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DIRECTOR NOTES

If there is a single area within the shock and vibration technology that affects all of us either directly or indirectly, it is the effect of dynamic environments on humans. Although the subject has been continuously covered in this DIGEST, in the Abstracts, and with the occasional review article, I have not previously discussed it in this column. With the current emphasis by our government on the protection of citizens against noise and vibration, it is a particularly timely subject.

By necessity, the military services have long been concerned with the adverse effects of shock and vibration on combat personnel. Much of the pioneering research in this area has therefore been accomplished by defense laboratories and this research is on the increase. In recent years with the creation of the Environmental Protection Agency, the Occupational Safety and Health Administration, and other agencies, research efforts have intensified throughout government, industrial, and academic institutions in this country and abroad. Significant progress has been made on national and international standards with respect to human response to vibration, noise, and shock.

In my opinion we have not given enough emphasis in our symposia and seminars to this important area. It is my intention to adjust our planning in the future to correct this deficiency. I would be pleased to receive comments on how this can be best accomplished.

As a separate note, I must alert our readers that the time for renewal of subscriptions for this DIGEST approaches. Regrettably, the subscription price beginning in 1978 will be increased to $60 per year. Higher costs have made this increase necessary. It is hoped that the usefulness of the periodical will continue to be worth your investment.

H.C.P.

EDITORS RATTLE SPACE

ENGINEERS IN WASHINGTON - LEGISLATION

The magazine of the American Institute of Physics, ***Physics Today***, devoted its August issue to the subject "Physicists and Washington." This is a significant topic for engineers as well. How do we as engineers influence legislation?

Not until a few years ago, when the engineering societies began to assign "Congressional Fellows" to Washington, did engineers have any influence on legislation. At first, some engineering society members were alarmed at these activities because they seemed to imply lobbying. Most technical societies and associations are of course not-for-profit corporations and thus cannot be extensively involved in lobbying. The role of the Congressional Fellow, however, has not been that of a lobbyist, rather it has been that of an educator of Congressmen.

How does education differ from lobbying? First, information is provided only after it has been asked for. Second, information on technology is aimed at informing the legislator so that he or she can make an intelligent decision about legislation or write technically adequate legislative material. In the past, much too much technically inadequate legislation has been passed by a poorly informed Congress.

The Congressional Fellow has been well received by both Congress and the engineering societies and is providing a real service to the nation.

R.L.E.

METHODS OF COMPONENT MODE SYNTHESIS

R. R. Craig, Jr.*

Abstract - A generalized substructure coupling, or component mode synthesis, procedure is described. Specific methods, applications, and such special topics as damping and experimental verification are surveyed.

The response of a complex structure to dynamic excitation is usually determined by analyzing a finite element model of the structure. The process of partitioning the structure into substructures or components that describe the physical displacements of the substructures in terms of reduced sets of generalized coordinates and the recombination of the reduced substructure models with interface compatibility equations has been called substructure coupling and component mode synthesis. Many variations of this basic procedure have been presented and are listed in this literature review.

GENERALIZED SUBSTRUCTURE COUPLING PROCEDURE

Bamford, et. al. [1] outlined the basic steps of a generalized substructure coupling procedure. Craig and Chang [2, 3] used the Lagrange multiplier technique in the more general procedure described below.

Figure 1 illustrates a cantilever beam that is partitioned into two substructures, α and β. The physical coordinates of the substructure consist of interior coordinates $\{x_i\}$ and junction (interface) coordinates $\{x_j\}$, as shown in Figure (1b). The equation of motion of a substructure is

$$\begin{bmatrix} m_{ii} & m_{ij} \\ m_{ji} & m_{jj} \end{bmatrix} \begin{Bmatrix} \ddot{x}_i \\ \ddot{x}_j \end{Bmatrix} + \begin{bmatrix} c_{ii} & c_{ij} \\ c_{ji} & c_{jj} \end{bmatrix} \begin{Bmatrix} \dot{x}_i \\ \dot{x}_j \end{Bmatrix} + \begin{bmatrix} k_{ii} & k_{ij} \\ k_{ji} & k_{jj} \end{bmatrix} \begin{Bmatrix} x_i \\ x_j \end{Bmatrix} = \begin{Bmatrix} f_i \\ f_j \end{Bmatrix} \quad (1)$$

or

$$[m]^\alpha \{\ddot{x}\}^\alpha + [c]^\alpha \{\dot{x}\}^\alpha + [k]^\alpha \{x\}^\alpha = \{f\}^\alpha$$
$$[m]^\beta \{\ddot{x}\}^\beta + [c]^\beta \{\dot{x}\}^\beta + [k]^\beta \{x\}^\beta = \{f\}^\beta \quad (2)$$

The substructure physical coordinates $\{x\}$ are represented in terms of substructure generalized coordinates $\{p\}$ so that the number of substructure coordinates can be reduced. The coordinate transformations are

$$\{x\}^\alpha = [\phi]^\alpha \{p\}^\alpha$$
$$\{x\}^\beta = [\phi]^\beta \{p\}^\beta \quad (3)$$

The ϕ-matrices contain Ritz vectors, or component modes.

Component modes can be classified as constraint modes, attachment modes, normal modes, or rigid-body modes [1-4]. Figure 1c illustrates constraint modes; attachment modes are shown in Figure 1d. Equation (3) can be written in the expanded form

$$\{x\} = [\phi_r\ \phi_c\ \phi_a\ \phi_k] \lfloor p_r\ p_c\ p_a\ p_k \rfloor^T \quad (4)$$

where $[\phi_r]$ is a set of rigid body modes, $[\phi_c]$ is a set of constraint modes, $[\phi_a]$ is a set of attachment modes, and $[\phi_k]$ is a truncated (or kept) set of elastic normal modes. The specific component modes used in particular substructure coupling methods are noted in the literature survey.

Substructure generalized mass, damping, and stiffness matrices are defined as follows:

$$[\mu] = \begin{bmatrix} [\phi^{\alpha T} m^\alpha \phi^\alpha] & 0 \\ 0 & [\phi^{\beta T} m^\beta \phi^\beta] \end{bmatrix} \quad (5)$$

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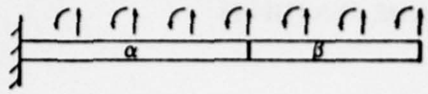
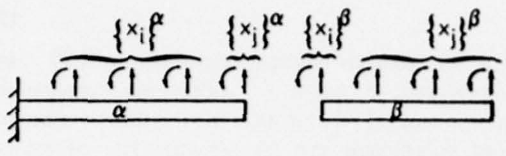
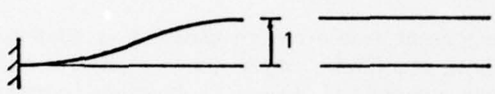


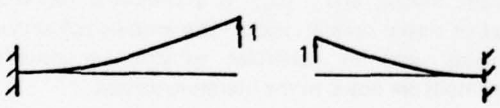
(a) Coupled Structure



(b) Substructures (Components); Substructure Physical Coordinates



(c) Constraint Modes of Substructures



(d) Attachment Modes of Substructures

Figure 1. Substructure Coupling Terminology

and similarly for the generalized damping matrix $[\xi]$ and generalized stiffness matrix $[\kappa]$. The substructure force vectors can be combined to form

$$\{f\} = \lfloor f^\alpha \ f^\beta \rfloor^T \tag{6}$$

The substructure generalized coordinates in equation (7) are not independent.

$$\{p\} = \lfloor p^\alpha \ p^\beta \rfloor^T \tag{7}$$

The interface compatibility equation

$$\{x_j\}^\alpha = \{x_j\}^\beta \tag{8}$$

must be used [1, 3], and other special constraints may also be necessary [3]. The complete set of constraint equations can be written

$$[A_{dd} \ A_{d\ell}] \lfloor p_d \ p_\ell \rfloor^T = \{0\} \tag{9}$$

Equation (9) can be solved for $\{p_d\}$ in terms of $\{p_\ell\} = \{q\}$, which is taken as the vector of independent system coordinates. Thus,

$$\{p\} = [S]\{q\} \tag{10}$$

where

$$[S] = \begin{bmatrix} -[A_{dd}]^{-1} \ [A_{d\ell}] \\ \\ [I_{\ell\ell}] \end{bmatrix} \tag{11}$$

The final equation of motion of the system is

$$[M]\{\ddot{q}\} + [C]\{\dot{q}\} + [K]\{q\} = \{F\} \tag{12}$$

where

$$\{F\} = [S]^T \{f\}$$
$$[M] = [S]^T [\mu] [S] \tag{13}$$

and similarly for [C] and [K].

SUBSTRUCTURE COUPLING METHODS

Specific substructure coupling methods are defined by the choice of component mode types used in the $[\phi]$ matrices in equation (3) and the procedure used to generate the [S] matrix in equation (10).

Some of the early methods on component mode synthesis [5, 6] are restricted to structures having statically determinate interfaces. Hurty [7, 8] developed the first method capable of analyzing structures with redundant interfaces; fixed-interface normal modes are used. The displacement of interface coordinates is related to a set of rigid body modes plus redundant constraint modes. Another method [9, 11], equivalent to Hurty's method, eliminates the necessity of treating rigid body modes separately from the other constraint modes. Fixed interface normal modes are used in addition to the constraint modes. A procedure for successive mode substitution for iterating the modes and frequencies of the system has also been described [10]. Bamford [12] developed a computer program utilizing Hurty's method and also introduced attachment modes as a means to improve convergence. Hurty [13, 14] described a perturbation analysis for estimating truncation errors and applied it to his component modes method.

A method for coupling lumped-parameter secondary structures to primary structure was described by Fourney [15]. The method is restricted and produces a determinantal system frequency equation, which is not as convenient as an algebraic eigenproblem.

Goldman [16] and Hou [17] employed free-interface normal modes but used different techniques to generate the system transformation matrix [S] in equation (10). With Hou's method equation (11) is used to generate [S]; Goldman's method involves a more complicated procedure [2]. The methods of Goldman and Hou could lead to significant error in calculating system frequencies. In addition, a possible drawback of Hurty-type methods could be the need to retain constraint coordinates equal in number to the number of interface degrees of freedom.

Benfield and Hruda [18] noted the disadvantages of the methods of Goldman and Hou and developed "branch component" methods that are generalizations of Gladwell's early work [6]. The basic requirement of branch component methods is that, if an interface of one component is fixed when its component normal modes are obtained, the corresponding interface of the attached component must be free. Benfield and Hruda [18] also considered interface stiffness and inertia loading as a generalization of Gladwell's branch modes and described four variations of the basic theme of branch modes.

MacNeal [19] described a procedure for employing hybrid component modes; i.e., modes obtained with some interface coordinates free and others fixed. He also discussed the use of statically derived modes to improve the representation.

Benfield and Hruda [18] used actual properties of attached components to obtain interface loading effects. However, Goldenberg and Shapiro [20] employed ad hoc lumped masses attached to interface nodes. The remainder of their procedure is essentially identical to that of Hou [17]. Berman [21] presented a substructure coupling method that does not involve modes of the substructures; rather the frequency-dependent response of the substructure to interface excitation is used.

In two related papers [22, 23] Dowell introduced the use of Lagrange multipliers to enforce constraints in structures represented by component modes. Only the case of undamped free vibration is discussed, and the procedure leads to a frequency equation of the form $|C_{ij}| = 0$ rather than the standard form of the algebraic eigenvalue problem. Related work on the Lagrange multiplier technique for component mode synthesis is part of Klein's thesis [24].

Klosterman and his associates [25 - 28] described modal synthesis techniques that combine analytical and experimental data for components and also provided for residual flexibility and inertia restraint. Good correlation between calculated and measured frequency response was noted.

A number of survey papers by Hurty and his coworkers appeared in 1971 and 1972. Some [29 - 31] are descriptive in nature and emphasize the various component mode types and the methods available to couple substructures. One paper [32] also provided some numerical comparisons of damping based on several component mode models.

NASA Marshall Space Flight Center sponsored a Symposium on Substructure Testing and Synthesis in 1972. Benfield, Bodley, and Morosow [33] presented a survey of substructure coupling procedures, including numerical comparisons of frequencies of a two-component truss obtained by nine substructure coupling methods. Damping papers are discussed below.

Hasselman and Hart [34] used Hurty's component mode synthesis method to study the effect of random structural properties on system modal properties.

A substructure coupling procedure involving substructures represented by free-interface normal modes connected by a flexible link (which can be viewed as a substructure described by constraint modes only) has been described [35 - 37]. The resulting hybrid method is a special case of the method discussed by MacNeal [19]. A dynamic transformation method that permits information from truncated modes to be incorporated in an approximate way has also been introduced [36, 37].

Rubin [38] described a component-modes model that employs residual flexibility to a second order of approximation. He suggested that the model would be useful in substructure coupling problems, but examples dealt only with a single component. The coupling of substructures represented by Rubin's component-modes model has been discussed [39 - 41] and numerical examples given. Craig and Chang [40] described three methods for reducing the number of interface coordinates required by Hurty-type fixed-interface coupling methods. Later, Craig and Chang [2, 3] showed that Rubin's component-modes model could be derived with a generalized substructure coupling method based on the Lagrange multiplier technique.

As noted previously, Hintz [4] provided good descriptions of all of the modes used in component mode synthesis. He also stressed the importance of using statically complete sets of modes, thereby emphasizing the importance of inertia relief modes.

SYNTHESIS OF DAMPED SYSTEMS; EXPERIMENTAL VERIFICATION OF COMPONENT MODE MODELS

Most of the references cited above deal with the determination of modes and frequencies of the system; i.e., with the undamped free-vibration problem. A few analytical studies concerning the representation of damping in component mode synthesis have also been conducted. In some cases experimental and analytical results have been compared. Klosterman and his co-workers [25 - 28] incorporated damping and used experimentally-determined component data to determine frequency responses of the system.

Kana and his co-workers [42 - 45] postulated a relationship between damping energy and peak kinetic energy and described a method for combining substructure damping energies. Results of experiments on early Shuttle models were correlated with the analysis. Three methods for developing proportional substructure damping matrices from test data and several alternatives for determining system damping have also been described [32, 46]. An error in one of the methods (CMII) invalidates some of the conclusions of the study.

Hasselman [47, 48] used both diagonal and off-diagonal damping terms to develop system damping matrices that involve various substructure coupling procedures. Experimental data obtained from an early Shuttle model at NASA Langley Research Center was used to compare predicted and measured modal properties of the system.

In an extension of earlier work on undamped systems [22 - 24] Klein and Dowell [49] used the Lagrange multiplier technique to couple damped substructures. The characteristic equation was obtained from a determinant whose coefficients are complex numbers obtained from substructure data.

COMPUTATIONAL ASPECTS OF COMPONENT MODE SYNTHESIS

With the possible exception of work currently in progress to incorporate substructure coupling for dynamic analysis into NASTRAN, little appears to have been done to date to incorporate this capability directly into finite element programs. Solutions have been obtained by combining structural analysis, eigensolution, and matrix manipulation using one or more suitable computer programs. Giescke [50], for example, describes NASTRAN coding that affects substructure coupling for transient analysis of nonlinear systems.

One computational aspect of component mode synthesis has received considerable attention: convergence and the related topic of mode selection. Hurty [13, 14, 30] developed a first-order perturbation technique for assessing the approximate contribution of truncated modes to system frequencies obtained by his method [8] of component mode synthesis. Bajan et. al. [10, 11] described similar procedures. Morosow and Abbott [51] derived an expression for determining the modal participation factors, or weighting factors, to assess which component modes should be included. Hasselman and Hart [52, 53] employed a minimization method for selecting modal coordinates.

When constraint modes and fixed-interface normal modes are used in component mode synthesis [8-10], the final set of system coordinates contains all of the interface coordinates plus the retained normal mode coordinates. Craig and Chang [54, 40] described procedures for reducing the number of interface coordinates, for estimating error, and selecting coordinates.

Although component mode synthesis appears in the title of a paper by Thomson and Fernandez-Sainz [55], only assumed modes are used; they are neither static nor dynamic component modes of the type used in all other component mode synthesis methods covered in this review. The significance of this paper is uncertain because of the type of component modes used, the specific functional forms chosen as assumed modes, and the treatment of interface constraint conditions.

Klosterman [56] examined the particular problems that arise when two substructures are coupled with a weak, or stiff, coupling element or when a weak substructure is coupled to a stiff substructure. He considered the implications for mode survey testing.

APPLICATIONS

Component mode synthesis has frequently been used in the dynamic analysis of specific structures. Studies of this type have been reported [1, 51, 57 - 65]. Undoubtedly, many more have been done.

CONCLUSIONS

During the past 15 years methods of component mode synthesis have been extensively developed and applied to the determination of modes and frequencies of complex structures. Several of these methods are currently being incorporated into general-purpose finite element codes. Topics that require further research include damping synthesis and the use of experimental data to formulate or verify component mode synthesis mathematical models.

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

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

This issue of the DIGEST contains review articles on dynamic modeling of pressure vessels and piping systems by R. H. Prause and flow-induced vibrations of cylindrical structures by S. S. Chen.

Mr. Prause reviews dynamic modeling of pressure vessels and piping systems. Dr. Chen's article is concerned with cross-flow induced vibration in circular cylindrical structures.

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DYNAMIC MODELING OF PRESSURE VESSELS AND PIPING SYSTEMS

R.H. Prause*

Abstract - This paper reviews dynamic modeling of pressure vessels and piping systems. It is intended to provide a background for identifying current problems and limitations. Recommendations and expected benefits from future research are included. The bibliography provides sources pertaining to specific modeling topics.

Accurate prediction of the dynamic response of pressure vessels, piping systems, and their support and restraint structures has become increasingly important because of public safety requirements for nuclear power generating plants. Pressure components must be able to withstand normal operating loads due to pressure, thermal cycles, and pressure transients as well as loads resulting from various natural phenomena -- earthquakes and tornadoes, for example -- and such accidents as instantaneous pipe breaks. The complexity of pressure vessels and piping systems and the possible disastrous consequences of their failure require care in designs for dynamic loading. Accurate dynamic models and reasonable predictions of response comprise a major part of the design process.

General-purpose finite element computer programs are the foundation for dynamic analysis. The most widely used general-purpose programs include NASTRAN, ANSYS, MARC, STARDYNE, SAP, SAGS, and WECAN. More specialized programs for piping systems are ADLPIPE, NUPIPE, PIPDYNE, PIPERUP, and PIPESD.

Descriptions and comparisons of these programs are available. A comprehensive set of survey papers published in 1974 [1] includes reviews of developments with pre- and post-processors and computer graphics and of trends in computer hardware and software. Problems having to do with program documentation, validation, and dissemination are also discussed. A more recent review of shock and vibration computer programs [2] contains a summary of techniques for particular problems as well as information about general-purpose programs. Both reviews contain sections on the analysis of shell structures and piping systems; the reviews supplement and update the evaluation of computer programs on design and analysis of pressure vessels and piping published by ASME [3].

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FORMULATION OF A MODEL

The dynamic response of a structure is predicted from a mathematical model. The model can be a one or two lumped-mass system or a finite element model of a complex pressure vessel. Differential equations of motion that describe the dynamic response of the model can usually be expressed in matrix form by

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F(t)\} \qquad (1)$$

where [M], [C], and [K] are the mass, damping, and stiffness matrices respectively; $\{F(t)\}$ is the force vector; and $\{x\}$ is the displacement vector describing the dynamic response. The relative difficulty of developing the [M], [C], and [K] matrices depends on the complexity of the structure. Much of the recent research on dynamic analysis has been directed toward assembling these matrices and calculating dynamic response for large structures having many degrees of freedom.

Most of the computer programs for the dynamic analysis of large structures, pressure vessels, or piping systems are based on the finite element models. Cost-effective analysis, a major factor in today's engineering projects, has generated interest in procedures for reducing problem size. A collection of papers published by ASME [4] reviews recent developments in formulating models for large structures by synthesis, or substructuring. Included are modal synthesis [5], the use of admittance and impedance concepts [6], and inductive methods [7, 8]. Historical development is reviewed, and current theory is assessed. Other papers [4] illustrate computer applications for large systems.

All of the various methods of synthesis involve assembling a large structure from a set of connected components, or substructures. The dynamic characteristics of each substructure are evaluated independently to determine displacements; generalized coordinates at selected interior points and at connection points are used. Displacement compatibility requirements at the connection points are used to formulate (synthesize) the equations of motion for the complete structure. The detailed responses of interior points of substructures can be obtained from the connection point forces of the complete structure.

The principal objectives of the various synthesis methods are:

- to reduce computer time and storage requirements by reducing the number of degrees of freedom required for large structures. Judicious selection of a subset of component modes can give accurate predictions for the complete structure. The reduction in computer time also reduces the risk of computer system failure during execution of a large structural analysis.
- to permit efficient utilization of substructure modes in a composite structural system so that the components can be designed by different engineering groups. The effect of modification of individual components can often be evaluated without using the entire structural model.
- to encourage detailed testing of components for early verification of substructure models. Such testing can reduce the need for testing the complete structure.
- to allow the efficient use of "super-elements." Super-elements are used to describe the stiffness characteristics of a complex, local section of a structure that would require excessive detail in a finite element model. The super-element is treated the same as a substructure.

The analytical techniques -- general-purpose digital computer programs -- for the dynamic analysis of large, complex structures are relatively well developed. Techniques for substructuring are being used successfully, although much work remains to be done on automating them for use with the most popular general purpose computer programs. Automation includes the efficient selection of a limited number of modes for each subsystem. A dynamic model should be adequate for a specified frequency range of excitation so that only the modes (or grid points) needed for an acceptable analytical solution are calculated. If the advantages of the dynamic-substructure technique are indeed real, software developers and suppliers should be encouraged to include this capability in their programs. If the advantages are not obvious, research is needed to demonstrate the advantages and to encourage software developers to make the necessary investment.

Dynamic modeling requires considerable engineering judgment for effective use of most of the sophisticated programs. The generation of detailed mass, stiffness, and damping matrices from engineering drawings is the principal task in model formulation.

Mass Matrix

Many finite element codes include two types of mass matrices, lumped and consistent. Lumped mass matrices are developed by concentrating the mass of the structure at the grid points used to define the translational and rotational degrees of freedom. The lumped mass matrix is diagonal; there is thus no inertial coupling between grid points. The development of consistent mass matrices [9] is the same as that of a stiffness matrix for a particular element; a consistent mass matrix is symmetric and nondiagonal and produces inertial coupling between adjacent grid points.

A review of mass matrix formulations [10] indicates that the best choice depends on the particular problem. Consistent mass matrices may give more accurate natural frequencies than a diagonal mass matrix but sometimes produce less accurate stress results at a greater cost. Clough [11] states that the increased complexity of the consistent mass matrix may not be justified unless the accuracy of the stiffness matrix is increased. These arguments suggest that more analytical formulations for the distribution of the mass of a structure are available than can be effectively applied to a specific structure.

Stiffness Matrix

Computer programs used for finite element analysis typcially include an extensive library of elements for formulating the stiffness matrix of a structure. General-purpose programs contain a variety of beam, rod, plate, and shell elements, and two-dimensional- and three-dimensional-solid elements for 1-, 2-, or

3-dimensional models. Special-purpose programs for piping systems [12] include special elements for tapered pipes, elbows, tees, and pipe restraints. These are the same as super-elements and represent a substructure of the system that would require excessive modeling by individual elements for adequate accuracy. Pipe elbows, for example, are represented by flexibility and stress intensification factors that relate deflections and stresses in an elbow to those of a straight pipe having the same loads. The flexibility factor is included in the stiffness matrix for the elbow. This approach gives reasonably accurate results for most linearly elastic problems. However, different techniques [13-15] are required for elastic-plastic and large deformation analysis.

