamics can be studied with the same computational effort necessary in analyzing a single subsystem. The procedure is illustrated by a numerical example.

86-516
A Survey of Bond Graph Modeling for Interacting Lumped and Distributed Systems

D.L. Margolis
Univ. of California, Davis, CA
J. Franklin Inst., 319 (1/2), pp 125-135 (Jan/Feb 1985) 8 figs, 28 refs

KEY WORDS: Mathematical models, Bond graph technique, Continuous parameter method, Lumped parameter method, Normal modes

Through use of normal modes, bond graphs can be used to construct perhaps the most accurate low order models for linear distributed systems. By requiring relatively few equations, when compared to finite difference and finite element models, a physically understandable model results for design and automatic control applications. These bond graph distributed models can also be directly combined with bond graph models of lumped systems or other distributed systems to yield an overall system model with all the analytical and computational advantages that bond graph modeling affords. The development of bond graph modeling applied to interacting lumped and distributed systems is surveyed.

86-517
Bond Graph Model of a Reciprocating Compressor
H. Engja
Univ. of Trondheim, Trondheim, Norway
J. Franklin Inst., 319 (1/2), pp 115-124 (Jan/Feb 1985) 9 figs, 8 refs

KEY WORDS: Mathematical models, Bond graph technique, Reciprocating compressors

Bond graph modeling techniques are used to develop a nonlinear model of a reciprocating compressor. Models are developed for different subsystems which are assembled into a final overall system bond graph. The orderly development of the governing state equations emanating from the bond graph is described. Some simulation results are included.

MODELING TECHNIQUES

86-518
Data Analysis Techniques to Support Structural Modeling
J.W. Jeter, P.H. Merritt
Hughes Aircraft Co., Albuquerque, NM
Shock Vib. Bull., #55, Part 2, pp 39-49, June 1985, 15 figs, 3 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Mathematical models, Data processing, Coherence function technique, Finite element technique

Finite element structural analysis of a complex system is generally restricted by the size of a structural model which can be realistically included in a computer analysis. The use of coherence analysis is used to attack both the problem of model complexity and the problem of input definition. The techniques utilized for simple and multiple coherence analysis are described, examples are presented, and the effects of the techniques on a practical analysis are discussed. The procedure has advantages which are applicable to most large scale applications of finite element modeling techniques.

86-519
Formula Manipulation in the Bond Graph Modelling and Simulation of Large Mechanical Systems
A.M. Bos, M.J.L. Tiernego
Twente Univ. of Technology, The Netherlands
J. Franklin Inst., 319 (1/2), pp 51-65 (Jan/Feb 1985) 13 figs, 13 refs

KEY WORDS: Bond graph technique, Mathematical models

A multibond graph element for a general single moving body is derived. A multibody system can be described as an interconnection of these elements. 3-D mechanical systems usually contain dependent inertias having both differential and integral causality. A method is described for the transformation of inertias with differential causality to an integral form, using formula manipulation. The program also helps to find experimentally the optimal choice for the generalized coordinates.

NUMERICAL METHODS

86-520
Transient Dynamic Solutions of Some Half Space Problems by the Boundary Element Method
J.M. Rice

Ph.D. Thesis, Univ. of Rhode Island, 138 pp (1984) DA8501299

KEY WORDS: Numerical methods, Boundary element technique

A numerical method to solve near field, transient, elastodynamic half space problems containing sub-surface sources and cavities has been developed. This was accomplished by developing a special Green's function which was used in conjunction with boundary integral equations to form a boundary element method. A time dependent, half space Green's function was utilized to reduce the complexity of the problem. Two numerical methods along with computer programs were constructed. This work describes many of the numerical obstacles involved in developing the method.

PARAMETER IDENTIFICATION

86-521
The Identification Matrix and Convergence of Parameters in "Off-Line" System Identification
K. Tomita, D.A. Frohrib
Univ. of Minnesota, Minneapolis, MN
Shock Vib. Bull., #53, Part 3, pp 91-98, June 1985, 8 figs, 3 tables, 10 refs (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: System identification techniques

The identification matrix characterizes the mathematical properties of a system's model in conjunction with an identification algorithm; uniqueness of obtained system parameters is guaranteed. The identification matrix is the second partial derivative of an error criterion with respect to system parameters. The matrix can be reformulated as part of the identification algorithm based on the least square identification concept. The identification matrix also relates least square identification to output distinction identifiability. Numerical examples of these roles of the identification matrix are presented.