The special elements developed for piping analysis illustrate one of the major difficulties in developing the stiffness matrix for a particular structure. Finite elements are available for modeling basic structural sections consisting of uniform shells, plates, and beams. However, such local areas in a structure as bolted or welded joints and reinforcements do not resemble the basic structural section. An accurate stiffness model requires considerable judgment or the use of a very detailed finite element model. Unfortunately, modeling errors at local discontinuities can seriously affect the adequacy of the final design. In addition, after the structure has been built, opportunities for sufficient tests needed to improve the models are rare.

Because analytic techniques are now relatively advanced, future research should be directed toward refining the modeling process and expanding the number of super-elements for structural joints. Experience with such components as piping elbows indicates that identification of inadequacies in current modeling techniques will require analysis and testing as well as careful correlation of test and analytic results for complex structures.

Damping Matrix

The dissipation of energy due to damping, hysteresis, or some other mechanism is one of the most important and least understood parameters affecting the dynamic response of a structure to a transient disturbance. Structural stiffness must be known accurately for both static and dynamic analysis, but damping is needed only for dynamic response analysis. This may partially explain the relatively low priority which has been assigned to research on damping mechanisms and modeling. In most practical dynamic analyses, damping is assumed to be the viscous type indicated in equation (1). This choice is made for mathematical convenience rather than for physical reasons; however, elements incorporating hysteretic, or material, damping or Coulomb (friction) damping are available in some finite element computer programs. The various damping mechanisms have been reviewed recently [16] for both single and multi-degree-of-freedom systems.

The damping matrix for a dynamic model is usually assumed to be proportional to the mass and/or stiffness matrices in the form

$$[C] = \alpha[M] + \beta[K] \tag{2}$$

This is known as proportional damping. The mathematical advantage of this formulation is that the constants α and β can be selected arbitrarily for any particular problem, and [C] can be diagonalized (uncoupled) by the normal modes from the undamped system; conventional normal mode solutions can thus be utilized.

If the damping matrix [C] is nonproportional, the equations of motion will not be diagonalized by the undamped normal modes and different, more complex solutions are required. Damping for most structures is relatively small, however; the simplest of several engineering approximations discussed by Nelson and Greif [16] for dealing with the nonproportional damping matrix is to ignore any off-diagonal coupling terms in the transformed matrix $[\varphi^T]$ $[C]$ $[\varphi]$, where $[\varphi]$ is the matrix of undamped mode shapes, and to proceed as usual with a normal mode solution. Damping is usually included in this way in the spectral techniques frequently used for seismic response analyses. An alternative is to use direct numerical integration of the original equations of motion as is usually done for nonlinear problems. Disadvantages include relatively higher costs and a loss of information about mode shapes and natural frequencies of the system.

Evaluation of the various mathematical formulations for including damping in a dynamic model is difficult because so little is known about the damping of an actual structure. Guidelines for assumed modal damping parameters are used (see in the Table). Additional damping data from nuclear power plant tests have been summarized [34, 35].

Table. Damping Values Recommended by the Nuclear Regulatory Commission for Seismic Design of Nuclear Power Plants [30]

Structures or Components	Operating Basis Earthquake or 1/2 Safe Shutdown Earthquake[b]	Safe Shutdown Earthquake
Equipment and large-diameter piping systems,[c] pipe diameter greater than 12 in.	2[d]	3[d]
Small-diameter piping systems, diameter equal to or less than 12 in.	1	2
Welded steel structures	2	4
Bolted steel structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

a table derived from recommendations given in Reference 35
b in the dynamic analysis of active components as defined in Regulatory Guide 1.48, these values should also be used for SSE
c includes both material and structural damping. If the piping system consists of only one or two spans with little structural damping, use values small-diameter piping
d as percent of critical damping

That the capability for accurately modeling the damping of a structure is less advanced technically than is that for developing the mass and stiffness parameters suggests topics for future research:

- development of techniques to identify and correlate the damping mechanisms in full-size structures and refinement of analytical models for future use
- an extensive program of laboratory tests to develop a handbook of damping values for a variety of typical structural elements
- development of effective approaches for including the damping and mass of fluids in pressure vessels and components

RESPONSE ANALYSIS FOR LINEAR SYSTEMS

The discussion of general techniques for formulating dynamic models did not differentiate between linear and nonlinear models. The most significant differences usually occur in the stiffness matrix [K]: for linear elastic analysis [K] is symmetric and sparse; for nonlinear analysis the terms in the stiffness matrix may be amplitude dependent. The differences require substantially different analytical procedures.

The important techniques for conducting a transient response analysis of a linear elastic system include direct integration and mode superposition. Various substructuring and condensation techniques -- first developed to reduce the dynamic degrees of freedom for a large structure -- can be used to reduce the storage requirements and computer time required for either method.

Direct integration methods utilize a step-by-step numerical integration of the coupled equations of motion. Nonproportional damping matrices and nonlinear material behavior and large deformations and strains can be included with no difficulty. The capability of including impacts and the effect of gaps in structural restraints are important for evaluating pipe whip and missile impact problems. Finite element programs now in use usually include one or more time integration algorithms such as Newmark's β-method [18], Wilson's θ-method [19], or Houbolt's method [20]. These mathematical procedures allow for various trade-offs between step size and stability; no single method is best for all problems. The relative accuracy of these and other methods has been evaluated [21, 22]. A detailed review and extensive bibliography of recent literature on solution techniques is included in Reference 23.

The modal superposition technique, as usually known, is restricted to linear systems. The eigenvalues (natural frequencies) and eigenvectors (mode shapes) of the undamped system are used to uncouple the equations of motion; the result is an independent, second-order differential equation for the dynamic response of each mode. The advantage of the modal superposition technique is that the dynamic response of most structures subjected to excitation from earthquakes, wave action, wind loads, and rotating machinery -- all of which excite only a few of the lowest structural natural frequencies -- can be accurately predicted by superimposing the transient response of fewer modes that the number of degrees of freedom for the analytical model of original system. Therefore, even though the same integration algorithm might be used for both the direct integration and mode superposition methods, the reduced number of equations and generally larger step sizes (lower frequency content) mean that the mode superposition method offers a significant economic advantage for large structures. The initial calculations of the natural frequencies and mode shapes also provide valuable insight into the dynamic characteristics of the structure that is not available with the direct integration method.

RESPONSE ANALYSIS FOR NONLINEAR SYSTEMS

Techniques for the dynamic analysis of nonlinear structural systems are available, but they are more expensive to run and are not as well developed as those for linear analysis. They are valuable in the evaluation of pipe whip problems, however, in which the nonlinear characteristics of pipe restraints and nonlinear material behavior of the piping system are important considerations. Less conservative designs of many pressure components that must withstand seismic loads might result from nonlinear analysis techniques that permit inelastic response. Considerable advancement in nonlinear analysis techniques and in understanding nonlinear behavior of materials and structures loaded above elastic limits will be necessary before the techniques can be considered practical.

Nonlinear response analysis is usually based on direct integration methods. The stiffness matrix for devices such as nonlinear springs or pipe restraints with gaps is modified as a function of selected displacement coordinates. Elastic-plastic material properties in finite element codes require a yield condition, a flow rule, and a hardening rule. Dynamic analysis requires the use of incremental theory to separate elastic and plastic strain components. Strain rate effects may become important, but they have not yet been incorporated in most computer programs. Judicious selction of stress-strain data for the appropriate strain-rate regime would allow approximations of the effects. The dynamic analysis of piping systems and structures with large deformations and strains can be handled by several available computer programs. The solution is obtained by an incremental procedure [24] that is combined with the step-by-step direct time integration discussed above [25-27].

Damping must be included in a nonlinear analysis either in a force-deformation relationship [28,29] or as a specific full damping matrix [C]. Both are complicated by the fact that most damping measurements give modal damping, which is difficult to use in developing a full damping matrix for a structure. Some research on this is now underway but more is needed.

The complexity of nonlinearities requires that an experienced engineer carry out dynamic response analysis. The choice of time step is influenced by the incremental loads, deformations, and the resulting elastic and plastic strain components. The usual effects of the natural frequencies of the structure and frequency content of the loading are also important, as they are in linear analysis. Considerable research is needed on these effects and on the time-dependent material properties that make a nonlinear dynamic analysis different from a nonlinear static analysis.

Test data often reveal that the response of a structure is significantly influenced by nonlinearities. Relatively little work has been done on identifying models for the physical behavior or parameters for a nonlinear model, however. Nonlinear effects can be of great importance in predicting structural response to high-level earthquake excitation. Some testing at San Onofre [31, 32] involved the identification of parameters for pre-established analytical models, but, no one has reported using test data to completely formulate the dynamic model of a pressure vessel system. What is required is a unified program of pre-analysis, detailed testing, and post-analysis of a structure with identification and improvement of the model as a major objective. The procedure selected for correlating analysis and test results will have a major influence on the test program and must therfore be included in the program plan.

TOPICS FOR FUTURE RESEARCH

Mathematical techniques and finite element computer programs for conducting dynamic analysis of large, complex structures are relatively well developed. However, the modeling and subsequent analysis of specific structures still requires considerable engineering judgment and many assumptions and approximations that can be critical to the validity of the results. One major obstacle to improving modeling techniques is the difficulty of correlating test data with detailed mass, stiffness, and damping matrices for a complex structure. This process, classified as "parameter identification," represents an effort to formalize and improve older methods for matching experimental and analytical results so as to make them compatible with computer-oriented models. The impetus for adopting a more organized approach is the potential for increasing the useful information from limited quantities of test data. In addition, improved utilization of test data could reduce costs for test programs while providing increased knowledge about accurate modeling and performance of specific types of structures.

Major research topics suggested as a result of this review are summarized as follows:

- expansion of the collection of special finite elements used as stiffness matrices for such structural details as bolted and welded joints, mitred joints, and shell/nozzle intersections.
- development of a handbook of damping values for a variety of typical structural elements and materials to aid in the formulation of detailed damping matrices. The nature of the predominant energy dissipation mechanism (e.g., friction, hysteretic, viscous, impact) must be identified for each typical pressure system component.
- development of improved parameter and system identification techniques for correlating test data and analytical results would improve finite element models and allow identification of specific structural elements requiring more- or less-detailed modeling or test data. The evaluation of nonlinear dynamic models is expected to become an increasingly important subject in the design of future pressure components. Test data from nuclear power plants should be collected and evaluated in formulations of improved dynamic models. Additional test programs having pre-established parameter and system identification objectives should be encouraged and supported.

techniques for including the effects of fluids in dynamic analysis of pressure components should be evaluated, as should the relative accuracy of simplified models, by comparing analytical predictions with measured data from controlled experiments.

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FLOW-INDUCED VIBRATIONS OF CIRCULAR CYLINDRICAL STRUCTURES
PART II: CROSS-FLOW CONSIDERATIONS

S.-S. Chen*

Abstract - The objective of this paper is to review the state-of-the-art of flow-induced vibration of circular cylindrical structures and to indicate areas that need further work. Both parallel and cross flow problems are considered. Part I of the review contains a general discussion of analytical methods, classification of structural responses, and characteristics of the vibration of cylinders in stationary fluid and parallel flow. Part II considers cross-flow-induced vibration, design, and research needs.

CROSS-FLOW-INDUCED VIBRATION

The various types of fluid excitations of cylinders in cross flow are not yet well enough understood to allow prediction of all vibration problems at the design stage or identification of the precise mechanism that causes system failure because of so-called cross-flow-induced vibration. However, experience and results of basic research have been helpful in understanding some of the most important mechanisms. The following discussion describes these mechanisms -- vortex-excited oscillation, fluidelastic instability, turbulence, and acoustic excitation -- and analytical/experimental results associated with them.

Vortex-Excited Oscillation

Vortex-induced vibration of cylinders has attracted the attention of investigators for many years. Concise histories have been published [3, 185].** Vortex shedding can excite cylinder vibration in the lift direction when the frequency approaches the natural frequency of the cylinder. The vortex shedding behind a stationary cylinder can be described by the Strouhal number, fD/V (D = cylinder diameter, V = flow velocity, and f = vortex shedding frequency). This number is equal to 0.2 for a single cylinder in the Reynolds number range $10^3 < Re < 2 \times 10^5$. A flexible cylinder can modify the vortex shedding process; i.e., vortex shedding tends to synchronize with the cylinder oscillation [34, 186-194]. Experiments have shown that the lock-in region occurs at values of V_r (=V/fD) near 5. The behavior outside the lock-in region is characterized by random vibration. Various models have been proposed to predict the amplitude of cylinder oscillation as a function of flow parameters. In the two basic models, the self-excited oscillation model and the forced vibration model, the entire influence of the flow is regarded as an integral force effect. The interaction between the fluid and the oscillation is taken into account by making the force dependent on the amplitude of vibration.

Self-excited oscillation model. Experimental observations enabled Bishop and Hassan [195] to point out the nature of self-excited vortex shedding and to suggest that the fluid behavior might be modeled by a simple nonlinear oscillator. These conclusions were pursued by Hartlen and Currie [34], who devised a model in which the lift coefficient satisfies a Van der Pol-type equation. The model, which has recently been refined [191-193], has successfully predicted the experimental characteristics of an elastically mounted cylinder and the lift force on an externally driven cylinder.

Funakawa [187] and Nakamur [188] also treated vortex excitation of cylinders in a uniform flow as a self-excited oscillation. They used Birkhoff's oscillator model for the added fluid region behind the cylinder and showed that flutter is possible in a limited range of flow velocity -- including the value at which the vortex shedding frequency for the cylinder coincides with the natural frequency of the cylinder.

Other self-excited models are those by Halle [190] and Di Silvio [194]. Halle proposed an oscillator model in which the fluid behavior is described by a second mechanical oscillator. The second oscillator is coupled to the cylinder by an equivalent viscous damping force proportional to the relative velocity of the fluid oscillator and the cylinder. Di Silvio [194] used the concept of a variable vortex-wake width that is dependent on cylinder amplitude and vortex-origin time. His self-excited model is able to reproduce

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**References 1 to 184 are listed in Part I a certain narrowing of the wake and agrees well with experimental results.

All of the approaches are similar in that model parameters are chosen on the basis of experimental observations or assumptions. The nonlinear model first proposed by Hartlen and Currie [34] has shown considerable promise and is widely used. The model proposed by Di Silvio [194] explains the physical meaning of the wake width with regard to both the frequency and the amplitude of the alternative driving force.

Forced vibration model. With the forced vibration model the vortex force is taken as the excitation. The amplitude of the oscillatory fluid force is expressed in terms of a force coefficient and the dynamic pressure. The problem is solved as a forced vibration problem of a single degree of freedom [196-199]. The finite correlation length and random nature of the fluid force on a cylinder have been considered in some detail [199]. The problem has thus been treated either as a deterministic problem or analyzed using random vibration theory.

In addition to the transverse oscillation in the lift direction, drag force in a dense fluid can also induce oscillations of the cylinder in the streamwise direction. Vibrations of cylinders in the flow direction have been observed for single cylinders [200, 201] and multiple cylinders [202, 203]. If cylinders in a light fluid are given a relatively large motion in the flow direction, oscillations in the flow direction can synchronize with vortex shedding; this oscillation has been demonstrated [204] for a single tube in a wind tunnel.

Vortex shedding for flow across cylinder arrays is complicated by the fact that the Strouhal number is no longer a constant; rather, it varies with the arrangement and spacing of the cylinders. Extensive studies have been made to measure the Strouhal number [14]; experimental results have been summarized [15]. If the Strouhal number is known, the vortex shedding theory can be used to predict the flow velocity at which resonance occurs. However, little detailed information has been published on the velocity range over which "lock-in" occurs, on the orbital paths of the cylinder motions, or on the amplitude of cylinder displacements. An important assumption of this theory -- that vortex shedding exists within cylinder arrays -- is questionable.

Fluidelastic Instability

The fluidelastic mechanism of cylinder arrays subjected to cross flow was first recognized in 1970 [16]. The instability is a classical flutter phenomenon extensively studied by the aerospace industry. The essential parameters associated with fluidelastic instability are system damping and fluidelastic forces. When flow velocity increases to a certain value, the work done on the cylinder array by fluidelastic forces exceeds the energy dissipated by damping. As a result, large-amplitude oscillations occur. Wind tunnel tests of cylinder oscillations and determinations of fluidelastic coefficients were used to develop a simple instability criterion for cross-flow-induced instability of cylinder arrays. The motion of a single cylinder in a cylinder array was analyzed; the threshold flow velocity is represented by equation (5).

$$\frac{V}{fD} = k\left(\frac{2\pi M\zeta}{\rho D}\right)^n \qquad (5)$$

M = total mass, including cylinder mass and added mass; ρ = fluid density; f = cylinder natural frequency; D = cylinder diameter; ζ = modal damping ratio; V = flow velocity, and n = 0.5 [16]. The instability has also been studied experimentally by the varying cylinder arrangements in order to determine the constant k [205-210]. Some of the experimental data have been assembled by Shin and Wambsganss [10]. The constant k depends on many parameters, including arrangement of cylinders, cylinder/fluid mass ratio, structural and fluid dynamic damping, fluid-elastic coupling, and natural frequencies of individual cylinders. Mathematical models have been developed to correlate the experimental data. Blevins [211, 212] proposed a mathematical model with fluidelastic coupling for cylinder-arrays consisting of identical cylinders. Critical flow velocity can be calculated if a mode is assumed. Chen [29, 213] has recently developed a model that includes fluid inertia coupling, fluid dynamic damping, fluidelastic forces, and other excitations. The model can be used to predict the response of cylinder arrays subjected to multiple excitations. The analytical results agree with existing experimental results.

Turbulence

Turbulent buffeting, or inflow turbulence, can induce cylinder vibration. In cylinder arrays boundary layers separate on a massive scale, and turbulence levels can be high. In addition, turbulent pressure fluctuations and other flow noises also exist in a flow loop; the magnitudes of the noises are likely to be system dependent. In general, fluid forces associated with turbulence are random. The greatest force is often associated with eddies the size of which are related in a simple way to the cylinder spacing and/or cylinder diameter. Cylinders subjected to random excitations respond primarily at the natural frequencies of the system. Numerous papers have been written on turbulence-induced cylinder vibration [e.g., 14, 18, 19, 198]. Owen [18], in an almost completely theoretical approach to the problem, disregarded any theory of a superposed regular pattern of excitations.

Theoretically, if the turbulence spectrum and spatial correlations in a cylinder array are known and if structural oscillations do not affect the fluid pressure field, cylinder responses can be calculated [67]. Very little work has been published on the level of turbulence with a cylinder array or its spectral distribution and scale for cylinder arrays, however. A systematic study on turbulence in a cylinder array is needed before the response of cylinder array to turbulence can be predicted.

Acoustic Excitation

Acoustic excitation can cause cylinder vibration normal to the flow direction and to the cylinder axis. In a rectangular flow duct, for example, the transverse acoustic oscillation of the lowest frequency has a wave-length equal to twice the duct width. If the natural frequency of vortex shedding is close to an acoustic natural frequency, the flow field and acoustic field couple and reinforce each other. As a result, large oscillations of the fluid occur. The worst case occurs when the acoustic natural frequency, vortex shedding frequency, and cylinder natural frequency are the same [21-23, 214]. Two methods can be used to predict acoustically-induced vibration problems. One is to match the acoustic natural frequency and the vortex shedding frequency. Barrington [215] has suggested that, if the vortex shedding frequency is within 20% of the acoustic frequency, an acoustic vibration problem is probable. The second approach is to impose an additional requirement. For example, Grotz and Arnold [22] stated that the ratio of wavelength of noise generated to the width of the free passage for the wave has to be less than 120 to generate coupled acoustic-aerodynamic oscillations in in-line cylinder arrays.

Acoustically-excited oscillations are important in large heat exchangers with gas flow. In liquid flow, acoustic natural frequencies are generally higher than the vortex frequency, and are thus not a problem. Nevertheless, studies have been made to assess the significance of acoustically-induced vibration in nuclear reactor cores [216]. The main concern is the effect of vibration caused by the pump on the various structural components in the reactor.

Several other excitation mechanisms also have been considered: jet switching [20], structure-borne noises, and flow pulsations. In some cases, those excitations may be important. However, it is believed that, in most cases, the four mechanisms described in this section are the most important ones.

DESIGN CONSIDERATIONS

From a practical point of view, the designer needs either a simple procedure that will assure that the design life of a structure will not be affected by flow-induced vibration or a simple method that can be adapted to vibration problems in a unit already in operation. Because of the complexity of the problem, no single solution will solve "all" vibration problems. But three methods are used to eliminate detrimental vibration: (1) modification of the structural system -- such that it is less susceptible to vibration; (2) modification of the flow field so that fluid excitation forces are eliminated or their characteristics modified; (3) modification of both the fluid field and structural system to reduce the vibration to a tolerable level.

For a known excitation mechanism such as vortex-induced vibration of a single cylinder, the first method can be used; that is, support parameters, stiffness, or damping can be changed in such a way that vibration will not be detrimental. The damper, for example, has been successfully used to alleviate wind-induced oscillations [217]. If the structure cannot be modified, the second method, modification of the fluid field, can sometimes be used. A thin splitter plate [218, 219] is useful for a fixed flow direction, helical strakes [220] and surface modification [221] are effective when the flow direction may change.

Acoustically-induced vibration in cylinder arrays can be suppressed in various ways. De-resonating baffles placed along the flow stream between cylinders have been used for a single-mode acoustic resonance [222, 223]. Grotz and Arnold [22] have fitted diagonal baffles to avoid the possibility of resonance with higher acoustic modes. For closely-spaced cylinder arrays, removal of certain cylinders changes the acoustic natural frequencies and reduces cylinder-fluid coupling. Walker and Reising [21] obtained the best results by removing cylinders longitudinally in the center of the cylinder array and in the transverse direction at positions that could be pressure nodes of the acoustic standing wave. Zdravkovich and Nuttall [224] also studied the effect of removing various cylinders and found that acoustic resonance can be eliminated by unequal longitudinal pitches in two successive rows.

Other methods can be used for cylinder-array vibrations caused by sources other than acoustic excitation. Zdravkovich [225] found that the axial-rod shroud is effective in suppressing vibrations of the tandem cylinder arrangement. Cylinder-array flutter usually involves the cylinders at the inlet region. Mirza and Gorman [226] suggested arranging a set of rigid "prison-bar" type cylinders at the bundle entrance or providing additional support at the inlet region to control flutter. Detuning of the cylinders has also been effective [29, 209]. Funakawa [227] used sprocket chains inserted between the cylinders and vertically tensioned with weights to control vibration in a steam raising unit. Eilers and Small [228] applied an elliptical bundle inserted in cylinder array to alleviate vibrations in a reboiler. All of these methods involve structural modification. Brown [229], however, successfully used a perforated grid to reduce the low frequency energy of turbulence.

FUTURE RESEARCH NEEDS

One major difficulty in solving flow-induced vibration problems is characterizing the fluid forces. The properties of near- and far-field flow noises, which exist in the absence of cylinder motion, must be known before cylinder response can be predicted. Extensive experimental programs are required to obtain the necessary information: the characteristics of flow noises in the cylinder array; the way in which these properties vary with Reynolds number, cylinder position, and other parameters; and the effect of upstream turbulence and nonuniform incident flow. In addition, because most flows are neither transverse nor parallel to cylinders, the value of using the independence principle to resolve flow velocity into transverse and parallel components must be assessed. Whether or not vortex shedding occurs within the cylinder array must be determined, as must its dependence upon parameters. Some efforts have been made [27, 143, 230, 231] to obtain this information, but many more studies are needed.

In addition to flow noises are other motion dependent forces; e.g., fluid inertia force, fluid damping force, and fluidelastic force. These forces play an important role in structural responses. For a simple case such as a single cylinder subjected to a uniform cross flow, these forces can be characterized if the motion is small. However, if the cylinder undergoes relatively large oscillations, these forces are difficult to characterize. Even more complicated are the forces in a cylinder array. A systematic experimental/analytical study [28, 69] has been made to obtain fluid inertia coupling, but no experimental data exist for fluid damping and fluidelastic force in cylinder arrays.

Analytical prediction methods are available but they need improvement. Consider two typical models: parallel-induced vibration and fluidelastic instability of cylinder arrays. All existing models for parallel-induced vibration have been based on a single cylinder. It is doubtful that these models can be applied to cylinder arrays because the coupling effect is significant in the cylinder bundle. Other analytical methods will therefore have to be developed. Connors' model [16] is frequently used for fluidelastic instability of cylinder arrays. The validity of the model -- see equation 5 -- has not been proved. For example, f, M, and ζ are based on the values for a single cylinder in stationary fluid. In a cylinder array, f, M, and ζ are coupled [29]. Further studies are needed to determine the dependence of critical flow velocity on such factors as cylinder geometry, damping parameters, and cylinder detuning. Other models should also be improved.

Mathematical models can provide practical information about the cylinder responses but not any information about the fluid-flow process. A model based primarily on the structure of fluid flow -- using Navier-Stokes equations or other approximate equations to develop fluid-force distribution -- would certainly be helpful in understanding the basic characteristics of cylinder/fluid interactions. Even for the simple problem of a single cylinder subjected to uniform cross flow no model is available for the basic fluid dynamics.

Methods are available for solving flow-induced vibration problems. But it is better to avoid the problem in the first place, by increasing structural stiffness and damping or reducing flow velocity. However, designs with a large margin of safety factors increase costs and decrease performance. Furthermore, the method used to reduce vibration frequently requires a compromise to satisfy other requirements; for example, increasing structural stiffness is beneficial from vibrational point of view, but it can also increase thermal stresses. Therefore, structural design should be optimized with respect to cost, performance, and safety. Unfortunately current state-of-the-art design procedures [e.g., 11, 232-234] leave much to be desired -- pointing up once again the need for in-depth understanding of excitation sources and characterization of system response. The solution to flow-induced vibration today remains a blend of science and art. The powerful tools of modern technology are used whenever possible, as is good judgment. Until such time as all significant design parameters can be fully identified and quantified, the engineer charged with design must avoid detrimental vibrations by relying on existing information and sound judgment in modeling and testing.

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BOOK REVIEWS

NOISE AND VIBRATION DATA

Trade and Technical Press Ltd.
England

This book is a collection of equations, tables, charts, nomograms, and standards summaries taken from other sources.

There is information about acoustics, as well as vibration equations for average sound pressure level, directivity index, rms, crest factor, transmissibility, and the coincidence frequency for plates. There are tables on typical sound levels, weightings and tolerances for sound level meters, phons, sones, and octave band sound level; perceived noise level conversions and conversions from pressure ratios to decibels are also given. Charts include air absorption by frequency, decibel addition, reverberation time approximations, and transmissibility. The Standards, Codes, and Recommendations section contains a summary of national and international standards pertaining to acoustics, noise measuring equipment, noise rating recommendations, noise in buildings, machine noise and vibrations, and vehicle and traffic noise. Representative values of airborne sound reduction indices for some common structures by octave bands are listed.

Although the idea of such a collection of information might seem to be a good one, this book has serious shortcomings many of the equations have been inaccurately copied, and some of the notation is misleading; in addition, the explanation of the equations are not adequate, and some of the charts are inadequately labeled. The standards information is out-of-date; coverage of U.S. standards is poor.

The most serious errors appear in retyped information and changes in original material. Those sections directly copied from other sources seem to be essentially correct. Unfortunately, the errors and inadequacies are serious enough to compel the reader to crosscheck any information he reads in the book. And, with the exception of general acknowledgments in the Preface, specific references do not generally accompany the borrowed information. In addition to being a discourtesy to the authors, the lack of citations complicates verification of material. I do not recommend this book in its present form.

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STABILITY AND VIBRATIONS OF SANDWICH SHELLS (Ustoichivost i kolebaniya trekhsloinykh obolochek)

Z. I. Grigolyuk and P. P. Chulkov
Moscow, "Mashinostroenie" (1973)
($3.50)

Authors develop in this little book a theory for the calculation of sandwich structures consisting of three layers. Based upon a modified Kirchhoff-Love hypothesis, saying that a normal to the reference surface of the shell remains a straight segment piecewisely within each of the three layers, the general equations for lateral bending, buckling, and vibrations of beams, plates, and shells are obtained. As the two surface layers of a sandwich structure are usually much thinner than the middle layer, these equations differ little from those obtained by using the conventional method, taking into account naturally the deflections due to shearing.

The book begins with a chapter on straight beams, in which some simple problems are solved. Chapter 2 gives the general equations of shallow shells with finite deflections. In Chapters 3 and 4 linear problems of stability and vibrations of circular cylindrical shells and panels are solved analytically. Chapter 5 discusses a semi-momentless theory for circular cylindrical shells, analogous to the Vlasov theory for shells of medium length. Equations for nonshallow shells at both small and finite deflections are derived in Chapter 6. Some linear problems for the buckling and vibrations of nonshallow cylindrical, conical, spherical, and toroidal shells are dealt with analytically in the last four chapters.

The main strength of this book is its clear and straight-forward approach to the topics covered. The book will probably be of interest to designers dealing with sandwich structures.

S. D. Lee, Sweden
Courtesy of Applied Mechanics Reviews

VIBRATIONS OF ENGINEERING STRUCTURES

C. A. Brebbia et al
Computational Mechanics Ltd.
Southampton, U.K. (1976)

This book is an outgrowth of a week-long lecture series conducted by the authors in 1975. Its main theme is structural vibration. The material intended to provide a review-survey course for practicing engineers. The coverage is broad -- ranging from elementary and fundamental vibrational principles to analyses of some recent problems of interest. Among the specific vibrations problems discussed are machine foundation vibrations, vibrations of shells and cooling towers, fluid-structure interactions, and response of offshore structures to random load.

This book will be useful to engineers desiring an overview of techniques available for treating vibrations problems and some recent applications. References cited at the end of each chapter are a good source for in-depth discussions.

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SHORT COURSES

DECEMBER

VIBRATION SURVIVABILITY

Dates: December 6 - 10, 1977
Place: Palo Alto, California
Objective: Increasing an equipment's ability to survive in the dynamic environments of vibration and shock will be the main subject of a 5-day short course near San Francisco. The course will meet at the facilities of Watkins-Johnson Co., 3333 Hillview Ave. in Palo Alto, California. Among the troublesome vibration and shock environments to be considered are missiles and aircraft, ships, automotive vehicles, modern buildings, and nuclear power plants. The course is designed to provide education in resonance and fragility phenomena, in environmental vibration and shock measurement and analysis, also in vibration and shock testing to prove survivability. This course will concentrate upon techniques and equipments rather than upon mathematics and theory.

Contact: Wayne Tustin, Tustin Institute of Technology, 22 East Los Olivos Street, Santa Barbara, CA 93105, (805) 963-1124

JANUARY

EARTHQUAKE SIMULATION AND RESPONSE

Dates: January 9 - 13, 1978
Place: Long Island, New York
Objective: Safe shut-down of a nuclear power generating station following an earthquake will be the main topic of this course, to be held at the facilities of Dayton T. Brown, Inc., Bohemia, Long Island, New York.-- one of the few laboratories in the world capable of earthquake simulation. This course, aimed at test and quality engineers, will stress interpreting standards and specifications and conducting tests (including the proper mounting of test specimens).

Contact: Wayne Tustin, Tustin Institute of Technology, 22 East Los Olivos Street, Santa Barbara, CA 93105, (805) 953-1124

FEBRUARY

MACHINERY VIBRATION MONITORING AND ANALYSIS SEMINAR

Dates: February 13, 14, and 15, 1978
Place: Houston, Texas
Objective: This seminar will be devoted to the understanding and application of vibration technology to machinery vibration monitoring and analysis. Basic and advanced techniques with illustrative case histories and demonstrations will be discussed by industrial experts and consultants. Topics to be covered in the seminar include preventive maintenance, measurements, analysis, data recording and reduction, computer monitoring, acoustic techniques, misalignment effects, balancing, turbomachinery blading, bearing fault diagnosis, torsional vibration problems and corrections, and trend analysis. An instrumentation show will be held in conjunction with this seminar.

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

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

CALL FOR PAPERS

The Seventy-third Annual Meeting of the Seismological Society of America will be hosted jointly by the Seismological Lab and the Dept. of Civil Engineering at the University of Nevada, Reno. Papers reporting original research in Seismology or Earthquake Engineering are invited. Abstracts must be submitted for all papers to be presented at the meeting, which will be held April 6 - 8, 1978, in Sparks, Nevada (near Reno). The deadline for abstracts is January 25, 1978. For more information, write: S.S.A., P. O. Box 826, Berkeley, CA 94701

ACOUSTICAL SOCIETY OF AMERICA STANDARDS PUBLICATION PROGRAM

The following standards are available from the Standards Secretariat of the Acoustical Society of America:

ANSI No.	ASA CATALOG No.	TITLE
S3.19-1974	ASA 1-1975	Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs
S2.19-1975	ASA 2-1975	Balance Quality of Rotating Rigid Bodies
ASA STD. 3-1975		Test-Site Measurement of Maximum Noise Emitted by Engine-Powered Equipment
S3.17-1975	ASA 4-1975	Method for Rating the Sound Power Spectra of Small Stationary Noise Sources
S1.23-1976	ASA 5-1976	Method for the Designation of Sound Power Emitted by Machinery and Equipment
S2.9-1976	ASA 6-1976	Nomenclature for Specifying Damping Properties of Materials
S3.22-1976	ASA 7-1976	Specification of Hearing Aid Characteristics
S2.4-1976	ASA 8-1976	Method for Specifying the Characteristics of Auxiliary Analog Equipment for Shock and Vibration Analysis (a revision of S2.4-1960)
S3.1-1977	ASA 9-1977	Criteria for Permissible Ambient Noise During Audiometric Testing (a revision of S3.1-1960)
S3.14-1977	ASA 21-1977	Standard for rating noise with respect to speech intelligibility

In addition to the above standards, there is available an Index to Noise Standards, *ASA STDS. INDEX 1-1976*, which covers both national and international noise standards. (All noise standards, both in published and draft form and developed by different organizations, are listed in the ASA Standards Index.) All previous American National (ANSI) Standards relating to Acoustics can also be purchased from the Acoustical Society of America through the Standards Secretariat. The complete set of standards is available at a 20% discount.

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ABSTRACTS FROM THE CURRENT LITERATURE

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

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1922)

77-1880

A Critical Examination of Discrete Models in Vibration Problems of Continuous Systems

E. Dokumaci

Dept. of Mech. Engrg., Ege Univ., Turkey, J. Sound Vib., 53 (2), pp 153-164 (July 22, 1977) 4 figs, 7 refs

Key Words: Boundary value problems, Eigenvalue problems, Lumped parameter methods, Continuum mechanics

The solution of vibration problems of continuous systems by means of discrete models is examined with reference to two point eigenvalue problems. Emphasis is placed on the generation of lower bounds to eigenvalues and criteria are derived for upper and lower bound elements.

77-1881

Upper and Lower Bound Eigenvalues of a Conservative Discrete System

A.B. Ku

Dept. of Civ. Engrg., Univ. of Detroit, MI 48221, J. Sound Vib., 53 (2), pp 183-187 (July 22, 1977) 6 refs

Key Words: Eigenvalue problems, Boundary value problems, Timoshenko theory

The Timoshenko quotient and a lower bound formula, which are available for continuous systems, are presented here for discrete systems. With both the upper and lower bound known, the estimation of eigenvalue becomes certain. Errors associated with these upper and lower bounds are discussed and an illustrative example given.

77-1882

Improved Numerical Dissipation for Time Integration Algorithms in Structural Dynamics

H.M. Hilber, T.J.R. Hughes, and R.L. Taylor

Div. of Struc. Engrg. and Struc. Mech., Dept. of Civ. Engrg. and Lawrence Berkeley Lab., Univ. of California, Berkeley, CA., Intl. J. Earthquake Engr. Struc. Dynam., 5 (3), pp 283-292 (July/Sept 1977) 6 figs, 8 refs

Key Words: Dynamic structural analysis, Damping effects

A new family of unconditionally stable one-step methods for the direct integration of the equations of structural dynamics is introduced and is shown to possess improved algorithmic damping properties which can be continuously controlled. The new methods are compared with members of the Newmark family, and the Houbolt and Wilson methods.

77-1883

A Note on the Ultraspherical Polynomial Approximation Method of Averaging

M.A.V. Rangacharyulu and P. Srinivasan

Dept. of Mech. Engrg., Univ. of Edinburgh, Edinburgh EH9 3JL, UK, J. Sound Vib., 53 (1), pp 63-69 (July 8, 1977) 13 refs

Key Words: Oscillation, Galerkin method, Approximation methods

The method of averaging based on ultraspherical polynomial approximation has been applied to several non-linear oscillation problems. It is shown that the above method can be interpreted as a Galerkin technique with an appropriate weight function. Even though the analysis is not rigorous mathematically, it does provide insight into this generalized method of averaging.

77-1884

On the Construction of Poincaré-Lindstedt Solutions: The Nonlinear Oscillator Equation

P.J. Melvin

Liberal Arts and Sciences Admin., Univ. of Illinois at Urbana-Champaign, Urbana, IL 61801, SIAM J. Appl. Math., 33 (1), pp 161-194 (July 1977) 7 figs, 7 tables, 10 refs

Key Words: Equations of motion, Power series method, Fourier series

The equation of motion in a potential energy well $Y'' = F(Y)$ is formally integrated by a combined power and Fourier series. A new notation is used to reduce the integration problem to the algebraic problem of the solution of two recursion relations in a finite form. Two general algorithms are obtained from the recursion relations for motions in asymmetrical and symmetrical, parabolic wells. A third algorithm is presented for the periodic solutions of a form of the Emden-Fowler equation. The computer versions of the algorithms for parabolic wells are checked against independent analytical solutions of the equation for time dependent radial motion in the Newtonian two-body problem and the equation of Blasius.

77-1885

Parametric Excitations of Linear Systems Having Many Degrees of Freedom

A.H. Nayfeh and D.T. Mook
Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061,
J. Acoust. Soc. Amer., 62 (2), pp 375-381 (Aug 1977) 1 fig, 12 refs

Key Words: Parametric excitation, Linear systems, Multidegree of freedom systems

The method of multiple scales is used to analyze parametrically excited, linear systems having many degrees of freedom and distinct natural frequencies. Explicit second-order expressions are obtained for the characteristic exponents which yield the transition curves. Various combination resonances are treated. The results are applied to the buckling of free-clamped columns under the influence of sinusoidally varying axial loads.

NONLINEAR ANALYSIS

77-1886

Nonlinear Mode Coupling of Elastic Waves

N. Sugimoto and M. Hirao
Dept. of Mech. Engrg., Faculty of Engrg. Science, Osaka Univ., Toyonaka, Osaka, 560 Japan,
J. Acoust. Soc. Amer., 62 (1), pp 23-32 (July 1977) 26 refs

Key Words: Elastic waves, Wave propagation, Nonlinear theories, Wires

The theory of nonlinear elasticity is applied to a study of mode coupling of elastic waves at a particular frequency, called the critical frequency, in a long circular wire. It is assumed that the wire is of homogeneous isotropic elastic material and that the nonlinearity of medium (the effects of higher-order elasticity) is primary rather than that involved in the Lagrangian stress and strain tensors. The method of multiple scales is employed to obtain a system of equations which describes the behavior of the amplitudes involved in the mode coupling.

OPTIMIZATION TECHNIQUES

(See No. 1890)

STATISTICAL METHODS

77-1887

Impulsive Sound-Level Response Statistics in a Reverberant Enclosure

E.K. Dunens and R.F. Lambert
Dept. of Electrical Engrg., Univ. of Minnesota, Minneapolis, MN 55455,
J. Acoust. Soc. Amer., 61 (6), pp 1524-1532 (June 1977) 7 figs, 12 refs

Key Words: Impact noise, Reverberation chambers, Statistical methods

Some response measures of a reverberant enclosure excited by an impulsive noise source are considered from both experimental and analytical viewpoints. The response measures of interest are the rms sound pressure and the sound-pressure-level exceedance probability distribution. A variety of experimental situations are examined for infrequently occurring source impulses - a situation for which an analytical approach can be readily developed. The model involves the use of an energy-partition method in order to estimate the rms sound pressure and the use of an equivalent linear single-degree-of-freedom system in order to calculate the normalized exceedance probability distribution. The calculated response statistics agree quite well with measured data. Results of these studies have applications in predicting total noise exposure, for example, when dealing with impulse noise-control problems.

FINITE ELEMENT MODELING

(Also see Nos. 2031, 2039)

77-1888

Application of Isoparametric Finite Elements in Vehicle Structural Mechanics

C.J. Parekh, J.E. Basas, and K.S. Kothawala
Engineering Mechanics Research Corp.,
SAE Paper No. 770 606, 15 pp, 23 figs, 1 table, 14 refs

Key Words: Isoparametric elements, Finite element technique, Automobiles, Ground vehicles

This paper is concerned with the application of the isoparametric elements in the vehicle structural mechanics fields. The basic concepts and the techniques used in developing a family of isoparametric elements having linear and parabolic displacement variations, and a suitable combination

of the same, are discussed. Comparative models using the conventional and isoparametric elements are presented to illustrate their differences.

MODELING

(See No. 1965)

DESIGN TECHNIQUES

77-1889

Investigation of Static and Dynamic Behavior of Machine Tool Components by Means of Computerized Simulation (Untersuchung des statischen und dynamischen Verhaltens von Baugruppen für Werkzeugmaschinen durch Anwendung der rechentechnischen Simulation)

B. Weber and R. Nollau
Forschungszentrum des Werkzeugmaschinenbaus im VEB Werkzeugmaschinenkombinat "Fritz Heckert" Karl-Marx-Stadt, German Dem. Rep., Maschinenbautechnik, 26 (5), pp 215-217 (May 1977) 6 figs, 3 refs
(In German)

Key Words: Computer-aided techniques, Machine tools, Mathematical modeling, Digital simulation

In the paper a digital simulation method for the determination of dynamic behavior of structural components is described. Particular attention is directed to the development of a mathematical model. An example demonstrates how the models of complicated systems are obtained from component system models. The economics resulting from the application of digital simulation techniques are described in detail.

77-1890

Singular Optimal Control Problems in the Design of Vibrating Structures

D. Carmichael
Dept. of Civ. Engrg., Univ. of Western Australia, Nedlands 6009, Western Australia, J. Sound Vib., 53 (2), pp 245-253 (July 22, 1977) 18 refs

Key Words: Optimum design, Optimum control theory, Vibrating structures

It is shown that several recent publications dealing with the design of vibrating structures by optimal control theory have problem formulations corresponding to singular control problems. For such problems, the conditions of neither the maximum principle nor the classical variational theory provide adequate tests for optimality of the solution. The singular control formulation of these publications is acknowledged here for the first time and the optimality of the solutions is examined by using supplementary necessary conditions.

CRITERIA, STANDARDS, AND SPECIFICATIONS

(Also see Nos. 1949, 1998)

77-1891

Economic Impact of a 90-dBA Noise Standard on Textile Spinning Operations

P.D. Emerson, J.R. Bailey, and W.D. Cooper
North Carolina State Univ., Raleigh, NC., ASME Paper No. 77-RC-15

Key Words: Textile looms, Industrial facilities, Noise reduction, Regulation

Textile spinning noise levels generally exceed 90 dBA. Recent research and mill tests, conducted under a grant from the National Institute for Occupational Safety and Health, have demonstrated that most spinning operations can be quieted to levels below 90 dBA. Costs for necessary corrective measures vary with type and age of machines, speed of operation, and acoustical properties of machine rooms. This paper examines various aspects of the economic impact resulting from compliance with a 90-dBA noise standard in textile spinning operations.

77-1892

Process Noise Control: A Critical Application that Worked

T.J. Wehrfritz and R.J. DelValle
Monsanto Co., Trenton, MI., ASME Paper No. 77-RC-12

Key Words: Noise reduction, Regulations

The impact of government regulations on a particular plant may vary significaqntly since the nature of some processes make standard engineering approaches not readily available. A case is described involving a 45-dBA reduction of a noise source in order to stay within the federal limits of employee exposure. Constraints from the environment, production techniques, and available acoustical technology were incorporated to achieve the desired attenuation. Emphasis is given to the materials and techniques of construction, OSHA compliance, the necessary operator duties to assure production capability, and the adaptation of acoustical techniques.

77-1893
Noise Control by Regulation -- An Engineering Challenge

W.S. Gatley
Univ. of Missouri-Rolla, Rolla, MO., ASME Paper No. 77-RC-16

Key Words: Regulations, Noise reduction

Major provisions of the Occupational Safety and Health Act of 1970 and the Noise Control Act of 1972 acts are summarized. The need for, and potential benefits from noise regulations are examined, and effects on capital investment, productivity, consumption of raw materials, and user costs are discussed. The engineering challenge is identified by the necessity to achieve compatibility between benefits and costs. Meeting this challenge is described in terms of programs required by engineering education, professional societies, trade associations, and governmental bodies.

SURVEYS AND BIBLIOGRAPHIES

77-1894
Balancing of Linkages

R.S. Berkof, G.G. Lowen, and F.R. Tepper
Advanced Technology, Gulf & Western Advanced Dev. and Engrg. Center, Swarthmore, PA 19081, Shock Vib. Dig., 9 (6), pp 3-10 (June 1977) 4 figs, 42 refs

Key Words: Reviews, Linkages, Balancing techniques

Interest in high-speed machine design has stimulated research and developmental efforts in balancing during the past few years. This paper reviews some of the recent literature dealing with balancing of linkages.

77-1895
Underwater Fluid-Structure Interaction. Part III: Acoustically-Applied Forces

L.H. Chen and M. Pierucci
General Dynamics Electric Boat Div., Groton, CT 06340, Shock Vib. Dig., 9 (6), pp 13-17 (June 1977) 58 refs

Key Words: Reviews, Interaction: structure-fluid

Fluid-structure interaction encompasses a broad spectrum of technical areas of interest in engineering application. This discussion is limited to "underwater" applications and includes the following topics: sound radiation and scattering, structural vibration and shock response, flow-induced noise, hydrodynamic divergence and flutter, boundary layer stability, and propeller-induced forces. The common thread linking these technologies, namely, the interaction phenomenon, is stressed. An attempt has been made to clarify some of the terminology within these diverse technical areas.

77-1896
A Review of Ship Hull Vibration. Part III: Methods of Solution

J.J. Jensen and N.F. Madsen
Dept. of Ocean Engrg., The Technical Univ. of Denmark, 2800 Lyngby, Denmark, Shock Vib. Dig., 9 (6), pp 19-27 (June 1977) 1 fig, 138 refs

Key Words: Reviews, Ship hulls, Ship vibration

This paper is a review of the analytical and numerical tools used to calculate hull vibrations. Mathematical Models were described in the first part. The second part on Modeling of Physical Phenomena contained descriptions of mathematical models of the hull. Numerical determination of the equations of motion is discussed in the third part -- Methods of Solution. The fourth part, Comparison of Beam Models, is a review of methods used to solve the equations of motion; an example problem illustrates various principles.

77-1897
Techniques for the Design of Highly Damped Structures

F.C. Nelson
Dept. of Mech. Engrg., Tufts Univ., Medford, MA 02155, Shock Vib. Dig., 9 (7), pp 3-11 (July 1977) 10 figs, 2 tables, 29 refs

Key Words: Reviews, Damped structures

The purpose of this review is to discuss three techniques for the design of highly damped structures, techniques which have proven successful for large-scale, low-frequency steel and concrete structures. The techniques are: the design of structural joints and interfaces to promote damping; the use of layers of viscoelastic material; and the employment of discrete dampers. The review explains how these techniques work and describes the ways in which they have been used.