86-522
System Identification Using a Standard Finite Element Program
J.W. Leonard, B.R. Khouri
Oregon State Univ., Corvallis, OR
Engrg. Struc., 7 (3), pp 190-197 (July 1985) 4 figs, 6 tables, 13 refs

KEY WORDS: System identification techniques, Finite element technique, Iteration, Mode shapes, Natural frequencies

Frequently, experimental results for scale models or for prototypes of structural systems do not produce mode shapes and natural frequencies which concur with analytical results for the same structure. An algorithm for an iterative identification process for improving structural models is described, which relates structural parameters to changes in system response by application of the Bayesian technique of probability and statistics. Revision of the structural parameters is made using expansions of differences between experimental and analytical mode shapes and frequencies. Since the revision is based on modification of partial stiffness and mass matrices of beam, membrane, and shell elements in the element library of a commonly available finite element program, a method is developed to calculate those partial matrices with the matrix generating subprograms of the finite element program itself.

86-523
Taylor Series Approach to System Identification, Analysis and Optimal Control
S.G. Mouroutsos, P.D. Sparis
Democritus Univ. of Thrace, Xanthi, Greece
J. Franklin Inst., 319 (3), pp 359-371 (Mar 1985) 7 refs

KEY WORDS: System identification techniques, Taylor series

The problems of system identification, analysis and optimal control have been recently studied using orthogonal functions. Solutions to these problems are derived using the Taylor series expansion. Due to the simplicity of the operational matrix of integration, the Taylor series presents considerable computational advantages compared with the other polynomial series.

86-524
AGARD Flight Test Techniques Series. Volume 2. Identification of Dynamic Systems
R.E. Maine, K.W. Iliff
AGARD, Neuilly-sur-Seine, France
Rept. No. AGARD-AG-300-VOL-2, 142 pp (Jan 1985) AD-A153 321/5/GAR

KEY WORDS: System identification techniques, Parameter identification technique

This AGARDograph is the second in AGARD's flight test technique series. It addresses the problem of estimating parameters of dynamic systems. The aim is to present the theoretical basis of system identification and parameter estimations in a manner that is complete and rigorous, yet understandable with minimum prerequisites. It concentrates in maximum likelihood and related knowledge of stochastic processes or functional analysis. No previous background in statistics is assumed. The treatment emphasizes unification of the various areas in estimation theory and practice.

COMPUTER PROGRAMS

86-525

Computer Program for Consolidation and Dynamic Response Analysis of Fluid-Saturated Media

B.L. Aboustit, R.S. Sandhu, S.J. Hong, M.S. Hireath

Ohio State Univ., Columbus, OH

Rept. No. OSURF-715107-84-5, AFOSR-TR-85-266, 122 pp (June 1983) AD-A151 922/2/GAR

KEY WORDS: Computer programs, Fluid-filled media, Soils, Finite element technique

A computer program was developed for evaluation of finite element models for soil consolidation and study of dynamic response of fluid-saturated soils. One- and two-dimensional consolidation problems were analyzed using different finite elements. Transient response of saturated porous elastic media for dynamic as well as quasi-static problems was studied. Results were compared with the numerical and analytical solutions available.

86-526

Application of the Hydraulic System Frequency Response Program to Propellant Feed Systems

B.S. DeHoff

Air Force Inst. of Tech., Wright-Patterson Air Force Base, OH

Rept. No. AFIT/GA/AA/80M-1, 194 pp (Dec 1984) AD-A151 824/0/GAR

KEY WORDS: Computer programs, Hydraulic systems, Frequency response

This thesis applies the hydraulic system frequency response (HSFR) computer program to a liquid propellant feed system analysis. During this investigation, the HSFR program was used to predict the oscillatory pressure, flow and impedance conditions existing in an experimental Saturn V first stage LOX suction duct. When necessary to model this system, additional capabilities were added to the program during this investigation. The results from the HSFR analysis are compared to previously published experimental and analytical data for this system.

86-527

Two Degree-of-Freedom Flutter Solution for a Personal Computer

D.L. Turnock

NASA Langley Res. Ctr., Hampton, VA

Rept. No. NASA-TM-86381, 43 pp (Feb 1985) N85-22379/0/GAR

KEY WORDS: Computer programs, Flutter, Personal computers

A computer programmed flutter solution has been written in the BASIC language for a personal computer. The program is for two degree-of-freedom bending torsion flutter applications and utilizes two dimensional Theodorsen aerodynamics. The aerodynamics were modified to include approximations for Mach number (compressibility) effects and aspect ratio (finite span) effects. Input options, user instructions, program listing, and a test case application are included.