77-1898
A Review of Ship Hull Vibration. Part IV: Comparison of Beam Models
J.J. Jensen and N.F. Madsen
Dept. of Ocean Engrg., The Technical Univ. of Denmark, 2800 Lyngby, Denmark, Shock Vib. Dig., 9 (7), pp 13-28 (July 1977) 8 figs, 138 refs

Key Words: Reviews, Ship hulls, Ship vibration, Beams, Mathematical models

This paper is a review of the analytical and numerical tools used to calculate hull vibrations. Mathematical Models were described in the first part. The second part on Modeling of Physical Phenomena contained descriptions of mathematical models of the hull. Numerical determination of the equations of motion was discussed in the third part -- Methods of Solution. The fourth part, Comparison of Beam Models, is a review of methods used to solve the equations of motion; an example problem illustrates various principles.

77-1899
Underwater Fluid-Structure Interaction. Part IV: Hydrodynamically Applied Forces (Moving Medium)
L.H. Chen and M. Pierucci
General Dynamics Electric Boat Div., Groton, CT 06340, Shock Vib. Dig., 9 (7), pp 29-37 (July 1977) 2 figs, 58 refs

Key Words: Reviews, Interaction: structure-fluid

Fluid-structure interaction encompasses a broad spectrum of technical areas of interest in engineering application. This discussion is limited to "underwater" applications and includes the following topics: sound radiation and scattering, structural vibration and shock response, flow-induced noise, hydrodynamic divergence and flutter, boundary layer stability, and propeller-induced forces. The common thread linking these technologies, namely, the interaction phenomenon, is stressed. An attempt has been made to clarify some of the terminology within these diverse technical areas.

MODAL ANALYSIS AND SYNTHESIS

77-1900
The Use of Discrete Frequency Testing for Modal Analysis of Engineering Structures
J. Williams
Solartron Schlumberger, SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 239-244 (Apr 4-6, 1977) 2 figs, 3 refs

Key Words: Modal analysis

Modal analysis , the name given to a technique for deriving a dynamical model of a structure or system from data on the vibration response characteristic of that structure, is discussed. It offers the possibility of performing the reverse process to a purely analytical vibration study, i.e., obtaining response characteristics experimentally and extracting from these the natural frequency and mode shape properties (the modal properties). Then, from a complete set of such properties, constructing a complete set of equations of motion (or mathematical model) for the test structure. The response characteristics used for this process are almost exclusively the structure's impedance properties - frequency response parameters such as mobility, mechanical impedance, inertance, etc.

77-1901
A Complete Modal Analysis System for the Mechanical Engineer
H.J. Wyman
Hewlett Packard, Ltd., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 245-252 (Apr 4-6, 1977) 7 figs, 4 refs

Key Words: Modal analysis, Fourier analysis

Fourier analyzers, capable of fast, precise measurements of a structure's dynamic characteristics as defined by its frequency response functions, are described. By outputting this data in the form of an animated mode shape it enables definition of the problem. Also by offering a facility for mathematically modeling the effect of changes in the structure can lead to development of optimum solution to problems.

77-1902
Modal Analysis Using Local Microprocessor with Time Share Computer System
G.J. Zobrist
Zonic Tech. Laboratories, Inc., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 164-206 (Apr 4-6, 1977) 4 refs

Key Words: Modal analysis, Fast Fourier transform

A microprocessor based data collection, test and terminal computer analysis system for advanced structural testing, evaluation and design is described. It links a local hardware-based system via telephone lines to an international time-sharing computer network which contains sophisticated dynamic analysis programs. The system offers a cost-effective approach for attacking dynamics problems using the modal analysis techniques. Its primary purpose has been to provide a low cost method for performing structural dynamic analysis using Fourier transform (FFT) techniques.

77-1903
Modal Analysis of Transient Response Data Using a Complex Exponential Algorithm
W.H. Dunn
National Engrg. Lab., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 207-221 (Apr 4-6, 1977) 3 figs, 5 tables, 7 refs

Key Words: Modal analysis, Transient response, Prony series analysis

An accurate method is described for obtaining modal information from the free transient response of a vibrating structure. The Prony series algorithm, which is a numerical procedure for converting a digital function into a sum of complex exponentials, has been used for computer software developed at the National Engineering Laboratory. This algorithm is later discussed in detail. The Prony series analysis produces modal parameters directly from responses which are easily excited on lightly damped structures without the use of electronic shakers. All the modal parameters in a frequency range can be obtained from a single set of responses.

77-1904
Systems Design with Substructures
C.R. Rogers
Swanson Analysis Systems, Inc., SAE Paper No. 770 603, 8 pp, 10 figs, 13 refs

Key Words: Component mode analysis

After a brief discussion of the theoretical basis of substructures for statics and dynamics, the handling techniques are described, including file management, modification utilities, and nested heirarchies. Examples of recent applications illustrate the economies that can be achieved by substructuring. Substructures are especially economical in repetitive analyses, such as nonlinear static and dynamic analyses in which major portions of the structure exhibit linear behavior, or in design studies where only a portion of the model is to be modified.

COMPUTER PROGRAMS

GENERAL

77-1905
Structural Mechanics Software. Volume 2. May 1975-May 1977 (A Bibliography with Abstracts)
D.W. Grooms
National Technical Information Service, Springfield, VA., Rept. No. NTIS/PS-77/0525/4GA, 156 pp (June 1977)

Key Words: Computer programs, Bibliographies, Dynamic structural analysis

The use of computer programs in structural analysis-design problems are cited. Detailed analyses are included of structural problems -- applied and theoretical -- including stress analysis, vibration problems, shear stress analysis, deformation analysis and others. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPERSCEPTRE, and SINGER. (This updated bibliography contains 151 abstracts, 74 of which are new entries to the previous edition.)

77-1906
Stress, Buckling and Vibration of Hybrid Bodies of Revolution
D. Bushnell
Lockheed Palo Alto Res. Lab., 3521 Hanover St., Palo Alto, CA 94304, Computers and Struc., 7 (4), pp 517-537 (Aug 1977) 35 figs, 2 tables, 32 refs

Key Words: Computer programs, Bodies of revolution, Shells

This analysis is applicable to bodies of revolution composed of thin shell segments, thick segments and discrete rings. The thin shell segments are discretized by the finite difference energy method and the thick or solid segments are treated as assemblages of 8-node isoparametric quadrilateral finite elements of revolution. Suitable compatibility conditions are formulated through which these dissimilar segments are joined without introduction of large spurious discontinuity stresses. Plasticity and primary or secondary creep are included.

77-1907
Computer Program Package for the Calculation of Torsional Vibration (Programmpaket zur Berechnung von Torsionsschwingungen)
F. Holzweissig and S. Liebig
Technische Universität Dresden, Sektion Grundlagen des Maschinenwesens, Bereich Dynamik und Betriebsfestigkeit, Dresden, German Dem. Rep., Maschinenbautechnik, 26 (6), pp 266-271 (June 1977) 1 fig, 24 refs
(In German)

Key Words: Computer programs, Torsional vibration

A computer program package for the calculation of torsional vibration systems and vibration chains is described. It can be used to solve parameter determination problems, as well as free and forced vibrations. The programs, along with sample problems are available at the University of Dresden computer library.

77-1908
Simulation of Multibody Vehicles Moving Over Elastic Guideways
W. Kortum and R. Richter
DFVLR, Inst. for Dynamics of Flight Systems, 8031 Oberpfaffenhofen, Germany, Vehicle Syst. Dyn., 6 (1), pp 21-35 (May 1977) 4 figs, 8 refs

Key Words: Computer programs, Interaction: vehicle-guideway

This paper describes the present state of a general purpose computer program for calculating the dynamic response of vehicles travelling over guideways which may be elastic. The linearized state-equations of motion for general multibody vehicles are constructed automatically by the program, these equations are supplemented by the equations for the active subsystems. Finally, the vehicle system equations are combined with the modal equations for elastic guideways and the complete set of coupled equations is solved simultaneously by numerical integration.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1891, 1892, 1893, 1949, 1994, 1995, 1997, 1998, 2002, 2003, 2012, 2013, 2014, 2021, 2022)

77-1909
Acoustic Radiation from Point Excited Rib-Reinforced Plate
G.F. Lin and S.I. Hayek
David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD 20084, J. Acoust. Soc. Amer., 62 (1), pp 72-83 (July 1977) 13 figs, 5 tables, 28 refs

Key Words: Elastic waves, Sound waves, Point source excitation, Reinforced plates

An analytic solution for the acoustic radiation from a rib-reinforced infinite elastic plate which is excited by a point force located on the rib was obtained. An expression for the radiated power was also obtained. Approximate formulas for the complex interaction between the beam and the plate were developed for frequencies above and below the coincidence frequency. Approximate expressions for the radiated power were obtained from simplified physical models.

77-1910
Acoustic Coupling Between Two Finite-Sized Spherical Sources
W. Thompson, Jr.
Applied Res. Lab. and Dept. of Engrg. Science and Mech., The Pennsylvania State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 62 (1), pp 8-11 (July 1977) 8 figs, 6 refs

Key Words: Elastic waves, Sound waves, Vibration excitation

The problem of acoustic radiation from a pair of spherical sources vibrating with time-harmonic velocity distributions which are constant in strength and axisymmetric about the same axis is considered. In particular, the modification of the radiation load on one source due to the presence of the other is evaluated. Numerical results are presented for the four cases of equal size sources which are either in phase or 180° out of phase from one another and vibrating in either the pulsating (monopole) or oscillating (dipole) modes.

77-1911
Method of Predicting L_{eq} Created by Urban Traffic
K.W. Yeow, N. Popplewell, and J.F.W. MacKay
Faculty of Engrg., Univ. of Malaya, Kuala Lumpur, Malaysia, J. Sound Vib., 53 (1), pp 103-109 (July 8, 1977) 2 figs, 1 table, 15 refs

Key Words: Urban transportation, Traffic noise, Noise prediction

The time-averaged overall mean-square sound pressure created by statistically stationary traffic travelling a finite, straight road segment is determined explicitly. This result is extended to a system of roads by using digital simulation. Theoretical predictions for a typical urban conurbation show encouraging agreement with measured values. Therefore the technique appears to offer a practical means of evaluating community plans before the introduction of road systems and changes in trunk routes and traffic controls, etc., are realized.

77-1912

Sampling Errors in the Measurement of Traffic Noise with Gamma Headway Distributions

D.E. Blumenfeld, J.E. Kiefer, and G.H. Weiss

Traffic Studies Group, Univ. College, London, UK, J. Sound Vib., 53 (1), pp 111-116 (July 8, 1977) 2 figs, 10 refs

Key Words: Traffic noise, Noise measurement, Error analysis

Fisk has elucidated the theory of sampling errors for measurements of noise from traffic characterized as point sources travelling with identically distributed negative exponential headways. The effect of gamma distributed headways is considered. The effect of excess attenuation is considered.

77-1913

Community Reactions to Noise from Freely Flowing Traffic, Motorway Traffic and Congested Traffic Flow

N.S. Yeowart, D.J. Wilcox, and A.W. Rossall

Dept. of Electrical Engrg., Univ. of Salford, Salford M5 4WT, UK, J. Sound Vib., 53 (1), pp 127-145 (July 8, 1977) 7 figs, 11 tables, 10 refs

Key Words: Traffic noise, Human response

Responses to a social survey were collected from residents of 27 different sites in the Greater Manchester (UK) area. The sites were exposed to noise emanating from freely flowing traffic on urban roads, motorway traffic, congested, or disturbed traffic flow on urban roads. Existing noise indices were tested on this general sample of traffic flow situations to determine their efficacy in the prediction of community dissatisfaction to traffic noise. No existing index could handle adequately all the traffic flow conditions. When the indices were combined with measures of traffic volume flow between midnight and 6 a.m. a marked improvement in their predictive capability was noted.

77-1914

Impedance Theory and Measurements on Porous Acoustic Liners

A.B. Bauer

Douglas Aircraft Co., Long Beach, CA., J. Aircraft, 14 (8), pp 720-728 (Aug 1977) 18 figs, 2 tables, 19 refs

Key Words: Acoustic linings, Acoustic impedance

The impedance of a point-reacting liner consisting of a thin, porous surface sheet backed by cavities filled with air or with porous materials has been predicted mathematically for a duct with flow. The mathematical model has been compared with experimental results obtained by using the two-microphone technique for various liners mounted in a 1-ft^2 duct with flow at Mach numbers of 0 to 0.6.

77-1915

One-Dimensional Model for Acoustic Absorption in a Viscoelastic Medium Containing Short Cylindrical Cavities

G. Gaunaurd

Naval Surface Weapons Center, White Oak Lab., Silver Spring, MD 20910, J. Acoust. Soc. Amer., 62 (2), pp 298-307 (June 1977) 8 figs, 23 refs

Key Words: Acoustic absorption, Underwater sound transmission, Viscoelastic media, Cavity-containing media

The equations of motion of linear viscoelasticity (Kelvin-Voigt Model) in cylindrical coordinates are reduced to an axisymmetric plane-stress situation valid for short hollow cylinders. The analysis models the deformations and oscillations occurring in the annular region conceptually constructed around one of the holes in a multiperforated rubber sheet to be used as an underwater acoustic absorber. The eigenvalue problem for the ring's natural frequencies is solved in two cases: first, when both rims of the ring are subjected to a stress boundary condition; second, when the inner rim ($r = a$) is stress free and the outer one ($r = b$) is fixed. For incompressible materials with Poisson's ratio very close to 0.5, the first few eigen-wave-numbers are numerically computed and plotted in nondimensional form versus the b/a ratio, in both cases, and the resulting sets of curves are shown to be interlaced, the ones from the first case being below those of the second. The transient vibration problem for the displacement u_r is solved by the Laplace-transform method in the first case only.

77-1916

Mode Conversion in Shallow-Water Sound Propagation

S.T. McDaniel
Applied Res. Lab., The Pennsylvania State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 62 (2), pp 320-325 (Aug 1977) 9 figs, 8 refs

Key Words: Underwater sound transmission

Coupled equations for modal power transfer are applied to calculate the energy transferred between normal modes as a result of scattering from the ocean floor. Numerical estimates are presented for mode conversion in a typical shallow-water environment. The results show that mode coupling can have a significant effect on propagation loss. Mode-coupling predictions obtained for farfield transmission loss are found to display both frequency- and range-dependent features in qualitative agreement with observed shallow-water transmission loss. Excellent agreement is obtained between mode-coupling predictions and experimentally measured mode attenuation.

SEISMIC

(Also see Nos. 2009, 2041)

77-1917

Interactive Artificial Earthquake Generation

A.C.Y. King and C. Chen
Gilbert Associates, Inc., Reading, PA 19603, Computers and Struc., 7 (4), pp 503-506 (Aug 1977) 4 figs, 7 refs

Key Words: Earthquakes, Computerized simulation

The time history method has been one of the analytical tools applied in the seismic resistant design of nuclear power plants. The time histories used are required to be consistent with the specified design spectra. Since the spectra of recorded strong motion earthquake or conventionally generated artificial time history have local peaks and valleys, iteration procedures must be applied to generate the artificial time history with desired spectra. References describe various methods of generating this kind of artificial time history. This paper describes a method in detail how this kind of time history can be generated. There are several advantages of this method described here. First the frequency content of the time history is well under control. Secondly, if three component earthquakes at one site are desired, the inherent nature of this method will make the correlations among these three components to simulate closely the actual recorded time histories. Thirdly, single time history can be generated to match spectra of different damping values.

77-1918

Safety of Structural Systems with Reserve Elements for Earthquake Protection

I.M. Eisenberg
Central Res. Inst. of Building Structures (TsNIISK Kutsherenko), Moscow, USSR, Intl. J. Earthquake Engr. Struc. Dynam., 5, pp 305-318 (1977) 6 figs, 4 tables, 23 refs

Key Words: Seismic response, Buildings, Earthquake damage

Some results of approximate analyses of the safety of earthquake protection systems with reserve elements are presented. Systems with one and several reserve elements are considered. The overshoot random vibration approximation is used for analysis. A numerical example is given.

77-1919

Seismic Risk Analysis of Discrete System of Sites

G. Taleb-Agha and R.V. Whitman
Dept. of Civil Engrg., Massachusetts Institute of Technology, Cambridge, MA., Intl. J. Earthquake Engr. Struc. Dynam., 5, pp 293-304 (1977) 11 figs, 1 table, 8 refs

Key Words: Earthquake damage, Seismic response, Buildings, Nuclear power plants

Two efficient schemes have been developed for the analysis of discrete systems of sites. Both schemes have the same objective of finding the probability of simultaneous failure of any number of sites belonging to a given system of sites subject to threats from a given set of earthquake sources with known seismic history. In the first scheme, systems with deterministic site resistances can effectively be analyzed using a non-linear transformation of variables. In the second scheme, systems with random site resistances can be analyzed.

SHOCK

(Also see Nos. 2027, 2028, 2029)

77-1920

Response of an Acoustic-Elastic System to a Transient Source in the Acoustic Medium: Analytical Modelling for the Air-Coupled Wave

F.R. Norwood
Computational Physics and Mech. Div. II., Sandia Laboratories, Albuquerque, NM 87115, Intl. J. Engr. Sci., 15 (6), pp 391-404 (1977) 5 figs, 17 refs
Sponsored by the U.S. Energy Res. and Dev. Admin.

Key Words: Mathematical models, Shock excitation, Ground shock, Coupled response

The present work considers an elastic solid half-space contiguous to an acoustic half-space. Since the acoustic half-space does not support shear, gases and liquids are included in the present study. By the analysis, one deduces the stresses in the solid produced by a spherical source of pressure embedded in the acoustic medium. The solution is obtained by using one-sided and two-sided Laplace transforms and by relying quite heavily on the properties of the Green's function for the acoustic medium. These properties make compatible the prescription of the source pressure on a spherical surface and the application of the boundary conditions at the plane acoustic-elastic interface.

77-1921

Measurement of Blast Waves from Bursting Pressurized Frangible Spheres. Final Report

E.D. Esparza and W.E. Baker

Southwest Research Inst., San Antonio, TX, Rept. No. NASA-CR-2843, 55 pp (May 1977) refs N77-24306

Key Words: Shock waves, Explosion effects

Small-scale experiments were conducted to obtain data on incident overpressure at various distances from bursting pressurized spheres. Complete time histories of blast overpressure generated by rupturing glass spheres under high internal pressure were obtained using eight side-on pressure transducers. A scaling law is presented, and its nondimensional parameters are used to compare peak overpressures, arrival times, impulses, and durations for different initial conditions and sizes of blast source. The nondimensional data are also compared, whenever possible, with results of theoretical calculations and compiled data for Pentolite high explosive.

77-1922

The Use of Inertia Relief to Estimate Impact Loads

M.F. Nelson and J.A. Wolf, Jr.

Research Labs, General Motors Corp., SAE Paper No. 770 604, 7 pp, 11 figs, 1 table, 7 refs

Key Words: Inertia relief method, Impact response (mechanical), Collision research (automotive), Framed structures

The method of inertia relief can provide a very inexpensive way of calculating dynamic forces in a structure. In order to perform an inertia relief analysis, an analyst must select single values to represent the force time histories which are applied to the structure. These forces are then applied to a partially or totally unrestrained structure (i.e., free-free), and the resulting rigid body accelerations are calculated. From these accelerations and the mass of the structure, the inertia forces can be calculated at all points in the structure and then applied along with the original forces. Finally, the structure is restrained from rigid body motion, and a conventional static analysis is performed.

GENERAL WEAPON

(See No. 1938)

TRANSPORTATION

(See Nos. 1911, 1912, 1913)

PHENOMENOLOGY

COMPOSITE

77-1923

Ultrasonic Spectrum Analysis for Nondestructive Testing of Layered Composite Materials

W.R. Scott and P.F. Gordon

Materials Engrg. Div., Air Vehicle Tech. Dept., Naval Air Development Center, Warminster, PA 18974, J. Acoust. Soc. Amer., 62 (1), pp 108-116 (July 1977) 10 figs, 7 refs

Key Words: Layered materials, Composite materials, Spectrum analysis, Ultrasonic techniques, Nondestructive testing

In this paper, a simple model is presented which predicts the ultrasonic frequency spectra for a broad class of layered composite materials having a finite number of laminas. This model predicts spectra for arrays of glass plates in water and these spectra are experimentally verified. Precisely regular spectra are predicted for single plates, while irregular spectra are predicted for all of the arrays studied. Results relating to nondestructive testing which have emerged from this investigation include methods for predicting spectra for layered composite materials and techniques for mapping small changes in the modulus and thickness of composite materials. Also discussed is the existence of forbidden frequency bands for which ultrasound transmission is strongly attenuated in thick layered composites.

DAMPING

(Also see Nos. 1897, 1926, 1986, 2039)

77-1924

Noise Abatement and Internal Vibrational Absorption in Potential Structural Materials

L. Kaufman, S.A. Kulin, and P.P. Neshe
Manlabs, Inc., Cambridge, MA., Rept. No. AMMRC-CTR-77-9, 237 pp (Feb 1977)
AD-A040 029/1GA

Key Words: Sound transmission, Noise reduction, Material damping

Efforts were directed toward identifying potential structural materials which combine high strength with damping characteristics in the audible range. The range of yield strengths and loss factors which are attainable exceed currently available commercial materials. Measurements of the enthalpy of transformation in a thermoelastic Cu-Al-Ni alloy has been conducted over a range of grain size and sample size to assess the stored elastic strain energy.

FLUID

(See Nos. 1895, 1899, 1972, 1973, 1982, 2041)

SOIL

(Also see No. 2011)

77-1925

Soil-Pile Interaction in Horizontal Vibration

M. Novak and T. Nogami
Faculty of Engrg. Science, The Univ. pf Western Ontario, London, Canada, Intl. J. Earthquake Engr. Struc. Dynam., 5 (3), pp 263-281 (July-Sept 1977)
12 figs, 2 tables, 7 refs

Key Words: Interaction: soil-structure, Pile structures

Interaction between soil and an elastic pile vibrating horizontally is theoretically examined. The soil is modeled as a linear, viscoelastic layer overlying rigid bedrock. The pile is assumed to be vertical and point bearing. This study utilizes the definition of soil resistance presented in a preceding paper. A direct solution is developed which yields closed form formulas for pile displacement, stiffness and damping. A parametric study clarifies the role of the parameters involved, illustrates the interaction between the soil and the pile and shows the stiffness and damping properties of the soil-pile system for typical values of the governing parameters.

77-1926

Resistance of Soil to a Horizontally Vibrating Pile

T. Nogami and M. Novak
Faculty of Engrg. Science, The Univ. of Western Ontario, London, Canada, Intl. J. Earthquake Engr. Struc. Dynam., 5 (3), pp 249-261 (July-Sept 1977)
11 figs, 11 refs

Key Words: Soils, Vibration response, Hysteretic damping

The resistance of a soil layer to steady horizontal vibration of an elastic pile is theoretically investigated. The pile is assumed to be vertical and of circular cross-section. The soil is modeled as a linear viscoelastic layer with hysteretic material damping. A closed form solution is obtained for the resistance of the soil layer to the motion. This resistance depends on shear modulus of soil, frequency, pile slenderness, material damping and Poisson's ratio. A parametric study of the effect of these parameters is included. The soil layer resistance is expressed in a form which can be used directly in the solution of the soil-pile interaction problem which is treated in a subsequent paper. The approach also applies for rigid deeply embedded footings.