86-528

Computer Generation of Physical System Differential Equations Using Bond Graphs

J.J. Granda

California State Univ., Sacramento, CA

J. Franklin Inst., 319 (1/2), pp 243-255 (Jan/Feb 1985) 10 figs, 14 refs

KEY WORDS: Bond graph technique, Computer programs

A computer aided modeling program (CAMP) is developed to process a bond graph representation of a physical engineering system into suitable source input used by digital simulation languages. The basic philosophy and fundamental principles behind the design of CAMP are presented. The preprocessed information information includes the state variable representation of the system differential equations in first-order form. The appropriate input and interface software that simulation programs require is included in CAMP.

86-529

Checking Computer Analysis of Random Vibration

R.M. Krupka, S.B. Bentley
Northrop Corp., Anaheim, CA

Mach. Des., pp 107-108 (Sept 26, 1985)

KEY WORDS: Computer programs, Error analysis, Random vibrations

Digital computers running finite-element programs are generally used to analyze multidegree-of-freedom systems subjected to random vibrations. While such programs are reliable and fast, it is not always possible to tell if the results have been skewed by an input error. To overcome this problem, a simple method has been developed to find the order of magnitude to expect in the answer.

86-530

Use of MMLE3 to Determine Lower Order Equivalent Systems in the Time Domain

R.A. Schroeder
Air Force Inst. of Tech., Wright-Patterson Air Force Base, OH

Rept. No. AFIT/GAE/AA/85M-6, 69 pp (Mar 1985) AD-A154 700/9/GAR

KEY WORDS: Aircraft, Maximum likelihood method, Computer programs, Frequency response, Time domain method

This thesis explains the data reduction technique for determining lower order equivalent system (LOES) parameters using flight test maneuver time history data. This technique uses MMLE3, a modified NASA-developed general program for maximum likelihood parameter estimation. MMLE3 requires a state-space model relating input to output and a time history of the input and the output. From this information, accurate estimates of the components of the state-space model can be made. The LOES parameters determined by MMLE3 would be aircraft short period frequency, damping ratio, and time delay. Based on simulation testing, it was determined that this data reduction technique was feasible and accurate.

GENERAL TOPICS

TUTORIALS AND REVIEWS

86-531

Dynamics R&D in the AFWAL Structures and Dynamics Division

J.J. Olsen
AFWAL/FIB, Wright-Patterson Air Force Base, OH

Shock Vib. Bull., #55, Part 1, pp 21-27, June 1985 (55th Symp. Shock Vib., Dayton, OH, Oct 22-24, 1984. Spons. SVIC, Naval Res. Lab., Washington, DC)

KEY WORDS: Dynamic structural analysis, Test facilities

This paper gives a brief overview of the recent accomplishments, current activities and plans for in-house R&D, contractual R&D and systems support in structural dynamics by the Structures and Dynamics Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories.

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TECHNICAL NOTES

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B.P. Shastry and G. Venkateswara Rao
Free Vibrations of Short Cantilever Columns Subjected to Axial Compressive Loads
J. Sound Vib., 99 (3), pp 449-451 (Apr 8, 1985) 4 tables, 6 refs

N.C. Hilyard
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J. Sound Vib., 100 (1), pp 151-153 (May 8, 1985) 2 figs, 2 refs

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J. Sound Vib., 100 (1), pp 146-148 (May 8, 1985) 2 figs, 4 refs

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Analytical and Experimental Investigation on a Vibrating Beam with Free Ends and Intermediate Supports
J. Sound Vib., 102 (4), pp 595-598 (Oct 22, 1985) 2 figs, 2 tables, 8 refs

G. Trevino
Time-Averaged Correlation for Uniformly Modulated Data
J. Sound Vib., 102 (4), pp 599-601 (Oct 22, 1985) 10 refs

Y. Kohama
Flow Structures Formed by Axisymmetric Spinning Bodies
AIAA J., 23 (9), pp 1445-1447 (Sept 1985) 4 figs, 15 refs

A. Bhimaraddi
Dynamic Response of Orthotropic, Homogeneous, and Laminated Cylindrical Shells
AIAA J., 23 (11), pp 1834-1837 (Nov 1985) 2 tables, 13 refs