VISCOELASTIC

77-1927

Stress and Dynamic Analyses of a Bonded, Non-Linear Viscoelastic Cylindrical Block

K.N. Morman, Jr., L.K. Dijauw, P.C. Killgoar, and R.A. Pett
Ford Motor Co., SAE Paper No. 770 599, 12 pp, 13 figs, 3 tables, 6 refs

Key Words: Viscoelastic media, Elastomers, Dynamic response, Dynamic stiffness

An approximate theoretical treatment is presented for the large deformation of non-linear viscoelastic cylindrical blocks bonded between rigid end-plates. The measured compressive force relaxation of two blocks of different initial radius to height ratios is shown. Measurements of dynamic stiffness k^* $(=k_1+k_2)$ for various compressive pre-loads and a frequency range of .05 to 30 Hz were conducted.

EXPERIMENTATION

BALANCING

(See No. 1894)

DIAGNOSTICS

77-1928

Monitoring Machinery Health - IV. Justifying the Cost of Monitoring Systems for Power-Plant Equipment

J.S. Mitchell

Endevco, San Juan Capistrano, CA., Power, 191 (8), pp 59-61 (Aug 1977)

Key Words: Diagnostic techniques

This last part of a series examines cost considerations and discusses potential advancements in the state-of-the-art of diagnostic systems.

77-1929

Real-Time Bispectral Analysis of Gear Noise and Its Application to Contactless Diagnosis

T. Sato, K. Sasaki, and Y. Nakamura

Faculty of Science and Engrg., Tokyo Inst. of Tech., 4259 Nagatsuda, Midori-ku, Yokohama-shi, Japan, J. Acoust. Soc. Amer., 62 (2), pp 382-387 (Aug 1977) 10 figs, 7 refs

Key Words: Diagnostic instrumentation, Gears

Real-time bispectral analyses of gear noises are carried out, intending to distinguish abnormal states from the normal one without stopping the machine. A real-time bispectral analyzer which consists of bandpass filters, multipliers, and integrators is constructed. Then, the noises of gears are analyzed. Finally a proper stochastic model of gear noise based on physical considerations as well as the spectral and bispectral characteristics obtained by our study, is proposed.

77-1930

Tracking Down the Cause of Coupling Failure

C.G. Wright

Power Systems, Fayetteville, PA., Mach. Des., 49 (14), pp 98-102 (June 23, 1977)

Key Words: Diagnostic techniques, Flexible couplings

Flexible coupling failures can almost always be traced to a problem somewhere in the system rather than to a defective coupling. Techniques for identifying the underlying cause of failure are described.

77-1931

Plotting of the Torque-Speed Curve During the Acceleration of Driving Engines (Aufzeichnung der Drehmomenten-Drehzahl-Kennlinie beim Beschleunigungsvorgang von Antriebsmaschinen)

D. Troppens and H. Biereichel

Wilhelm-Pieck-Universität Rostock, Sektion Landtechnik, German Dem. Rep., Maschinenbautechnik, 26 (6), pp 271-274 (June 1977) 5 figs, 10 refs (In German)

Key Words: Diagnostic techniques, Torque, Velocity, Internal combustion engines

In the complex diagnostics of many driving engines, torque and speed are used as parameters. A particularly suitable method for measuring these parameters is the acceleration method, which is described in this article. In addition, measuring instrumentation developed in Czechoslovakia and Russia are described. To stimulate further application of the method, a diagnostic facility comprising instrumentation built in East Germany is discussed.

77-1932

A Digital Approach to Rotating Machinery Analysis

G. Roriston

Time/Data Div., GenRad, Ltd., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 58-80 (Apr 4-6, 1977) 16 figs

Key Words: Diagnostic techniques, Digital techniques, Reciprocating engines, Rotors

Vibration levels produced by rotating or reciprocating machines usually vary considerably over their operating speed range. Many machines frequently operate with different loads or speed settings etc, thereby making the design and maintenance procedures very complex. There are a number of vibration analysers used in the design and maintenance cycles of machinery, and each contributes to providing the many parameters required to ensure satisfactory performance re: balancing, twisting of shafts, shaft whirl, bending, mechanical coupling, gear noise, and fixed component resonances. The system presented here can measure, and compute, most of these vital parameters with ease, yet without the supervision of high grade engineers. Direct comparisons with previous machine operating data can be carried out in the same system so that vibration trends may be monitored throughout its life.

77-1933

Signal Processing for Advanced Structural Testing

W.P. McKinlay and D.H.D. Robertson

Structures and Materials Group, National Engineering Lab., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 142-163 (Apr 4-6, 1977) 14 figs, 8 refs

Key Words: Ground vehicles, Diagnostic techniques, Signal processing techniques, Testing techniques, Computer-aided techniques, Digital techniques

This paper describes the signal processing techniques which are used to produce displacement control signals for a multi-actuator structural endurance test on a commercial vehicle cab chassis assembly. The problems associated with numerically integrating a time series service history are discussed and a solution to the problem of removing slowly varying trends present in the signal to be integrated is provided in the form of the design and synthesis of a digital high-pass filter.

77-1934

Digital Frequency Analysis of Engineering Signals

R. Williams and B.S. Gabri

Environmental Sciences Res. Unit, Cranfield Inst. of Tech., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 1-17 (Apr 4-6, 1977) 28 figs, 7 refs

Key Words: Diagnostic instrumentation, Frequency analyzers, Spectrum analysis, Signal processing techniques, Digital techniques

Digital analysis techniques are now widely used in the measurement and interpretation of noise and vibration signals. Although digital analyzers are extremely fast and potentially extremely accurate, they possess a number of fundamental limitations which can severely limit the quality of the results and lead to erroneous interpretation of experimental data. This paper is a guide to the methods and applications of digital spectral analysis. Emphasis is placed on illustrating the most significant sources of measurement and computation error together with techniques for their minimization.

77-1935

An Objective Comparison of Analog and Digital Methods of Real-Time Frequency Analysis

R. Upton

Bruel & Kjaer, 2850 Naerum, Denmark, SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 41-47 (Apr 4-6, 1977) 1 fig

Key Words: Frequency analyzers, Fast Fourier transforms, Diagnostic instrumentation, Analog techniques, Digital techniques

The development of analog and digital methods of real-time frequency analysis is documented. Comparison of techniques, giving advantages and disadvantages for different applications, is made.

77-1936

Signal-to-Noise Enhancement Techniques Using a Real Time FFT Processor

A.C. Keller

Spectral Dynamics Corp., San Diego, CA., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 26-40 (Apr 4-6, 1977) 32 figs

Key Words: Diagnostic techniques, Signal processing techniques, Fast Fourier transforms

Signal enhancement techniques can be applied in either the time or frequency domain. Some of these techniques are examined. The effectiveness of each technique depends upon the types of signal available and whether a reference signal or condition is also available. Goals of signal-to-noise enhancement include removing or reducing hum frequencies, looking at exact waveform characteristics, detecting signals which might normally reside below a threshold of noise, cleaning up a signal or removing unwanted characteristics of a signal and tracking rapidly changing signals. Signals which require further enhancement are usually generated by an operating system. In this context, signals analyzed were from the operation of various machines, as well as from signal sources buried in a variety of noise.

77-1937

Signal Processing Methods Enabling Rapid Appreciation of Gas Turbine Vibration Problems

D.S. Pearson and R. Wood

Measurement Engrg., Rolls-Royce (1971), Ltd., SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 128-141 (Apr 4-6, 1977) 9 figs, 2 refs

Key Words: Gas turbine blades, Vibration monitoring, Signal processing techniques, Diagnostic techniques

The procedure described provides a simple and inexpensive gas turbine blade vibration monitoring method. The method is subject to some limitations. It is not a substitute for strain gage testing. Frequency, blade stress and mode shape detail has to be found by prior testing in conjunction with the pressure transducer described. It is not suitable for monitoring frequencies which are synchronous with shaft speed, since pressure associated amplitudes would be masked by other signal components at harmonics of shaft order. It is not suitable for measuring assembly vibration where the nodal pattern remains stationary in space.

77-1938

The Pre-Processing of Shock Measurements for Simulation Testing

D.K. Ewing, J. Young, and A. Findlay
National Engrg. Lab., East Kilbride, Glasgow, UK,
SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 120-127 (Apr 4-6, 1977) 24 figs, 4 refs

Key Words: Gunfire effects, Signal processing techniques, Fast Fourier transform, Diagnostic techniques

Processing shock measurements by computer can be especially advantageous in eliminating the interference effects and background noise that sometimes occur in field measurement work. The technique, based on a computer graphics system for signal editing with Fourier Transform filtering, is illustrated by gun firing transient measurements.

77-1939

Methods and Industrial Applications of the Acoustic Pattern Recognition (Methoden und industrielle Anwendungen der akustischen Mustererkennung)

H. Gudat
Institut für Informationsverarbeitung in Technik und Biologie (IITB) der Fraunhofer-Gesellschaft e.V., Sebastian-Kneipp-Str. 12-14, 7500 Karlsruhe 1., Federal Rep. of Germany,
Technisches Messen ATM, 44 (5), pp 175-180 (May 1977), pp 209-216 (June 1976) 9 figs, 43 refs
(In German)

Key Words: Diagnostic techniques, Mechanical elements, Pattern recognition techniques, Signal processing techniques, Computer-aided techniques

This paper deals with the structure of pattern recognition systems, modern signal processing methods, and principles important for their design and industrial implementation. The state of the art is demonstrated by several examples. The application of pattern recognition systems in industrial production is expected to increase mainly for two reasons: first the semiconductor technology leads to more efficient and economic devices and secondly the high degree of production automation makes a further automation of the quality control desirable.

77-1940

Noise Analysis for Preventive Failure Detection on Stationary Turbomachines as a Problem of Pattern Recognition (Geräuschanalyse zur Schadenfrüherkennung an stationären Turbomaschinen als Problem der Mustererkennung)

D. Barschdorff, W. Hensle, and B. Stühlen
Institut für Thermische Strömungsmaschinen, Universität (TH) Karlsruhe, Kaiserstr. 12, 7500 Karlsruhe 1, Federal Rep. of Germany,
Technisches Messen ATM, 44 (5), pp 181-189 (May 1977) 12 figs, 29 refs
(In German)

Key Words: Diagnostic techniques, Turbomachinery, Pattern recognition techniques, Computer aided techniques, Signal processing techniques

Pattern recognition methods are described which are able to supply additional information on the performance of turbomachinery, thus facilitating earlier failure detection. New measurement techniques and signal analysis are discussed. The methods were successfully tested in the laboratory. They are now being applied to power plant turbines.

77-1941

Use of Tracking Filter in Machinery Vibration Analysis

A.D. Diercks
Endevco, San Juan Capistrano, CA.,
SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 48-57 (Apr 4-6, 1977) 9 figs

Key Words: Tracking filters, Rotors (machine elements), Machinery vibration, Diagnostic techniques

The tracking filter is a bandpass filter whose center frequency can be electrically tuned over a broad range of frequencies. When properly applied, the tracking filter is a useful, cost effective tool for spectrum analysis. A novel implementation of circuitry results in the so-called "Zero IF" type tracking filter which combines most of the advantages of other slave filter designs with a considerable decrease in complexity, and cost. An examination of the functional schematic and the operating principles of the circuitry provide a better understanding of the advantages and limitations of this design. These advantages and limitations make the tracking filter most useful when applied to rotating machinery vibration where the critical frequency components are related to the rotational frequency of the machine under examination. Machinery balancing and machinery run-up resonance testing are examples of circumstances under which the tracking filter can be used to full advantage.

FACILITIES

77-1942

Characteristics of an Anechoic Chamber for Fan Noise Testing

J.A. Wazyniak, L.M. Shaw, and J.D. Essary
Lewis Res. Center, NASA, Cleveland, OH, ASME Paper No. 77-GT-74

Key Words: *Test facilities, Fans, Noise generation*

Acoustical and mechanical design features of NASA Lewis Research Center's engine fan noise facility are described. Acoustic evaluation of the 1420-m^3 (50,000-cu-ft) chamber, which is lined with an array of stepped wedges, is described. Results of the evaluation in terms of cut-off frequency and *nonanechoic areas near the walls are detailed.*

INSTRUMENTATION

(Also see Nos. 1931, 2016)

77-1943

Tube Method of Sound-Absorption Measurement Extended to Frequencies Far Above Cutoff

F.D. Shields, H.E. Bass, and L.N. Bolen
Physical Acoustics Res. Group, Dept. of Physics and Astronomy, Univ. of Mississippi, University, MI, 38677, J. Acoust. Soc. Amer., 62 (2), pp 346-353 (Aug 1977) 10 figs, 9 refs

Key Words: Acoustic absorption, Measuring instrumentation

Equipment had been constructed for measuring sound absorption in the frequency range from 4 to 100 kHz in a large tube 25.4 cm in diameter and 4.8-m long. The technique employs a large, moveable, solid-dielectric capacitance transducer that completely fills the tube cross section and generates pulses of plane waves. An identical transducer terminates the other end of the tube and serves as a microphone to detect and reflect the sound pulses.

77-1944

Industrial Measurement in Acoustics and Vibration Engineering - A Survey. Part 1: Introduction to the Fundamentals of Sound Measurement Transducers (Industrielles Messen in der Akustik und Schwingungstechnik - eine Übersicht. Teil 1: Einführung in die Grundlagen der Schallausbreitung und Funktionsbeschreibung von Messschallwandlern)

I. Veit
Postfach 701050, 6000 Frankfurt 70, Frankfurt a. Main, Federal Rep. of Germany, Technisches Messen ATM, 44 (5), pp 163-173 (May 1977) 13 figs, 31 refs
(In German)

Key Words: Sound transmisison, Measuring instruments, Transducers

This two part survey presents a detailed review of acoustic transducers, as well as methods and instrumentation for the analysis of the measure data. In the first part, the article briefly introduces the concept of sound propagation in gaseous, liquid and solid media. Then it goes on to describe the functions of the most common sound transducers, such as the condenser-microphone, hydrophone, and accelerometer.

77-1945

Industrial Measurement in Acoustics and Vibration Engineering - A Survey. Part 2: Measuring Apparatus, Methods of Evaluation and Calibration (Industrielles Messen in der Akustik und Schwingungstechnik - eine Übersicht. Teil 2: Messgerätetechnik, Auswertungsverfahren und Kalibrierung)

I. Veit
Postfach 701050, 6000 Frankfurt 70, Frankfurt a. Main, Federal Rep. of Germany, Technisches Messen ATM, 44 (6), pp 217-225 (June 1977) 8 figs, 24 refs
(In German)

Key Words: Sound transmission, Measuring instruments, Measurement techniques, Correlation techniques

This is the second part of a survey article presenting a detailed review of acoustic transducers, as well as methods and instrumentation for the analysis of the measured data. The most important measuring instruments and methods for the measurement of sound-pressure levels and for the analysis of frequencies are described. In addition, the possibilities for the application of correlation techniques are discussed (Part 1: T.M., 44 (5), pp 163-173 (May 1977).

77-1946

Optical Detection of Blade Flutter

W.C. Nieberding and J.L. Pollack
Lewis Res. Center, NASA, Cleveland, OH., ASME Paper No. 77-GT-66

Key Words: Blades, Flutter, Optical measuring instruments

A joint Air Force-NASA flutter research program using full-scale turbine engines is being conducted at the NASA Lewis Research Center. The initial phase is a fan flutter program using a YF-100 turbofan engine. In these tests, dynamic strain gages mounted on rotor blades are being used as the primary instrumentation for detecting the onset of flutter and defining the vibratory mode and frequency. Optical devices, however, are being evaluated for performing the same measurements as well as providing supplementary information on the vibratory characteristics. Two separate methods are being studied: stroboscopic imagery of the blade tip and photoelectric scanning of blade tip motion. Both methods give visual data in real time as well as video tape records. The optical systems are described and representative results are presented. The potential of this instrumentation in flutter research is discussed.

77-1947

Hydro-Optic Vibration Detector

J.C. McKechnie

Dept. of the Navy, Washington, D.C., PAT-APPL-774 285/GA, 17 pp (Mar 4, 1977) Avail: This Government-owned invention available for U.S. licensing and, possibly, for foreign licensing. Copy of application available NTIS

AD-D003 792/9

Key Words: Vibration detectors, Vibration meters

A vibration sensing and measuring system is disclosed as including a series connected signal generator, vibration sensor adapted for being connected to any appropriate compatible object from which the vibration information and/or parameters analogous thereto are desired, and utilization apparatus - such as, for example, a readout - for indicating or otherwise utilizing the measured vibrations of said vibrating apparatus.

TECHNIQUES

(Also see Nos. 1923, 2039)

77-1948

Obtaining Good Results from an Experimental Modal Survey

E.L. Peterson and A.L. Klosterman

Experimental Div., SDRC-International, Inc., - UK Branch, Harrow, Middlesex, UK, SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 253-274 (Apr 4-6, 1977) 11 figs, 4 refs

Key Words: Modal tests, Computer-aided techniques

With the advent of mini-computer based data analysis systems, data collection and analysis techniques have become sophisticated and can be automated. However, it is possible to get poor results (and not know it) by either collecting bad data or by analyzing it inaccurately. The accuracy and consistency of the mode shape data and modal parameters is especially important when the empirical data is going to be interfaced with analytical data from finite element models in a system simulation. The authors discuss several areas which are most likely to be troublesome.

77-1949

Measuring of Noise Emission in the Neighborhood of Expanded Industrial Plants (Messung der Schallimmission in der Umgebung von grossflächigen Industrieanlagen)

D. Kühner

Bayer AG, IN AP-MSR, Bayerwerk, 5090 Leverkusen, Federal Rep. of Germany, Technisches Messen ATM, 44 (6), pp 199-208 (June 1977) 12 figs, 2 tables, 18 refs

(In German)

Key Words: Noise measurement, Industrial facilities, Measurement techniques, Regulations

Using the results obtained from ambient noise measurements in the neighborhood of chemical plants by means of a new automatic technique, problems concerning the application of noise regulations are discussed and suggestions for their reformulation are made. Additionally, a new concept is presented for a statistical based comparison between measured values and threshold values.

77-1950

An Investigation of the Measurement of Transmission Loss

D.A. Bies and J.M. Davies

Dept. of Mech. Engrg., Univ. of Adelaide, Adelaide, South Australia 5000, J. Sound Vib., 53 (2), pp 203-221 (July 22, 1977) 11 figs, 1 table, 13 refs

Key Words: Sound transmission loss, Measurement techniques

The determination, by means of the two reverberant room method, of the transmission loss of apertures of even very large size is shown to be practical and a new data reduction procedure is presented. The new procedure requires the measurement of sound pressure level differences in both directions and measurements of the Sabine absorption in each room. The use of apertures of large size as effective standard partitions of zero transmission loss is then possible and has allowed the investigation of the measurement technique. Theoretical analysis and measurements on nine different apertures in four different testing facilities have provided the data upon which the conclusions are based.

COMPONENTS

SHAFTS

77-1951

On Bounds for the Torsional Stiffness of Shafts of Varying Circular Cross Section

E. Reissner

Dept. of Appl. Mech. and Engrg. Sciences, California Univ., San Diego, La Jolla, CA., 9 pp (May 1977) AD-A040 323/8GA

Key Words: Shafts, Variable cross section, Torsional response, Stiffness

The upper and lower bound formulas for the torsional stiffness of shafts of varying circular cross section are computated. The general results are used to obtain explicit first-approximation bounds which, for the limiting case of the cylindrical shaft, reproduce the known elementary exact results.

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1886, 1898, 2036)

77-1952

Dynamic Crushing of Strain Rate Sensitive Box Columns

T. Wierzbicki and T. Akerström

Inst. of Fundamental Technological Res., Poland, SAE Paper No. 770 592, 13 pp, 12 figs, 10 refs

Key Words: Box beams, Columns, Dynamic response

The regular deformation patterns of axially compressed box section beams is analyzed. Assuming a simple collapse mechanism, the theory is then extended to cover the influence of strain rate sensitive material. The dynamic strength of a beam-column is significantly higher than the static strength. Correlation of the present theoretical results with the available experimental data is discussed.

77-1953

The Prediction of Transient Response of Beams by Transform Techniques

V.H. Neubert and V.P. Rangaiah

Dept. of Engrg. Sciences and Mech., Pennsylvania State Univ., State College, PA 16801, J. Sound Vib., 53 (2), pp 173-181 (July 22, 1977) 5 figs, 7 refs

Key Words: Beams, Shock excitation, Transient response, Laplace transformation, Mathematical models

Analysis of response of structures to shock loads is one of the important aspects of structural design in the design office. In the past, efficient mathematical models, which predict accurate dynamic response, were devised. A lumped parameter beam model based on mechanical impedance has been used to predict dynamic response, the dynamic response being the transient response arising when a ground or base motion is given to the beam. In the work reported here the transient response (shear force and bending moment) of a beam, when its ends are subjected to acceleration pulse or half-sine wave, has been computed by Laplace transform methods. The shear force and bending moment at the ends of the beam as computed by Laplace transform methods compare well with the values obtained by closed form solutions. The superiority of the Laplace transform solutions over normal mode solutions is demonstrated.

77-1954

Impulsive Loading of an Ideal Fibre-Reinforced Rigid-Plastic Beam

F. Laudiero and N. Jones

Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA., Rept. No. 77-3, 26 pp (Mar 1977) AD-A039 912/1GA

Key Words: Beams, Dynamic response, Fiber composites, Reinforced beams

This article examines the dynamic plastic response of an impulsively loaded ideal fibre-reinforced (strongly anisotropic) rigid-plastic beam. It is demonstrated that the response duration and permanent transverse displacements are significantly less than the corresponding quantities in an equivalent rigid perfectly plastic isotropic beam.

77-1955

Experiments on the Dynamic Response of a Flexible Strip to Moving Loads

D.M. Albrecht, E.G. Laenen, and C. Lin

IBM J. Res. Dev., 21 (4), pp 379-383 (July 1977) 6 figs, 1 table, 5 refs

Key Words: Strips, Movings strips, Magnetic tape, Dynamic response, Moving loads, Experimental data

Experimental findings are reported on the dynamic response of a flexible strip to moving loads traveling at an oblique angle to its edges. The strip is wrapped under tension around a pair of supporting pressurized cylinder halves. The moving loads are applied to the flexible strip at the gap between the two cylinder halves. A capacitance displacement transducer measures the dynamic response of the strip, which is shown in isometric perspective for various boundary conditions. It is shown that waves on the strip created by the moving loads can be eliminated by providing a hydrodynamic air film support to the flexible strip in the vicinity of the moving loads. Experiments demonstrate that response to the loads along the edges of the strip differs from that near its center, which is to be expected because of the reflection of flexural waves from the boundaries of the strip.

77-1956

The Dynamics and Optimal Control of Spinning Spacecraft with Movable Telescoping Appendages. Part C: Effect of Flexibility During Boom Deployment. Final Report

P.M. Bainum and P.K. James

School of Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-153220, 50 pp (May 1977) refs

N77-24163

Key Words: Spacecraft, Antennas, Stiffness

The dynamics of a spinning symmetrical spacecraft system during the deployment (or retraction) of flexible boom-type appendages were investigated. The effect of flexibility during boom deployment is treated by modeling the deployable members as compound spherical pendula of varying length (according to a control law).

BEARINGS

77-1957

A Numerical Solution of the Dynamic Characteristics of an Aerostatic, Porous Thrust Bearing Having a Uniform Film Subjected to Linear Axial Load Variations

R. Taylor

Univ. of Aston in Birmingham, UK, J. Mech. Engr. Sci., 19 (3), pp 122-127 (June 1977) 8 figs, 9 refs

Key Words: Dynamic structural analysis, Bearings

A numerical method of solution is presented for the pressure distribution in the uniform air film of a porous thrust bearing in which the top plate is subjected to vertical vibrational motion. From this pressure distribution it is possible to compute the bearing's dynamic characteristics, the knowledge of which is essential for the design of these bearings if unstable operating regions are to be avoided.

77-1958

A Variable Wave Speed Technique for the Steady-State Analysis of Low-Clearance Gas Bearings

J.W. White

Mech. and Aerospace Engrg., The Univ. of Tennessee, Knoxville, TN, J. Lubric. Tech., Trans. ASME, 99 (3), pp 339-345 (July 1977) 10 figs, 2 tables, 8 refs

Key Words: Gas bearings, Periodic response

A method is described which utilizes an artificial fluid viscosity as a means of adjusting the pressure wave speed in asymptotic steady-state analysis of gas bearings. The approach is shown to be useful for producing steady numerical solutions of low-clearance bearings with minimum computation. The technique is first developed for a rigid boundary step bearing of infinite width and then extended to the finite width case by a semi-implicit solution procedure. Last, the method is shown to be useful for the analysis of foil bearings in which case the pressure wave speed is "tuned" to that of the foil wave so as to produce an optimum computational approach to steady state.

BLADES

(Also see Nos. 1937, 2035)

77-1959

Effect of Modified Aerodynamic Strip Theories on Rotor Blade Aeroelastic Stability

P. Friedmann and C. Yuan

Univ. of California, Los Angeles, CA., AIAA J., 15 (7), pp 932-940 (July 1977) 4 figs, 24 refs

Key Words: Rotary wings, Blades, Aerodynamic stability

Various existing unsteady aerodynamic strip theories that have been developed in the past for both fixed and rotary wing aeroelastic analyses are modified to make them applicable to the coupled flap-lag-torsional aeroelastic problem of a rotor blade in hover. These corrections are primarily because of constant angle of attack, constant inflow, and variable freestream velocity due to lead-lag motion. The modified strip theories are incorporated in a coupled flap-lag-torsional aeroelastic analysis of the rotor blade in hover, and the sensitivity of the results to aerodynamic assumptions is examined.

77-1960
Torsional Flutter in Stalled Cascade
S. Yashima and H. Tanaka
Ishikawajima-Harima Heavy Industries, Tokyo, Japan,
ASME Paper No. 77-GT-72

Key Words: Blades, Flutter, Torsional response

Applying free streamline theory and singularity methods, a theoretical study is developed for the torsional flutter problem in fully stalled cascade. Aerodynamic moment acting on a vibrating blade is calculated for some cascade conditions. Computational results show that critical reduced frequency is much higher in the case of stalled cascade than unstalled one and affected by the position of pitching center.

DUCTS

(Also see No. 1963)

77-1961
Effect of Flow on Quasi-One-Dimensional Acoustic Wave Propagation in a Variable Area Duct of Finite Length
E. Lumsdaine and S. Ragab
Dept. of Mech. and Aerospace Engrg., Univ. of Tennessee, Knoxville, TN 37916,
J. Sound Vib., 53 (1), pp 47-61 (July 8, 1977) 8 figs, 16 refs

Key Words: Ducts, Variable cross-section, Sound waves, Wave propagation, Perturbation theory

The general equation for the velocity potential of quasi-one-dimensional acoustic wave motion in a variable area, finite duct with one-dimensional flow is derived by using a perturbation technique. The non-linear second-order partial differential equation is linearized and then solved, by either a power series expansion method or the Runge-Kutta fourth-order method, for harmonic time dependence. The boundary condition taken at the duct mouth is that of matching the impedance of the duct sound field to that of the radiation field at the duct opening. Three axial Mach number variations along the duct axis are considered and the results obtained are compared with those for the case of constant Mach number, to determine the influence of the axial velocity gradient on sound propagation. The effect of flow on the radiation impedance is also considered.

77-1962
Sound Attenuation in Acoustically Lined Curved Ducts in the Absence of Fluid Flow
S.H. Ko and L.T. Ho
New London Lab., Naval Underwater Systems Center, New London, CT 06320,
J. Sound Vib., 53 (2), pp 189-201 (July 22, 1977) 10 figs, 2 tables, 8 refs

Key Words: Ducts, Acoustic linings, Noise reduction

A study has been made of the sound attenuation in a lined curved duct with rectangular cross-section. In this study, the derivation of the eigenvalue equation was based on the continuity of the normal component of the particle displacement and the matching of the acoustic pressure on the acoustic lining surface. The sound attenuation was calculated by using the acoustic energy expression for the waves propagating in a curved duct. For a given duct geometry and known acoustic lining impedances, a computer program was developed to solve for the eigenvalues and to obtain the sound attenuation of the propagating waves in the lined curved duct. It was found that in the case studied here the fundamental mode was least attenuated. The total sound attenuation was calculated on the assumption that the amplitudes for all propagating waves were equal at a given frequency. Effects of aspect ratio, bend angle and the acoustic impedance on the sound attenuation were investigated in the present work.

FRAMES, ARCHES

77-1963
On Lateral-Torsional Instability of Arches Subjected to Motion-Dependent Loading
M. Farshad
School of Engrg., Pahlavi Univ., Shiraz, Iran,
J. Sound Vib, 53 (2), pp 165-171 (July 22, 1977) 2 figs, 11 refs

Key Words: Rings, Arches, Torsional response, Flutter

The problem of dynamic lateral-torsional instability of circular arches acted upon by generally non-conservative forces is treated herein. The influence of motion-dependency of loading on the stability characteristics is determined in certain cases. It is also found that a semi-circular arch which is only capable of rigid-mode-buckling [illegible]rding to static analysis may lose its stability through [illegible]d modes if the dynamic criterion is utilized.

GEARS

(See No. 1929)

LINKAGES

(See No. 1894)

PANELS

77-1964

Influence of Support Location on Panel Flutter

P. Shanthakumar, V.T. Nagaraj and P. Narayana Raju
Design Bureau, Hindustan Aeronautics Ltd., Bangalore 560017, India, J. Sound Vib., 53 (2), pp 273-281 (July 22, 1977) 7 figs, 3 tables, 10 refs

Key Words: Panels, Flutter, Galerkin method, Finite element technique

The Galerkin finite element method is used to obtain the flutter characteristics of two-dimensional panels, with use also made of an improved beam element with an internal node. For panels with both ends simply supported or clamped, it is shown that only a few elements are required to obtain very accurate results. The method has been used to predict the flutter characteristics of simply supported panels with the following combinations of support locations: rear support kept fixed at the trailing edge and the forward support moved aftwards; forward support held fixed at the leading edge and the rear support moved progressively forwards; both supports moved symmetrically towards the center.

PIPES AND TUBES

77-1965

Mathematical Model for Cross-Flow Induced Vibrations of Tube Rows

S.S. Chen
Argonne National Lab., Argonne, IL, Rept. No. ANL-CT-77-4, 49 pp (Sept 1976) refs
N77-24435

Key Words: Tubes, Heat exchangers, Fluid- induced excitation, Mathematical models

A mathematical model for flow-induced vibrations in heat exchanger tube banks is presented which includes the effects of vortex shedding, fluidelastic coupling, drag force, and fluid inertia coupling. Once the fluid forces are known, the model can predict the details of complex tube-fluid interactions: natural frequencies and mode shapes of coupled vibrations; critical flow velocities; responses to vortex shedding, drag force, and other types of excitations; and the dominant excitation mechanism at a given flow velocity. The analytical results are in good agreement with the published experimental results.

77-1966

The Effect of the Surroundings on the Natural Frequencies of Rod-Shaped Structural Elements (Beeinflussung der Eigenfrequenzen stabartiger Bauteile durch Umgebungsmedien)

D. Albrecht and G. Tschirner
Ingenieurhochschule Zittau, Sektion Kraftwerksanlagen und Energieumwandlung, German Dem. Rep., Maschinenbautechnik, 26 (4), pp 158-160 (Apr 1977) 7 figs, 4 refs
(In German)

Key Words: Piping systems, Heat exchangers, Fluid-induced excitation, Natural frequencies

The author reports the results of an experimental investigation of the effects of a stationary covibrating media on the vibration of a submerged rod-shaped structural element. The information gained is useful in the design of piping systems of heat exchangers. The investigation is extended to flowing media. These results, as well as the damping effect of the media, will be described later.

77-1967

A Method to Design Shell-Side Pressure Drop Constrained Tubular Heat Exchangers

K.P. Singh and M. Holtz
Joseph Oat Corp., Camden, NJ, J. Engr. Power, *Trans. ASME*, 99 (3), pp 441-448 (July 1977) 5 figs, 20 refs

Key Words: Tubes, Heat exchangers, Nuclear power plants, Fluid-induced excitation, Design techniques

In shell and tube heat exchangers, the triple segmental baffle arrangement has been infrequently used, even though the potential of this baffle system for high thermal effectiveness with low pressure drop is generally known. This neglect seems to stem from the lack of published design guidelines on the subject. Lately, however, with the rapid growth in the size of nuclear heat exchangers, the need to develop unconventional baffling pattern has become increasingly important. A method to effectively utilize the triple segmental concept to develop economical designs is presented herein. The solution technique given in this paper is based on a flow model named "Piecewise Continuous Cosine Model." The solution procedure easily lends itself to detailed analysis to determine safety against flow-induced vibrations.

77-1968

Pulsation in Centrifugal Pump and Piping Systems

C.R. Sparks and J.C. Wachel

Southwest Research Inst., San Antonio, TX, Hydrocarbon Processing, 56 (7), pp 183-189 (July 1977) 15 figs, 3 refs

Key Words: Piping systems, Centrifugal pumps, Fluid-induced excitation, Resonant response, Vibration response

The ability of centrifugal machines to amplify or attenuate piping pulsations has been documented in both the field and the laboratory. Co-existing acoustic resonances of the piping system can further amplify pulsations at frequencies corresponding to conventional organ pipe resonances of pipe components or by interacting system acoustic resonances of multiple components. The net result is that relatively low level excitation sources such as vortex formation at junctions in the piping systems can be amplified to levels which cause failure of piping and compressor or pump internals. Techniques for prediction of these resonant buildups are described enabling minimization of such pulsation problems. Case histories are presented to prove the applicability of acoustically modifying pump and piping internal design to solve system vibration problems.

77-1969

Study of Pump Pulsation, Surge, and Vibration Throws Light on Reliability vs. Efficiency

W.H. Fraser, I.J. Karassik, and A.R. Bush

Worthington Pump, Inc., Power, 121 (8), pp 46-49 (Aug 1977) 5 figs

Key Words: Piping systems, Centrifugal pumps, Fluid-induced excitation, Vibration response

Unwanted hydraulic phenomena limit performance, wider flow range, and lower net positive suction head of centrifugals. In the article the state-of-the-art on solutions for common difficulties is presented.

77-1970

Dynamic Characteristics of a Pneumatic Flapper Valve

C.R. Burrows and R.G. Peckham

School of Engrg. and Appl. Sciences, Univ. of Sussex, UK, J. Mech. Engr. Sci., 19 (3), pp 113-121 (June 1977) 8 figs, 18 refs

Key Words: Dynamic structural analysis, Pneumatic valves

The validity of using the steady-state characteristics of a pneumatic flapper-nozzle valve under dynamic conditions is examined by comparing experimental frequency response results with those generated from a digital simulation model.

77-1971

A Method for Estimating Steam Hammer Effects on Swing-Check Valves During Closure

E.M. Uram

Dept. of Mech. Engrg., Univ. of Bridgeport, Bridgeport, CT., J. Engr. Power, Trans. ASME, 99 (3), pp 437-440 (July 1977) 4 figs, 4 refs

Key Words: Steam hammer, Valves

This paper presents an analysis and interpretation of the valve disk dynamics and steam-hammer effects that allows a rapid estimate of the disk impact speed. Simple relationships are used to represent the nature of the valve pressure drop variation during closure in a phase-plane or hodograph analysis which allows determination of the disk velocity at closure.

PLATES AND SHELLS

(Also see Nos. 1906, 1909)

77-1972

Fluid-Loaded Vibration of an Elastic Plate Carrying a Concentrated Mass

B.E. Sandman

Naval Underwater Systems Center, Newport, RI 02840, J. Acoust. Soc. Amer., 61 (6), pp 1503-1510 (June 1977) 6 figs, 16 refs

Key Words: Plates, Fluid-induced excitation

The vibration of a simply supported rectangular plate with a discretely attached mass and fluid radiation loading is considered. The equations of motion are solved by utilizing the in vacuo eigenfunctions of a homogeneous panel as the basis for Fourier decomposition of both the fluid loading and attached mass loading. A modal matrix equation is established for the interactive system which includes the cross-modal coupling induced by the discrete mass and acoustic fluid. The solution is exemplified by the numerical investigation of a centrally excited plate with a concentrated mass at center and off-center locations. The influence of mass attachment upon both the plate response and radiated pressure is illustrated.

77-1973

Vibration Response of Fluid-Loaded Structures to Low-Speed Flow Noise

K.L. Chandiramani

Bolt Beranek and Newman, Inc., Cambridge, MA 02138, J. Acoust. Soc. Amer., 61 (6), pp 1460-1470 (June 1977) 6 figs, 9 refs

Key Words: Plates, Fluid-induced excitation

Consider a spatially homogeneous and temporally stationary random pressure field exciting a spatially homogeneous structure. It is well known that when the power exchange between the pressure field and the structure results from a "surface interaction" rather than from a scattering-induced "edge interaction," it is immaterial whether a finite or infinitely extended model of the structure is used to calculate this power exchange. This equivalence is discussed and used to estimate vibration response of fluid-loaded structures when excited by a low-speed turbulent boundary-layer flow. Connections, established previously for structures in vacuo, between group velocity, modal density, and point and line conductances, are also generalized to apply to fluid-loaded structures. Finally, an approximate but simple method is suggested for estimating vibration characteristics of spatially nonhomogeneous structures excited by surface interactions.

77-1974

Vibrations of Constrained Plates by a Rayleigh-Ritz Method Using Lagrange Multipliers

L. Klein

Dept. of Aerospace and Mech. Sciences, Princeton Univ., Princeton, NJ, Quart. J. Mech. and Appl. Math., 30 (1), pp 51-70 (Feb 1977) 11 figs, 10 refs

Key Words: Plates, Natural frequencies, Mode shapes

The natural frequencies and mode shapes of plates with a wide variety of support conditions are accurately determined by a Rayleigh-Ritz analysis using Lagrange multipliers. The internal stresses and bending moments arising at the supports are also determined directly by the method. In the first part, emphasis is placed on the role played by the constraint or support conditions in the convergence of the method. In the second part an example is studied for which independent results are available, and the analysis is extended to more general support configurations.

77-1975

Influence of an Unbounded Elastic Plate on the Radiation of Sound by a Point Source

G.H. Schmidt

Dept. of Civil Engrg., Univ. of Technology, Delft, Holland, J. Sound Vib., 53 (2), pp 289-300 (July 22, 1977) 7 figs, 9 refs

Key Words: Plates, Sound waves, Point source excitation

A sound source is placed at a finite distance from an unbounded elastic plate. The source and the plate are submerged in an unbounded fluid at rest. The source has harmonic time dependence. A linear theory is used to compute how much energy is radiated into the fluid and how much energy travels along the plate from the source to infinity.

77-1976

Holographic Study of Flexural Vibrations of Uniform Circular Plates

O. Rusu and D. Borza

Polytechnik Institut of Bucarest, Rev. Roum. Sci. Techn. - Mec. Appl., 22 (2), pp 267-286 (Mar-Apr 1977) 32 figs, 5 tables, 17 refs

Key Words: Circular plates, Flexural vibration, Holographic techniques

This paper describes a theoretical and experimental study of flexural vibrations of uniform circular plates having different boundary conditions. The theoretical part describes the movement equations and determines the eigenvalues, giving also numerical calculations. Then, there are presented two adequate experimental techniques – holography and classical interferometry.

77-1977

Vibration Analysis of Variable Thickness Discs Subjected to Centrifugal and Thermal Stresses

W. Kennedy and D. Gorman

Dept. of Dynamics and Control, Univ. of Strathclyde, Glasgow G1 1XJ, UK, J. Sound Vib., 53 (1), pp 83-101 (July 8, 1977) 11 figs, 7 tables, 17 refs

Key Words: Disks, Variable cross section, Flexural vibration, Natural frequencies

The paper presents a numerical technique whereby the natural frequencies of transverse vibration of a disc of varying thickness profile may be determined when the disc is subject to the combined actions of centrifugal loading and complex radial temperature distribution. The study includes an optimizing program for the generation of the most representative temperature gradient across the disc surface, resulting from peripheral heating and surface convection. In-plane stress levels, arising from the thermal gradient and rotational effects, are determined at a number of radially spaced points across the disc and, by means of annular finite elements, the effect of the resulting stress distribution upon the natural frequencies of the disc is examined.

77-1978

Forced Vibrations of a Rectangular Plate with Non-Uniform Thickness

T. Sakata
Dept. of Mech. Engrg., Chubu Inst. of Tech., Kasugai, Nagoya-sub., Japan, 487, J. Sound Vib., 53 (1), pp 147-152 (July 8, 1977) 4 tables, 14 refs

Key Words: Rectangular plates, Variable cross section, Periodic excitation

The dependence on frequency of the maximum deflection and surface stresses of a simply supported rectangular plate subjected to a uniformly distributed sinusoidal excitation is discussed. Simple formulae are proposed for estimating the deflection and surface stresses. The thickness of the plate varies linearly in one direction parallel to a side of the plate.

77-1979

Response of Structures to Random Noise

W.A. Nash
Dept. of Civil Engrg., Massachusetts Univ., Amherst, MA, Rept. No. AFOSR-TR-77-0696, 80 pp (Nov 1976)
AD-A040 513/4GA

Key Words: Plates, Shells, Free vibration, Random excitation, Statistical analysis

A new method has been developed for determination of natural frequencies and associated mode shapes of thin elastic plates and shallow shells. The method permits consideration of arbitrary boundary conditions along each side of a polygonal plate or polygonal plan-form shell and further offers a comprehensive evaluation of how well the boundary conditions have been satisfied along each edge. The structural reliability of geometrically nonlinear structures subject to stationary random excitation has been investigated by two approaches. A technique has been developed for prediction of the statistical characteristics of the response of a nonlinear system to nonstationary random excitation.

77-1980

Vibrations of Initially Stressed Cylinders of Variable Thickness

S.K. Radhamohan and M. Maiti
Structural Engrg. Div., Vikram Sarabhai Space Centre, Trivandrum - 695022, India, J. Sound Vib., 53 (2), pp 267-271 (July 22, 1977) 2 figs, 4 tables, 7 refs

Key Words: Cylindrical shells, Variable cross section

Natural frequencies and buckling loads for cylindrical shells having linearly varying thickness are obtained by using a segmentation technique. The effect of the thickness variation on the frequencies of a cylindrical shell is studied. Frequencies are also calculated for a cylinder of variable thickness under axial compression and a relationship between the frequency and axial compression is obtained for a particular wave number.

77-1981

Resonant Response of Orthotropic Cylindrical Shells

G.B. Warburton and S.R. Soni
Dept. of Mech. Engrg., Univ. of Nottingham, Nottingham NG7 2RD, UK, J. Sound Vib., 53 (1), pp 1-23 (July 8, 1977) 12 tables, 14 refs

Key Words: Cylindrical shells, Orthotropism, Resonant response, Modal analysis, Hysteretic damping, Transverse shear deformation effects, Rotatory inertia effects

The resonant response of simply supported, thin and thick, orthotropic cylindrical shells is determined by using modal analysis, for three levels of hysteretic damping. This response is significantly changed if the larger of the elastic constants associated with normal stresses refers to the meridional, instead of the circumferential, direction. These changes may be related to changes in the relevant natural frequency. The causes of the latter are studied by considering the modal amplitudes and the contributions to the strain energy function associated with the various stress resultants.

77-1982

Dynamics of a Cylindrical Shell System Coupled by Viscous Fluid

T.T. Yeh and S.S. Chen
Components Tech. Div., Argonne National Lab., 9700 S. Cass, Argonne, IL 60439, J. Acoust. Soc. Amer., 62 (2), pp 262-270 (Aug 1977) 8 figs, 1 table, 9 refs

Key Words: Cylindrical shells, Fluid-induced vibration, Nuclear reactor containment

This study was motivated by the need to design the thermal shield in reactor internals and other system components to avoid detrimental flow-induced vibrations. The system component is modeled as two coaxial shells separated by a viscous fluid. In the analysis, Flügge's shell equations of motion and linearized Navier-Stokes equation for viscous fluid are employed. First, a traveling-wave-type solution is taken for shells and fluid. Then, from the interface conditions between the shells and fluid, the solution for the fluid medium is expressed in terms of shell displacements. Finally, using the shell equations of motion gives the frequency equation, from which the natural frequency, mode shape, and modal damping ratio of coupled modes can be calculated.

STRUCTURAL

77-1983

Dynamic Characteristics of Core Wall Structures Subjected to Torsion and Bending

D.V. Mallick and R. Dungar

Tripoli Univ., Struc. Engr., 55 (6), pp 251-261 (June 1977) 12 figs, 1 table, 14 refs

Key Words: Walls, Dynamic structural response, Finite element technique

A general method using the theory of thin walled structures is given for determining the natural frequencies and mode shape of core wall structures having closed or open section, subjected to torsion and bending using a finite element approach. Consistent mass matrices related to torsion and bi-moment effects have been derived using shape functions corresponding to the static deflection configuration and an assumed polynomial deflection configuration. The stiffness matrix developed on the basis of the proposed theory includes warping deformations and its use with the finite element method enables the possible changes in the story segments to be fully represented, such as the thickness of the wall and the cross-sectional characteristics.

77-1984

Practical Considerations in a Field Evaluation of Acoustically Effective Party Walls and Floors

J.K. Hilliard

Hilliard & Bricken, Consulting Acoustical Engrs., 1971 E. Fourth St., Suite 18, Santa Ana, CA 92705, Noise Control Engr., 8 (3), pp 138-142 (May/June 1977) 6 figs, 3 tables, 14 refs

Key Words: Walls, Noise reduction, Standards

Since the California Noise Insulation Standards became effective, many developers are conducting field tests on the party wall in their model homes; some cities require field tests upon completion, to determine compliance with this regulation. These tests are made in accordance with ASTM and A-weighted sound level reduction methods. The author discusses the results of measurements made on a variety of walls, indicating the average amount of attenuation that can be expected from a completed construction.

TIRES

77-1985

Impact Vibrations of Rolling Tires

M.R. Barone

Research Labs, General Motors Corp., SAE Paper No. 770 612, 8 pp, 9 figs, 8 refs

Key Words: Tire characteristics, Ride dynamics

This paper is concerned with in-plane (horizontal and vertical) tire vibrations due to "impulsive" input forces which result when tires impact small or cleat-like bumps (e.g., tar strips). Such high frequency vibrations (20-100 Hz) are commonly associated with vehicle harshness. Quantitative information relating output spindle forces to different cleat inputs is obtained from rolling drum experiments on radial tires.

SYSTEMS

ABSORBER

(Also see No. 1990)

77-1986

Analysis and Experiments of the Electro-Magnetic Servo Vibration Damper

Y. Okada

Faculty of Engrg., Ibaraki Univ., Hitachi, Bull. JSME, 20 (144), pp 696-702 (June 1977) 25 figs, 1 table, 5 refs

Key Words: Vibration dampers, Modal damping, Active damping, Machine tools

To improve the modal damping of a structure, some types of active dampers such as an electro-dynamic or an electro-hydraulic servo damper were investigated and reported.

77-1987

Materials for Noise and Vibration Control

W. E. Purcell

Bechtel Corp., San Francisco, CA, S/V, Sound Vib., 11 (7), pp 4-29 (July 1977)

Key Words: Absorbers (materials), Acoustic absorbers, Noise barriers, Vibration dampers, Vibration Isolators

A comprehensive mini-handbook for the selection and application of commonly available noise and vibration control materials. Basic information is provided on the characteristics of sound absorption, sound barrier, vibration damping, and vibration isolation materials. Application recommendations are also included.