CALENDAR

MARCH

5-7 Vibration Damping Workshop II [Flight Dynamics Laboratory of the Air Force Wright Aeronautical Labs.] Las Vegas, NV (Mrs. Melissa Arrajj, Administrative Chairman, Martin Marietta Denver Aerospace, P.O. Box 179, Mail Stop M0486, Denver, CO 80201 - (303) 977-8721)

24-27 Design Engineering Conference and Show [ASME] Chicago, IL (ASME)

APRIL

8-11 International Conference on Acoustics, Speech, and Signal Processing [Acoustical Society of Japan, IEEE ASSP Society, and Institute of Electronics and Communication Engineers of Japan] Tokyo, Japan (Hiroya Fujisaki, EE Department, Faculty of Engineering, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan)

13-16 American Power Conference [ASME] Chicago, IL (ASME)

29-1 9th International Symposium on Ballistics [Royal Armament Research and Development Establishment] RMCS, Shrivenham, Wiltshire, UK (Mr. N. Griffiths, OBE, Head/XT Group, RARDE, Fort Halstead, Sevenoaks, Kent TN14 7BP, England)

MAY

5-9 32nd Annual Technical Meeting of the Institute of Environmental Sciences [IES] Dallas/Ft. Worth Airport, TX (IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)

12-16 Acoustical Society of America, Spring Meeting [ASA] Cleveland, OH (ASA Hqs.)

JUNE

3-6 Symposium and Exhibit on Noise Control [Hungarian Optical, Acoustical, and Cinematographic Society; National Environmental Protection Authority of Hungary] Szeged, Hungary (Mrs. Ildiko Baba, OPAKFI, Anker koz 1, 1061 Budapest, Hungary)

8-12 Symposium on Dynamic Behavior of Composite Materials, Components and Structures [Society for Experimental Mechanics] New Orleans, LA (R.F. Gibson, Mech. Engrg. Dept., University of Idaho, Moscow, ID 83843 - (208) 885-7432)

24-26 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Las Vegas, NV (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

JULY

20-24 International Computers in Engineering Conference and Exhibition [ASME] Chicago, IL (ASME)

21-23 INTER-NOISE 86 [Institute of Noise Control Engineering] Cambridge, MA (Professor Richard H. Lyon, Chairman, INTER-NOISE 86, INTER-NOISE 86 Secretariat, MIT Special Events Office, Room 7-111, Cambridge, MA 02139)

24-31 12th International Congress on Acoustics, Toronto, Canada (12th ICA Secretariat, P.O. Box 123, Station Q, Toronto, Ontario, Canada M4T 2L7)

SEPTEMBER

14-17 International Conference on Rotordynamics [IFToMM and Japan Society of Mechanical Engineers] Tokyo, Japan (Japan Society of Mechanical Engineers, Sanshin Hokusei Bldg., 4-9, Yoyogi 2-chome, Shibuyak-ku, Tokyo, Japan)

22-25 World Congress on Computational Mechanics [International Association of Computational Mechanics] Austin, Texas (WCCM/TICOM, The University of Texas at Austin, Austin, TX 78712)

29-30 VDI Vibrations Meeting [Society of German Engineers] Wurzburg, Fed. Rep. Germany (Society of German Engineers)

OCTOBER

5-8 Design Automation Conference [ASME] Columbus, OH (ASME)

5-8 Mechanisms Conference [ASME] Columbus, OH (ASME)

7-9 2nd International Symposium on Shipboard Acoustics ISSA '86 [Institute of Applied Physics TNO] The Hague, The Netherlands (J. Buiten, Institute of Applied Physics TNO, P.O. Box 155, 2600 AD Delft, The Netherlands, Telephone: xx31 15787053, Telex: 38091 tpddt nl)

14-16 57th Shock and Vibration Symposium [Shock and Vibration Information Center] New Orleans, LA (Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375-5000 - (202) 767-2220)

19-23 Power Generation Conference [ASME] Portland, OR (ASME)

20-22 Lubrication Conference [ASME] Pittsburgh, PA (ASME)

NOVEMBER

3-6 14th Space Simulation Conference [IES, AIAA, ASTM, NASA] Baltimore, MD (Institute of Environmental Sciences, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)

30-5 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] San Francisco, CA (ASME)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA Acoustical Society of America
335 E. 45th St.
New York, NY 10017

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

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

ASME American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE Institution of Mechanical Engineers
1 Birdcage Walk, Westminster
London SW1, UK

IFToMM International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA Instrument Society of America
67 Alexander Dr.
Research Triangle Pk., NC 27709

SAE Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis)
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375-5000