ACOUSTIC ISOLATION

(See No. 1987)

NOISE REDUCTION

(Also see Nos. 1924, 1984, 1992, 1996, 1999, 2000, 2001, 2023)

77-1988

The Acoustic Modes of a Rectangular Cavity Containing a Rigid, Incomplete Partition

M. Petyt, G.H. Koopmann, and R.J. Pinnington

Inst. of Sound and Vibration Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 53 (1), pp 71-82 (July 8, 1977) 10 figs, 3 tables, 8 refs

Key Words: Cavities, Enclosures, Noise reduction

A theoretical and experimental study of the acoustic modes of a rectangular cavity containing a rigid, incomplete partition is presented. The theoretical results are obtained by using finite element techniques. It is shown that component mode synthesis techniques, developed for dynamic structural analysis, can be used for acoustic analysis to increase efficiency. The experimental measurements were made on a Perspex model.

77-1989

The Suppression of Sound by Sound of Higher Frequency

W.L. Willshire, Jr.

Applied Research Labs, Texas Univ. at Austin, TX, Rept. No. ARL-TR-77-22, AFOSR-TR-77-0656, 135 pp (May 1977)
AD-A040 008/5GA

Key Words: Noise reduction

The purpose of this research was to study the suppression of one sound by another sound of higher frequency. More specifically, the planar propagation in air of a finite amplitude tone (the pump) and a smaller amplitude tone (the weak signal) of lower frequency was investigated both theoretically and experimentally. Suppression is caused by an acoustic modulation process.

77-1990

Active Sound Absorption

G.A. Mangiante

Laboratoire de Mecanique et d'Acoustique, Equipe "Absorbeurs Acoustiques Actifs", 31 Chemin Joseph Aiguier, 13274 Marseille Cedex 2, France, J. Acoust. Soc. Amer., 61 (6), pp 1516-1523 (June 1977) 12 figs, 81 refs

Key Words: Active absorption, Acoustic absorption

Sound attenuation is usually obtained by means of absorbing materials. This technique, which works well for sounds of medium and high frequencies, is very inefficient at low frequencies, because the thickness of absorbing material necessary to produce a constant attenuation increases with decreasing frequency. There is another technique by which destructive interference is used to silence sound fields: it is active sound absorption. Hitherto, this was based on Young's principle of interference. This paper proposes a general theory, using Huygens' principle, for three-dimensional sound-wave propagation. Some experiments are also reported and discussed.

77-1991

Noise Barrier Design Handbook

M.A. Simpson

Bolt Beranek and Newman, Inc., Arlington, VA., Rept. No. BBN-3199, FHWA/RD-76-58, 269 pp (Feb 1976)

Key Words: Structural design, Noise barriers, Handbooks

This handbook is intended to be a tool for use by the highway designer to aid in the design of noise abatement barriers. It provides a means of defining the geometric configuration of a barrier to produce a desired noise reduction, and also provides a design evaluation and selection procedure in which specific barriers are detailed, and then evaluated in terms of cost, acoustical characteristics, and non-acoustical characteristics (such as durability, ease of maintenance, safety, aesthetics and community acceptance). This handbook guides the designer in the preparation of a design which he believes will be accepted by the community and perform as desired both acoustically and non-acoustically, for reasonable cost.

AIRCRAFT

(Also see No. 2021)

77-1992

Airframe Noise Prediction Method

M.R. Fink

United Technologies Research Ctr., East Hartford,

CT, Rept. No. UTRC/R77-912607-11, FAA-RD-77-29, 141 pp (Mar 1977)
AD-A039 664/8GA

Key Words: Aircraft noise, Noise prediction

A noise component method is presented for calculating airframe noise. Noise from clean wing and tail surface is represented as trailing edge noise caused by the turbulent boundary layer. Landing gear noise is given by an empirical representation of model data.

77-1993

Interior and Exterior Fuselage Noise Measured on NASA's C-8A Augmentor Wing Jet-STOL Research Aircraft

M.D. Shovlin
Ames Research Ctr., NASA, Moffett Field, CA., Rept. No. NASA-TM-X-73235; A-7012, 50 pp (Apr 1977) refs
N77-24137

Key Words: Aircraft noise, Noise measurement

Interior and exterior fuselage noise levels were measured on NASA's C-8A Augmentor Wing Jet-STOL Research Aircraft in order to provide design information for the Quiet Short-Haul Research Aircraft (QSRA), which will use a modified C-8A fuselage. The noise field was mapped by 11 microphones located internally and externally in three areas: mid-fuselage, aft fuselage, and on the flight deck. Noise levels were recorded at four power settings varying from takeoff to flight idle and were plotted in one-third octave band spectra. The overall sound pressure levels of the external noise field were compared to previous tests and found to correlate well with engine primary thrust levels. Fuselage values were 145 + or - 3 dB over the aircraft's normal STOL operating range.

77-1994

Flight Effects on JT8D Engine Jet Noise Measured in a 40 x 80 Tunnel

F.G. Strout and A. Atencio, Jr.
Boeing Commercial Airplane Co., Seattle, WA., J. Aircraft, 14 (8), pp 762-767 (Aug 1977) 18 figs, 3 refs

Key Words: Aircraft noise, Noise measurement

A JT8D-17 turbofan engine was tested in the NASA Ames Research Center 40 x 80 ft wind tunnel to determine flight effects on jet noise. The engine was configured as a baseline with conical nozzle, a quiet-nacelle 20-lobe ejector/suppressor, and an internal mixer with conical nozzle. Tunnel-off and tunnel-on noise tests were conducted over a range of nozzle pressure ratios (1.2 to 2.1), primary jet velocities (275 to 550 m/sec), and tunnel velocities up to 100 m/sec. Aft quadrant noise data were measured by a pair of traversing microphones located on a 3-m sideline relative to the engine centerline. Unique correlations and analysis procedures were developed in order to define far-field flight effects from the relatively near-field noise measurements.

77-1995

Some Measured and Calculated Effects of Forward Velocity on Propeller Noise

R.J. Pegg, F. Farassat, and B. Magliozzi
Langley Research Ctr., NASA, Hampton, VA., ASME Paper No. 77-GT-70

Key Words: Propeller noise, Noise measurement

The results of a program investigating the sources of noise in unshrouded propellers under forward flight conditions and a comparison with theory are reported. Tests were conducted using an instrumented three-bladed propeller installed on a turbine-powered, twin-engine, general aviation airplane. Measurements included far-field noise on the ground and on the aircraft wing tip, propeller blade surface pressures, atmospheric turbulence, and aircraft operating conditions.

77-1996

Flow Noise; A Perspective on Some Aspects of Flow Noise, and of Jet Noise in Particular - Part II

A. Powell
David W. Taylor Naval Ship Res. and Dev. Center, Bethesda, MD 20084, Noise Control Engr., 8 (3), pp 108-119 (May/June 1977) 31 figs, 142 refs

Key Words: Jet engines, Jet noise, Aircraft noise, Noise reduction

The jet engine's vast acoustic power has motivated extensive research into the implications and control of its mechanism. In the second half of a two-part review, the author continues his analysis of the technical and theoretical developments in the field of flow noise.

77-1997

Wind-Tunnel Investigation of Vortex Refraction Effects on Aircraft Noise Propagation

R.W. Jeffery, E.G. Broadbent, and A.F. Hazell

Royal Aircraft Establishment, Farnborough, Hants, UK, J. Aircraft, 14 (8), pp 737-745 (Aug 1977) 17 figs, 8 refs

Key Words: Aircraft noise, Noise reduction, Wind tunnel tests

One possible method for reducing aircraft flyover noise is to site the engines so that the wing vortex can refract sound away from the ground. A series of experiments was carried out in the RAE 24-ft wind tunnel using a model of the HP 115 slender delta research aircraft, which produced a strong leading-edge vortex when set at incidence. The engine noise was simulated by a Hartmann whistle mounted above the engine intake. The results are compared with a theoretical prediction based on ray theory and a simplified representation of the wing vortex structure.

77-1998

Evaluation of Proposed Standards for Aircraft Flyover Noise Analysis Systems

D.J. Stouder and J.C. McCann

McDonnell Douglas Corp., Long Beach, CA., J. Aircraft, 14 (8), pp 713-719 (Aug 1977) 3 figs, 12 tables, 4 refs

Key Words: Aircraft noise, Noise measurement, Standards

A unique test is discussed in which identical tape recordings of aircraft flyover noises were analyzed by 12 different organizations in the United States and Europe to determine the degree of uniformity in data analysis that could be achieved. Although all organizations did not use the same analysis system, each system conformed to standard specifications proposed by a Society of Automotive Engineers Instrumentation and Analysis Subcommittee. The purpose of the test was to evaluate the proposed standard. The statistical analyses of the test results are presented. Also described are the proposed standard, the elements of the evaluation test, and the analysis systems used.

77-1999

Static and Flyover Noise Measurements of an Inverted Profile Exhaust Jet

F.W. Burcham, Jr., P.L. Lasagna and F.J. Kurtenbach

Dryden Flight Research Ctr., NASA, Edwards, CA., ASME Paper No. 77-GT-81

Key Words: Aircraft noise, Noise reduction

Tests using a TF30 mixed flow afterburning turbofan engine in an F-111 airplane were conducted to study the noise characteristics of an inverted velocity profile jet. Full-authority digital engine control allowed the inverted profile jet to be compared to a uniform jet of equal thrust statically and in flight.

77-2000

Noise Reduction Potential for the Existing Business Jet Fleet

W.J. Galloway, J.F. Wilby, and H.C. True

Bolt Beranek and Newman, Inc., Canoga Park, CA., ASME Paper No. 77-GT-76

Key Words: Aircraft noise, Noise reduction

The business jet fleet registered in the U.S. as of July 1975 consisted of approximately 1500 aircraft, of which only 10 percent were powered by new, medium bypass ratio turbofan engines, and 75 percent by turbojet engines. A review of the noise reduction potential for existing aircraft has been completed on a model-by-model basis. An optimal combination of flight operational procedures and noise suppression techniques for existing engines has been derived for each aircraft model to minimize noise levels at FAR 36 certification measurement locations, consistent with existing noise control technology and operating economics. The alternative of new engine installations has also been evaluated. Comparisons between noise levels for modified and unmodified aircraft are presented.

77-2001

Air Transport Noise Reduction

R.J. Koenig

Environmental Res. Branch, ARD-550, Federal Aviation Admin., 2100 Second St., SW, Washington D.C. 20591, Noise Control Engr., 8 (3), pp 120-130 (May/June 1977) 18 figs, 2 tables, 41 refs

Key Words: Aircraft noise, Human response, Noise reduction

Aircraft noise is a critical constraint on the growth of civil aviation. The author reviews efforts to reduce the impact on people who live in areas surrounding airports. The discussion includes regulations and recent federal aviation noise abatement policy, trends in air transport noise, and noise reduction of the older, preregulation transport fleet. Technology relating to future design aircraft noise levels is also summarized.

77-2002

Sound Radiation from Aircraft Wheel-Well/Landing-Gear Configurations

H.H. Heller and W.M. Dobrzynski

Abteilung Technische Akustik, DFVLR, Braunschweig, Germany, J. Aircraft, 14 (8), pp 768-774 (Aug 1977) 14 figs, 12 refs

Key Words: Aircraft noise, Landing gear

An experimental program was initiated to determine the noise radiation from landing-gear/wheel-well configurations of large commercial aircraft. Scale models of typical nose gear and main gear (synthesized from different type aircraft) were exposed to flow of typical landing approach speeds on a stationary outdoor wall-jet flow facility and attached to the wings of an aerodynamically very clean glider.

77-2003

Noise Characteristics of a Can-Type Combustor

B.N. Shivashankara and R.W. Crouch

Boeing Commercial Airplane Co., Seattle, WA., J. Aircraft, 14 (8), pp 751-756 (Aug 1977) 10 figs, 1 table, 9 refs

Key Words: Aircraft noise

The effects of flow rate, combustor temperature rise, inlet temperature, nozzle exit diameter, and duct length on spectral content, directionality, radiated sound power, and thermoacoustic efficiency are deduced experimentally using an 8-in.-diam combustor. Even at a high exit velocity of 900 fps, the combustor-on noise is seen to dominate jet noise. Internal and far-field spectra are similar below 1000 Hz (broadband with spikes at longitudinal duct resonance frequencies). Directionality is weak except at exit velocities in excess of 550 fps. At a given nozzle exit temperature and diameter, the internal overall sound pressure levels appear to be related linearly to the far-field levels.

77-2004

Methods and Techniques of Ground Vibration Testing

G. Piazzoli

Office National d'Etudes et de Recherches Aerospatiales, Paris, France, In: AGARD Flight Test Tech, 9 pp (Apr 1977) refs (N77-24107)
(In French)
N77-24110

Key Words: Aircraft vibration, Vibration tests

Flight vibration tests, an important and sophisticated part of the aeroelastic research carried out for prototype clearance and certification of production aircraft, are described along with methods used for dynamic investigations of structural stability. The different techniques for delivering excitation forces, the special equipment of measurement and conditioning, and present methods of data processing and analysis are illustrated. Typical installations on aircraft of various types are described.

77-2005

Flight Control System Structural Resonance and Limit Cycle Results

P.W. Kirsten

Air Force Flight Test Center, Edwards AFB, CA., In: AGARD Flight Test Tech., 17 pp (Apr 1977) (N77-24107)
N77-24108

Key Words: Aircraft vibration, Structural resonance

Theory, testing, and results pertaining to limit cycle and structural resonance characteristics of aircraft flight control are presented. Methods for insuring that limit cycling and structural resonance do not occur unexpectedly during flight are suggested. Ground tests and inflight envelope expansion tests were used with success in the past to determine limit cycle and structural resonance characteristics. Data obtained from these tests are presented for several aircraft. Also, control system modifications made on several aircraft to eliminate control system instabilities which were uncovered through ground testing are included. Additional topics are discussed which include digital sampling effects on limit cycle characteristics, large amplitude saturation limit cycles, and pilot-in-the-loop instabilities.

77-2006

Stabilization, Gust Alleviation and Elastic Mode Control for an Aircraft Model Moving in the Wind Tunnel

G. Hoffmann

European Space Agency, Paris France, Rept. No. ESA-TT-359, 150 pp (Apr 1977) (Engl. transl. of DLR-76-44, 100 pp (Aug 1976) (N77-17104)
N77-24148

Key Words: Aircraft, Wind-induced excitation, Vibration damping, Wind tunnel tests

For an elastic aircraft model which can move in the wind tunnel with several degrees of freedom, the development and practical test of a multivariable controller is discussed. The controller stabilizes the elevation and the pitch angle, alleviates vertical gusts, and improves the damping of the first elastic mode. The control system synthesis depends on principles of optimization and simulation in the state space. Some low order linear filters are needed to meet the technical conditions.

77-2007
Comparison of Several Models Describing the Gust Loads on Aircraft Structures
O. Buxbaum and J.M. Zaschel
Laboratorium fuer Betriebsfestigkeit, Darmstadt, West Germany, Rept. No. LBF-TB-130/76, 50 pp (1976) refs
(In German)
Sponsored by Bundesmin. fuer Verkehr
N77-24149

Key Words: Aircraft, Wind-induced excitation, Mathematical models

Two gust models and their application in airworthiness regulations are described. Their suitability in determining static and fatigue strength of aircraft structures was investigated. The models considered were: discrete gust model based on a sequence of single isolated gusts, and a model of continuous turbulence accounting for turbulence as a stochastic process.

BUILDING
(Also see No. 1983)

77-2008
Developing Methodologies for Evaluating the Earthquake Safety of Existing Buildings
B. Bresler, T. Okada, D. Zisling, and V.V. Bertero
Earthquake Engrg. Res. Center, California Univ., Berkeley, CA., Rept. No. UCB/EERC-77/06, 155 pp (Feb 1977)
PB-267 354/9GA

Key Words: Buildings, Earthquake damage, Seismic design

This report contains four papers written during an investigation of methods for evaluating the safety of existing school buildings under NSF RANN (Research Applied to National Needs) Grants. These papers are not readily available to researchers and engineers in the United States and are therefore issued as a single Earthquake Engineering Research Report. The titles of the papers are the following: Evaluation of earthquake safety of existing buildings; Assessment of earthquake safety and of hazard abatement; Seismic safety of existing low-rise reinforced concrete buildings; Design and engineering decisions -- failure criteria (Limit States).

77-2009
Seismic Design Spectra and Mapping Procedures Using Hazard Analysis Based Directly on Oscillator Response
R.K. McGuire
Branch of Earthquake Hazards, U.S. Geological Survey, Denver, CO., Intl. J. Earthquake Engr. Struc. Dynam., 5 (3), pp 211-234 (July-Sept 1977) 21 figs, 4 tables, 23 refs

Key Words: Seismic design, Buildings

The calculation of design spectra for building sites threatened by seismic ground motion is approached by considering the maximum responses of linearly elastic oscillators as indicators of ground motion intensity. Attenuation functions describing the distribution of response as a function of earthquake magnitude and distance are derived using 68 components of recorded ground motion as data. With a seismic hazard analysis for several hypothetical building sites, the distributions of maximum oscillator responses to earthquakes of random magnitude and location are calculated, and spectra are drawn to indicate the maximum responses associated with specified probability levels. These spectra are compared to design spectra calculated from published methods of amplifying peak ground motion parameters.

FOUNDATIONS AND EARTH

77-2010
Spillway Vibration, Pressure, and Velocity Measurements, Ozark Lock and Dam, Arkansas River, Arkansas
C.A. Pugh
Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES-TR-H-77-6, 55 pp (Apr 1977)
AD-A040 132/3GA

Key Words: Dams, Vibration tests

Tests were conducted in bay 8 of the low-overflow spillway at Ozark Dam, Arkansas River, Arkansas, in September 1974 to study vibrations and pressure fluctuations as related to flow through the spillway. Pressures were measured on the spillway sill to determine whether fluctuations are correlated with structural vibrations. Velocity distributions were measured to study boundary layer development and to determine an equivalent roughness for the spillway surface. Gate vibrations were measured to attempt to confirm model results. Pressure fluctuations on the overflow spillway did not exhibit a root-mean-square (RMS) value large enough to be considered as a source of excitation of spillway vibration.

77-2011

Soil-Structure Interaction at Higher Frequency Factors

G.N. Bycroft

U.S. Geological Survey, Menlo Park, CA., Intl. J. Earthquake Engr. Struc. Dynam., 5 (3), pp 235-248 (July-Sept 1977) 8 figs, 11 refs

Key Words: Interaction: soil-structure, Circular plates, Foundations, Machinery foundations, Nuclear power plants

Approximate solutions to the forced vibrations of a rigid circular plate attached to the surface of an elastic halfspace are presented for large values of the frequency factor. These results are important when solving soil-structure interaction problems when such problems involve high-frequency factors. This situation arises when high-frequency components of earthquakes are associated with a relatively rigid foundation of a large base area and located on a soft terrain. Similar situations occur in cases of blast loadings and impact and in the foundations of large high-speed machinery. These solutions are used to solve the problem of the motion of a rigid mass on an elastic halfspace subjected to steady state and transient horizontal accelerations.

HELICOPTERS

77-2012

Helicopter Noise Measurements Data Report. Volume I. Helicopter Models: Hughes 300-C. Hughes 500-C, Bell 47-G. Bell 206L

H.C. True and R.M Letty

Systems Res. and Dev. Service, Federal Aviation Admin., Washington D.C., Rept. No. FAA-RD-77-57-1, 384 pp (Apr 1977)

AD-A040 561/3GA

Key Words: Helicopter noise, Noise measurement

This data report contains the measured noise levels obtained from an FAA Helicopter Noise Test Program. The purpose of this test program was to provide a data base for a possible helicopter noise certification rule. The noise data presented in this two volume report are primarily intended as a means to disseminate the available information. Only the measured data are presented in this report. All FAA/DOT data analysis and comparisons will be presented in a later report which is scheduled for distribution in July, 1977. The eight helicopters tested during this Helicopter Noise Test Program constituted a wide range of gross weights and included participation from several helicopter manufacturers.

77-2013

Helicopter Noise Measurements Data Report. Volume II. Helicopter Models: Bell 212 (UH-1N), Sikorsky S-61 (SH-3A), Sikorsky S-64 'Skycrane' (CH-54B), Boeing Vertol 'Chinook' (CH-47C)

H.C. True and R.M Letty

Systems Res. and Dev. Service, Federal Aviation Admin., Washington D.C., Rept. No. FAA-RD-77-57-2, 420 pp (Apr 1977)

AD-A040 562/1GA

Key Words: Helicopter noise, Noise measurement

The helicopter models used in this test program were the Hughes 300C, Hughes 500C, Bell 47-G, Bell 206-L, Bell 212 (UH-1N), Sikorsky S-61 (SH-3A), Sikorsky S-64 'Skycrane' (CH-54B), and Boeing Vertol 'Chinook' CH-47C. Volume I contains the measured noise levels obtained from the first four helicopters while Volume II contains the data from the remaining four.

HUMAN

77-2014

Evaluation of C-Weighted L_{dn} for Assessment of Impulse Noise

P.D. Schomer

U.S. Army Construction Engrg., Research Lab, Champaign, IL 61820, J. Acoust. Soc. Amer., 62 (2), pp 396-399 (Aug 1977) 2 figs, 1 table, 13 refs

Key Words: Noise tolerance, Human response

Community response to impulsive noise, such as sonic boom, artillery fire, and other military ordinance, and quarry and mining operations, is currently a matter of great public interest. Recently, the EPA has proposed a new interim impulsive noise measure for the evaluation of the C-weighted day-night level to estimate community response to large amplitude single-event impulsive noise. This measurement and its associated exposure criteria have been derived largely on the basis of existing community response to sonic boom data. Recent laboratory measurements of human reaction to artillery-type noise, reported on herein, strongly support this C-weighted measure.

77-2015

Application of Machine Dynamics Methods to the Investigation of Mechanical Properties of Skulls (Übertragung von Verfahren der Maschinendynamik auf die Untersuchung mechanischer Eigenschaften von Schädeln)

F. Holzweissig and C. Christmann
Maschinenbautechnik, 26 (6), pp 259-261 (June 1977) 8 figs, 8 refs
(In German)

Key Words: Head (anatomy), Vibration measurement

Vibration of a macerated skull is investigated using the methods of machine dynamics. It was found that natural frequencies are widely scattered, however, the vibration modes are relatively uniform. The possibility of a diagnostic application of the technique is suggested.

ISOLATION

77-2016
Vibration Isolation by Means of Fluidly Regulated Pneumatic Springs Demonstrated on a Holographic Test Stand (Schwingungsisolierung mittels fluidisch geregelter Luftfederung, dargestellt am Beispiel eines Holographietischs)
E. Hosp and R. Wulkau
Laboratorium Experimentelle Spannunganalyse und Optische Verfahren der Bundesanstalt für Materialprüfung, Berlin, Federal Rep. of Germany, Konstruktion, 29 (6), pp 227-230 (June 1977) 7 figs, 1 ref
(In German)

Key Words: Vibration isolation, Pneumatic springs, Instrumentation

For mounting highly sensitive measuring instruments, such as holographic test stands, interferometers, scales, and microscopes, a passive vibration isolation is generally used, which requires that the natural frequency of the spring-mass system of the foundation is as low as possible. In the article the properties of a pneumatically cushioned system are described, which facilitate low tuning even for small foundations. In addition the natural frequencies of the system, under certain conditions, do not depend on the mass of the foundation.

77-2017
The Analysis of Measured Data for the Determination of the Fundamental Dynamic Properties and Vibration Transmission Characteristics of Structures
H.G.D. Goyder and R.G. White
Inst. of Sound and Vibration Research, Univ. of Southampton, UK, SEECO-77, Society of Environmental Engineers, Proc., Symp., Imperial College, London, pp 222-238 (Apr 4-6, 1977) 10 figs, 12 refs

Key Words: Machinery vibration, Vibration isolation, Noise reduction

Three aspects of noise and vibration reduction in machinery installations are discussed. They are: measurement of point response, energy transmission paths, and the construction of mathematical models. The measurement of frequency response data by means of transient testing is outlined since it is the basis for two of the measurement procedures examined.

METAL WORKING AND FORMING

(See No. 1889)

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1937, 1968, 1969, 2035)

77-2018
Noise Control in the Turbine Room of a Power Station
G. Pleeck
LABORELEC, B-1640 Rhode-St-Genese, Brussels, Belgium, Noise Control Engr., 8 (3), pp 131-136 (May/June 1977) 9 figs, 2 tables, 4 refs

Key Words: Turbines, Electric power plants, Noise reduction

Belgian occupational noise control regulations recommend that the mean-weighted sound pressure level in areas occupied by workers does not exceed 90 dB(A). The author relates his country's first efforts to keep the noise levels below that limit in the turbine room of a new power-generating plant. Built in Kallo, in northern Belgium, from 1969 to 1970, this station comprises two steam turbine generators of 290 MW each, both equipped with a pressurized boiler fed with liquid fuel or natural gas.

77-2019
Measurements of Torsional Dynamic Characteristics of the San Juan No. 2 Turbine-Generator
D.G. Ramey, P.F. Harold, H.A. Maddox, R.B. Starnes, and J.L. Knickerbocker
Large Rotating Apparatus Div., Westinghouse Electric Corp., East Pittsburgh, PA., J. Engr. Power, Trans. ASME, 99 (3), pp 378-384 (July 1977) 7 figs, 2 tables, 9 refs

Key Words: Turbines, Torsional vibration, Mode shapes

The San Juan Generating Station is located in the northwestern part of New Mexico. Expansion plans for the transmission system include the addition of series capacitors on lines leaving the plant, necessitating a detailed study of potential subsynchronous resonance problems. A field test was performed on the San Juan No. 2 turbine-generator to obtain measured data for use in these studies. The required data included measurements of torsional resonant frequencies below 60 Hz, mode shapes, and damping characteristics. Test procedures and measurement techniques for obtaining these data are described. The results show that the disturbances caused by line switching in transmission systems can be closely calculated. They also show the correlation between calculated and measured torsional frequencies and mode shapes. The damping coefficient for the first torsional mode is shown to be strongly influenced by electrical system parameters as well as machine loading.

77-2020

Dynamic Model of a Rotating, Nonhomogeneous Gas-Turbine Disc for Flexural Vibration Analysis by the Finite Element Method

Z. Dżygadło

Polish Academy of Sciences, Inst. of Fundamental Tech. Research, Warszawa, Poland, J. Tech. Physics, 18 (1), pp 99-111 (1977) 1 fig, 7 refs

Key Words: Turbine components, Discs, Rotating structures, Natural frequencies, Forced vibration, Finite element technique

The method for analyzing the natural and forced vibrations of rotating nonhomogeneous turbine disc, which is presented in this paper, and consists in dividing the disc into deformable annular elements, has been checked by practical numerical computations and has been found correct and convergent. In comparison with the classical approximate methods, the method in question has a number of advantages. In view of the recurrent form of the relationships used for determining the equation of frequency and form of vibrations, this method is well suited to automation of calculations on computers.

77-2021

Fan Stage Redesigned to Decrease Stator Lift Fluctuation Noise

J.H. Dittmar and R.P. Woodward

Lewis Research Ctr., NASA, Cleveland, OH, J. Aircraft, 14 (8), pp 746-750 (Aug 1977) 6 figs, 4 tables, 10 refs

Key Words: Aircraft noise, Fans, Noise reduction

An existing fan stage, redesigned to reduce stator lift fluctuations, was tested acoustically for reduced noise generation. The lift fluctuations on the stator were reduced by increasing the stator chord, adjusting incidence angles, and by adjusting the rotor velocity diagrams. The experiments showed significantly reduced broadband noise levels in the middle to high frequencies. Blade passage tone power was not reduced, but decreases in the harmonics were observed. Aerodynamic improvements in both performance and efficiency were obtained.

77-2022

Vortex Shedding Noise of Low Tip Speed, Axial Flow Fans

R.E. Longhouse

Fluid Dynamics Res. Dept., General Motors Res. Labs, Warren, MI 48090, J. Sound Vib., 53 (1), pp 25-46 (July 8, 1977) 23 figs, 27 refs

Key Words: Fans, Noise generation, Vortex shedding, Noise reduction

Noise and performance tests were conducted on three low tip speed, half-stage, axial flow fans to determine the nature of the vortex shedding noise mechanism. Each fan was 356 mm in diameter and had eight equally spaced, variable pitch blades. The noise measurements were made in a free field environment and the fan back pressure and speed were varied during the tests. An acenaphthene coating on the blades was used to determine the regions of laminar and turbulent flow.

77-2023

Noise Reduction in Centrifugal Fans by Means of an Acoustically Lined Casing

M. Bartenwerfer, T. Gikadi, W. Neise, and R. Agnon

DFVLR-Institut für Turbulenzforschung, Berlin, Germany, Noise Control Engr., 8 (3), pp 100-107 (May/June 1977) 10 figs, 1 table, 14 refs

Key Words: Fans, Noise reduction, Acoustic linings

The authors evaluate a method in which acoustical lining of the volute of centrifugal fans reduces both the harmonic sound and the random noise. The A-weighted sound level in the outlet duct is lowered by as much as 12 dB, while the reduction in the inlet duct is insignificant. The aerodynamic fan performance remains almost unchanged.

77-2024

Stiffening of a Boat Propeller Shaft Bearing Support Bracket by a CFRP Overlay

R. Ellis
Aeronautical Research Labs, Melbourne, Australia, Rept. No. ARL/STRUC.425, 23 pp (Apr 1976)
PB-266 915/8GA

Key Words: Marine propellers, Foundations, Stiffness

Vibration problems have occurred in the propeller shafts of ten meter boats operated by the Royal Australian Navy. Each shaft runs in a bearing which is attached to the hull by an aluminum bronze bracket and there was a requirement to increase the stiffness of this bracket. An efficient, cheap and quick method was sought for a first unit and here a description is given of how this was achieved by the construction of a carbon fiber reinforced plastic overlay for the existing bracket.

RAIL

77-2025
Development of a Simulation Methodology for Optimizing Locomotive Suspension Systems
V.K. Garg, K.L. Hawthorne, E.H. Chang, and P.W. Hartmann
Association of American Railroads, Technical Center, Chicago, IL, ASME Paper No. 77- RT-6

Key Words: Railroad trains, Locomotives, Suspension systems (vehicles), Mathematical models

The dynamic response of a six-axle locomotive subjected to vertical and/or lateral track irregularities is analyzed by a 39-deg-of-freedom locomotive model. This model, which is currently partially validated, will soon be available to track-train dynamics participants. The hunting speeds of the locomotive, with variable relative stiffnesses between primary and secondary suspensions, are evaluated using a 21-deg-of-freedom, lateral stability model. The effects of primary and secondary suspension stiffness on the dynamic and tractive characteristics of the locomotive are studied. A methodology for selecting the primary and secondary locomotive truck suspension stiffnesses, which provide "optimum" tractive effort and minimize the undesirable behavior is presented.

77-2026
Static and Dynamic Stability of a Class of Three-Axle Railway Vehicles Possessing Perfect Steering
A.H. Wickens
British Rail Res. and Div., Div., Derby, UK, Vehicle Syst. Dyn., 6 (1), pp 1-19 (May 1977) 7 figs, 4 refs

Key Words: Railroad trains, Stability, Flutter, Steering effects

For railway vehicles having coned wheels mounted on solid axles there is, in general, a conflict between stability of lateral deviations from the motion along the track and ability to steer round curves. However, the three-axle vehicle with zero bending stiffness and with shear elasticity between all wheelsets can satisfy the requirement of perfect steering and for a range of values of equivalent conicity possesses both static and dynamic stability. The static and dynamic stability of the most general form of symmetric three-axle vehicle is investigated, and stability criteria derived.

RECIPROCATING MACHINE
(See Nos. 1931, 1932)

ROAD
(Also see Nos. 1922, 1933)

77-2027
The Application of Optimization Techniques to Problems of Automotive Crashworthiness
J.A. Bennett, K.-H. Lin, and M.F. Nelson
Research Labs, General Motors Corp., SAE Paper No. 770 608, 8 pp, 9 figs, 1 table, 5 refs

Key Words: Collision research (automotive), Crashworthiness, Optimization

An improved impact simulation model which calculates the steering column envelopment is introduced. To express the effect of passenger compartment deceleration on potential injury, a vehicle crash severity index is introduced and is shown to be positively correlated with potential injury based on the chest severity index. An optimization technique is used to find a set of design variables which will satisfy constraints placed on the above measures of crashworthiness; namely, the steering column envelopment and the vehicle crash severity index.

77-2028
A Design-Analysis Method for the Frontal-Crush Strength of Body Structures
D.C. Chang
Research Labs, General Motors Corp., SAE Paper No. 770 593, 9 pp, 9 figs, 8 refs

Key Words: Collision research (automotive), Limit analysis

A simplified design-analysis method is developed for estimating the ultimate load-carrying capacity and the associated collapse mechanism of a body structure subjected to a frontal crush load. The analysis is based on the principles of limit analysis; the computation scheme consists of repeated stepwise analyses for each incremental load, and repeated searching for the collapse mechanism which requires the least load (the collapse load). Very good agreement was obtained between analysis and crush-test results of production body structures. This design analysis method provides a simple and direct means for design engineers to evaluate the effect of design variations on the body crush strength.

77-2029

Dynamic Validation of a Computer Simulation for Vehicle Crash

I.K. McIvor and W.J. Anderson

Univ. of Michigan, SAE Paper No. 770 591, 9 pp, 14 figs, 7 refs

Key Words: Collision research (automotive), Computerized simulation, Experimental data

This paper describes two crash tests designed to validate a computer simulation developed for predicting the large dynamic plastic response of vehicle structures under crash conditions. The test structures were idealized quarter scale models consisting of frame and rigid body elements. Both direct and oblique pole impacts are reported. Impact speed was 30 MPH. Predicted and experimental results are compared for the crush displacements, impact force at the pole barrier, and acceleration histories at two points on the "passenger compartment" mass.

77-2030

Design Through Analysis of an Experimental Automobile Structure

J.A. Augustitus, M.M. Kamal, and L.J. Howell

Research Labs, General Motors Corp., SAE Paper No. 770 597, 13 pp, 17 figs, 5 tables, 13 refs

Key Words: Automobiles, Design techniques, Computer-aided techniques

It is evident that the use of impact simulation, static, and dynamic analyses in the pre-prototype phase of the design process can significantly improve the structural efficiency of the automobile. As a result of this design project, the accuracy of the structural modeling and analysis was verified by experimental data obtained from a fabricated test vehicle, and the potential value of design through analysis was demonstrated by a significant reduction in structural weight of the project vehicle.

77-2031

Novel Developments and Applications of Finite Element Methods at Daimler-Benz

D. Radaj, A. Zimmer, and H. Geissler

Daimler-Benz AG, Germany, SAE Paper No. 770 596, 10 pp, 8 figs, 16 refs

Key Words: Automobiles, Finite element technique, Computer-aided techniques, Design techniques, Testing techniques

The objective of the paper is a survey on new finite element software and application developments at Daimler-Benz since the Detroit Conference 1974 at which the authors gave a similar paper on developments at that time. The organizational background in which finite element analysis is taking place at Daimler-Benz is given: computation giving support to design and testing, decentralized computation groups, centralized computer hardware and software, NASTRAN and ESEM/TPS10 at Daimler-Benz, in-house and out-of-house software development, verification and efficiency tests.

77-2032

Steady State Steering Response

A.G. Thompson

School of Automotive Studies, Cranfield Inst. of Tech., UK, Vehicle Syst. Dyn., 6 (1), pp 37-40 (May 1977) 2 figs, 2 refs

Key Words: Automobiles, Steering effects, Periodic response

The yaw rate response for a two-degree-of-freedom car model requires a family of curves for different degrees of oversteer or understeer. By use of non-dimensional coordinates this family is reduced to one single curve. The ordinate ρ is the ratio of yaw rate response to that of a neutral steering car at the same speed and is less than 1 for understeer and greater than 1 for oversteer. Since ρ is also the ratio of the side-slip angle response it is hence, a unique measure of the steady-state steering characteristics.

77-2033

Truck Ride Improvement Using Analytical and Optimization Methods

J.H. Baum, J.A. Bennett, and T.G. Carne

GMC Truck & Coach Div., General Motors Corp., SAE Paper No. 770 609, 10 pp, 18 figs, 19 refs

Key Words: Trucks, Ride dynamics, Optimization, Finite element technique, Mathematical model

A two-tier approach is applied to the analysis of a cab-over-engine tractor. A detailed three-dimensional finite element model was developed and verified with data acquired from road input. In addition, a simpler two-dimensional model was developed and used with an optimization technique to develop alternative designs. The root-mean-square accelerations of the driver in the vertical and fore-aft directions were used as performance measures. The proposed designs were then evaluated using the detailed finite element model, and additional improvements were suggested. This approach led to a modification of the cab mounting system which resulted in a predicted 44 percent reduction in the fore-aft rms acceleration from an initial design.

77-2034

System Modeling Techniques to Improve the Ride and Vibration Isolation Characteristics of Heavy Equipment

R.A. Shryock, J.W. Klahs, and D.A. Dieterich

Structural Dynamics Research Corp., SAE Paper No. 770 594, 13 pp, 18 figs, 29 refs

Key Words: Ground vehicles, Ride dynamics, Human response, Vibration isolation, Design procedures, Computer-aided techniques

Much attention has been devoted to the importance of vehicle dynamics relative to human response ride criteria. The present work extends this effort by providing a practical computerized design approach in which the vehicle designer selects a representative terrain input, either sinusoidal or power spectral density, to excite a vehicle model constructed by the modal building block method. To evaluate vehicle ride the resulting system response, accounting for human dynamic characteristics, is compared to accepted ride criteria, such as ISO spectra and absorbed power. An example involving an agricultural tractor is presented to illustrate the approach.

ROTORS

(Also see Nos. 1932, 1941)

77-2035

Design and Manufacturing of a Gas Turbine Rotor for Temperature and Vibration Measurements

O. Frei

Sulzer Brothers Ltd., Winterthur, Switzerland, ASME Paper No. 77-GT-54

Key Words: Gas turbine blades, Gas turbine components, Rotors, Vibration measurement

A special gas turbine test rotor has been manufactured to measure compressor blade vibrations and turbine rotor temperatures. This will be used to provide experimental verification of design calculations. The design and manufacture of thermocouple and strain gage instruments are described.

SHIP

(Also see Nos. 1896, 1898)

77-2036

A Steady State and Dynamic Analysis of a Mooring System

J.P. Radochia

New London Lab., Naval Underwater Systems Ctr., New London, CT., Rept. No. NUSC-TR-5597, 210 pp (Mar 25, 1977)

AD-A039 831/3GA

Key Words: Moorings, Digital simulation, Computerized simulations, Dynamic structural response

This report investigates the forces acting upon a cable-buoy-ship system and develops a digital computer simulation of its dynamics in three dimensions. The system that is discussed is excited by ship motions caused by ocean waves. For the dynamic case, in which ship motions do exist, a lumped mass model of the cable and subsurface buoys is used. A particular cable-buoy-ship system is investigated, and the results are analyzed.

77-2037

Some Acoustical Properties of Floating-Floor Constructions

A.C. Nilsson

Det norske Veritas, DMT, P.O. Box 300, Hoevik, Norway, J. Acoust. Soc. Amer., 61 (6), pp 1533-1539 (June 1977) 6 figs, 1 table, 12 refs

Key Words: Noise reduction, Ships, Floors

Expressions giving the velocity level difference between bottom and top plates are derived. Calculated and measured values are compared. The frequency dependence of the level difference is found to be between 25 and 40 dB/decade. The slope of the curve depends on the material parameters for the floor. Radiation ratios and reduction indices for some floating-deck constructions are also discussed.

SPACECRAFT
(Also see No. 1956)

77-2038
Resonance Testing of Space Shuttle Thermoacoustic Structural Specimen. Final Report
A.L. Abrahamson and J. Osinski
Scientific Services and Systems Group, Wyle Labs., Inc., Hampton, VA., Rept. No. NASA-CR-145154; Rept-50621, 85 pp (Mar 1977) refs
N77-24531

Key Words: Space stations, Resonance tests

The resonance testing of a structural specimen related to the space shuttle vehicle is described. The specimen consisted of a thin aluminum skin reinforced by hat-section stringers and supported by two ribs or bulkheads of corrugated web. A representative section of the space shuttle thermal protection system was bonded to the outer surface of the skin. The tests were completed by using miniature accelerometers to collect vibration data from locations forming a predetermined mesh over the tiles and base structure. The signals were recorded on FM magnetic tape and subsequently analyzed on a modal analysis system.

77-2039
Comparison of Finite Element Analysis and Test Response on a Space Shuttle Leading Edge Segment Under Acoustic Loading
C.A. Ford and Y.F. Hwang
Vought Corp., Inst. Environ. Sci., Proc., 23rd Annual Mtg., Los Angeles, CA, pp 339-343 (Apr 25-27, 1977) 7 figs, 1 ref

Key Words: Space stations, Experimental results, Damping effects, Finite element technique, Mathematical models

Finite element structural analysis techniques were used in an essentially straightforward manner in this evaluation of acoustic response. The analysis had to be supplemented with test determined values of damping. By the same token, significance of test-peculiar influences were efficiently evaluated with the analytical model.

77-2040
Liquid Rocket Disconnects, Couplings, Fittings, Fixed Joints, and Seals. NASA Space Vehicle Design Criteria (Chemical Propulsion)
NASA, Washington D.C., Rept. No. NASA-SP-8119, 164 pp (Sept 1976) refs
N77-24191

Key Words: Liquid propellant rocket engines, Rocket components

State of the art and design criteria for components used in liquid propellant rocket propulsion systems to contain and control the flow of fluids involved are discussed. Particular emphasis is placed on the design of components used in the engine systems of boosters and upper stages, and in spacecraft propulsion systems because of the high pressure and high vibration levels to which these components are exposed. A table for conversion of U.S. customary units to SI units is included with a glossary, and a list of NASA space vehicle design criteria monographs issued to September 1976.

STRUCTURAL

77-2041
Wind and Seismic Effects - Proceedings of the Joint Panel Conference of the U.S.-Japan Cooperative Program in Natural Resources (8th) Held at National Bureau of Standards, Gaithersburg, Maryland on May 18-21, 1976
H.S. Lew
Center for Building Tech., National Bureau of Standards, Washington, D.C., Rept. No. NBS-SP-477, 630 pp (May 1977)
PB-267 316/8GA

Key Words: Structural design, Wind-induced excitation, Seismic design, Earthquake damage

The Eighth Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects was held in Gaithersburg, Maryland on May 18-21, 1976. The proceedings of the Joint Meeting include the program, the formal resolutions, and the technical papers. The subject matter covered in the papers includes wind effects on structures and design criteria; extreme winds for structural design; earthquake ground motions and instrumentation; seismicity and earthquake risk; seismic effects on structures and design criteria; lessons learned from recent natural disasters; design of nuclear reactor facilities.

77-2042
Dynamics and Failure Criteria of Structural Connections
J.H. Smith, K.L. Hoitsma, and W.P. Vann
Dept. of Civil. Engrg., Texas Tech. Univ., Lubbock, TX, Rept. No. AFOSR-TR-77-0702, AFATL-TR-

77-71, 97 pp (May 1977)
AD-A040 460/8GA

Key Words: Protective shelters, Concrete construction, Aircraft, Dynamic tests

This research was conducted to establish new knowledge of failure criteria for concrete connections which will enable the USAF to predict, with acceptable accuracy, the failure modes of aircraft shelters. Of primary importance was the effect of extremely high stress rates on ultimate failure strength of the crown connections. A total of seven static and fourteen dynamic tests were conducted and comparison made of the two test series to establish a dynamic strength factor. A drop-tower was constructed for the dynamic tests which enabled rise times to failure of under 4 milliseconds to be achieved. Although most of the effort was concentrated on full-scale connections, static tests to failure were also conducted on one-third scale models.

USEFUL APPLICATION

77-2043

Aerospace Technology Can be Applied to Exploration "Back on Earth"

L.D. Jaffe

Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA., Oil and Gas J., 75 (33), pp 92-97 (Aug 15, 1977) 7 figs, 2 tables, 1 ref

Key Words: Drills, Vibratory techniques

A study which considered possible applications of aerospace technology in petroleum exploration is described. It includes 21 concepts aimed at the specific exploration problems. They comprise: seismic reflection concepts, sea-floor imaging and mapping, remote geochemical sensing, identification of geological analogies, drilling concepts (e.g., resonant vibration drilling), and down-hole acoustic concepts.

AUTHOR INDEX

CALENDAR

NOVEMBER 1977

27 - Dec 2 **Winter Annual Meeting,** [ASME] Atlanta, GA *(ASME Hq.)*

DECEMBER 1977

6-8 **Sixth Turbomachinery Symposium,** Houston, TX *(Dr. M.P. Boyce, Gas Turbine Labs., ME Dept., Texas A&M, College Station, TX 77843)*

13-16 **Acoustical Society of America, Fall Meeting,** Miami Beach, FL *(ASA Hq.)*

MARCH 1978

25-27 **Applied Mechanics Western and J.S.M.E. Conference,** Honolulu, Hawaii *(ASME Hq.)*

APRIL 1978

3-5 **Design Engineering Conference & Show** [ASME] Chicago, IL *(R.C. Rosaler, Rice Assoc., 400 Madison Ave., N.Y., NY 10017)*

9-13 **Gas Turbine Conference & Products Show,** [ASME] London *(ASME Hq.)*

MAY 1978

4-5 **IX Southeastern Conference on Theoretical and Applied Mechanics,** [SECTAM] Nashville, TN *(Dr. R.J. Bell, SECTAM, Dept. of Engrg. Sci. & Mech., Virginia Polytechnic Inst. & State Univ., Blacksburg, VA 24061)*

8-10 **Inter-NOISE 78,** San Francisco, CA *(INCE, W.W. Lang)*

8-11 **Offshore Technology Conference,** Houston, TX *(SPE, Mrs. K. Lee, Mtgs. Section, 6200 N. Central Expressway, Dallas, TX 75206)*

14-19 **Society for Experimental Stress Analysis,** Wichita, KS *(SESA, B.E. Rossi)*

JUNE 1978

Eighth U.S. Congress of Applied Mechanics, Los Angeles, CA *(ASME)*

OCTOBER 1978

1-4 **Design Engineering Technical Conference,** Minneapolis, MN *(ASME Hq.)*

8-11 **Diesel and Gas Engine Power Conference and Exhibit,** Houston, TX *(ASME Hq.)*

8-11 **Petroleum Mechanical Engineering Conference,** Houston, TX *(ASME Hq.)*

17-19 **Joint Lubrication Conference,** Minneapolis, MN *(ASME Hq.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, N.J. 07645
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, N.Y. 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, N.Y. 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, Ill. 60605
AHS:	American Helicopter Society 30 E. 42nd St. New York, N.Y. 10017
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, N.Y. 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, N.Y. 10017
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, N.Y. 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, Ill. 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, Wis. 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, Pa. 19103
CCCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, N.Y. 10017
IES:	Institute Environmental Sciences 940 E. Northwest Highway Mt. Prospect, Ill. 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME, Amherst, Mass. 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603
ISA:	Instrument Society of America 400 Stanwix St., Pittsburgh, Pa. 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy, Arlington, Va. 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pa. 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, England
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, Conn. 06880
SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, N.Y. 10006
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, Mass. 02173

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