

LIBRARY, 42

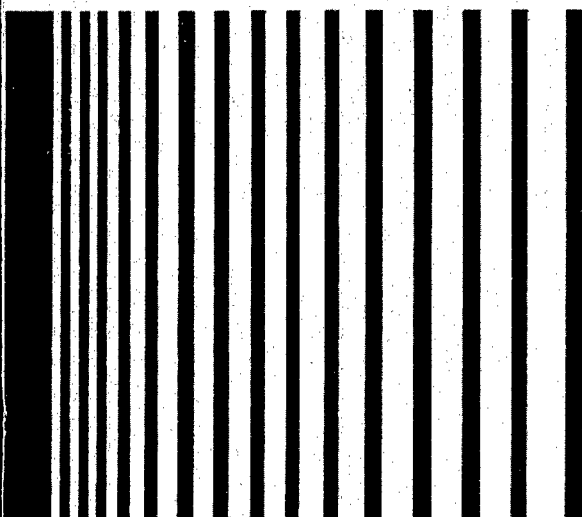
AD A062673

VOLUME 10, NO. 12
DECEMBER 1978

20 DEC 1

TECHNICAL LIBRARY
REFERENCE COPY

1868



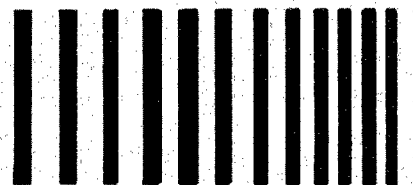
THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

Best Available Copy



OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING



2004 0204 153

Approved for public release; distribution unlimited.

AN 42241

THE SHOCK AND VIBRATION DIGEST

Volume 10 No. 12
December 1978

STAFF

EDITORIAL ADVISOR: Henry C. Pusey
TECHNICAL EDITOR: Ronald L. Eshleman
EDITOR: Judith Nagle-Eshleman
RESEARCH EDITOR: Milda Tamulionis
PRODUCTION AND SECRETARIAL: Valda L. Liesz
Martha N. Moss

BOARD OF EDITORS

R. Belsheim	W.D. Pilkey
R.L. Bort	A. Semmelink
J.D.C. Crisp	E. Sevin
C.L. Dym	J.G. Showalter
D.J. Johns	R.A. Skop
G.H. Klein	C.B. Smith
K.E. McKee	J.C. Snowdon
J.A. Macinante	R.H. Volin
C.T. Morrow	H. von Gierke
J.T. Oden	E.E. Ungar

A publication of

THE SHOCK AND VIBRATION
INFORMATION CENTER

Code 8404 Naval Research Laboratory
Washington, D.C. 20375

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordan Showalter

Barbara Szymanski

Carol Healey

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

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

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$60.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available by volume (12 issues) for \$15.00. Orders may be forwarded at any time, in any form, to SVIC, Code 8404, Naval Research Laboratory, Washington, D.C., 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

DIRECTOR NOTES

This issue marks the end of a decade of publication of this **DIGEST**. During that time we have seen a number of changes in style and content. These changes have been introduced in part to reflect changing technological emphasis, but mostly to serve the information needs of the reader more effectively. The indications are that we have been at least partially successful in our efforts, since your response as readers has been generally favorable. In spite of this, we are well aware that there is always room for improvement. I look forward to a flow of constructive suggestions during the coming year. Whenever possible we will use those suggestions to advantage.

We have not been without our problems. The cost of preparing and distributing the **DIGEST** has increased markedly. We have therefore been required to increase the subscription price to one hundred dollars for the coming year for domestic delivery. Our foreign subscriptions are increased accordingly. It is my expectation that the readers will continue to find the **DIGEST** a prudent investment. Wisely purchased, information is still one of the cheaper commodities on today's market.

During the coming year, we at SVIC plan to issue some interesting publications. I am pleased to announce the first of these, "An International Survey of Shock and Vibration Technology," which will be available for distribution early next year. This report may well be the first of its kind. It is a very broad survey of the complete shock and vibration technology from an international viewpoint. A more complete announcement, along with price, is expected to be given in the January **DIGEST**. Other publications will be announced as they are about to become available.

The encouragement of the shock and vibration community over our many years of service has been gratifying. I look upon 1979 as a new and exciting year of challenge. With your continued support, we will meet that challenge.

H.C.P.

Best Available Copy

EDITORS RATTLE SPACE

THE ADVANCE OF TECHNOLOGY

This issue of the DIGEST marks the end of ten years of publication. During this time the abstracts of almost 20,000 papers, reports, and theses have been published. In addition, more than 200 feature and review articles have appeared. It is an appropriate time to pause and reflect upon the focus of these technological advances -- that is, are they concerned mostly with solving problems or with understanding basic phenomena and environments in vibration and shock?

The abstracts of the past ten years indicate that problems are being studied in ever greater detail but that there has been little accomplished in understanding basic phenomena or developing new techniques. In my opinion this trend is a result of the evaluation of the digital computer as a practical tool for solving engineering problems. In fact the major advances in shock and vibration technology have been in the electronics area -- digital computers for mathematical computation, data handling, and data analysis; and instrumentation for measurement, data analysis, and data display.

The digital computer stimulated work aimed at perfecting numerical methods. For example, the finite element method was developed for solving practical engineering problems in machines and structures. This method has been extended to many physical problems by the development of specific "elements" to represent its physical behavior. The numerical methods used to manipulate equations are thus a by-product of finite element work. Developments of the past ten years have provided the tools for solving most dynamics problems.

The second major area of technological advancement has to do with measurement and data processing. New high response sensors, including proximity probes and accelerometers, allow measurement of vibration and shock phenomena in all frequency ranges. These devices have greatly simplified measurement and made it less of an art. The fast Fourier analyzers have advanced data processing far beyond our expectations. All of this technology is applicable to solving current problems.

What about the advances in the next ten years? In my opinion they will involve digital computers -- the development of more practical minicomputers and desk computers. Not only computation will be done on the minicomputer but also much data processing for machine monitoring and diagnostics. Research in understanding basic phenomena is lagging and will continue to do so. Evolution of technology to solve practical problems has been adequate, but it has tended to create an atmosphere in which no one is interested in understanding basic physics other than that absolutely necessary to solve a problem.

R.L.E.

SHOCK AND VIBRATION ANALYSIS USING FINITE ELEMENT TECHNIQUES

T.V. Seshadri*

Abstract - This paper reviews current state of the art in shock and vibration analyses using finite element techniques. The development of a total finite element model using a combination of analytical and experimental techniques is described.

The finite element technique consists of dividing a continuum into a number of discrete elements and imposing conditions (force and displacement compatibilities) at points shared by the elements. These points are called joints or nodes. The increasing use of finite element techniques is largely due to the advancement in sophisticated digital computers. Several finite element codes are available from various sources. Most of these codes use the so-called stiffness method as opposed to the flexibility method.

In the stiffness method, the matrix equation for static force is written as

$$\{F\} = [K] \{x\} \quad (1)$$

where

$$\begin{aligned} \{F\} &= \text{column force vector} \\ [K] &= \text{square stiffness matrix} \\ \{x\} &= \text{column displacement vector} \end{aligned}$$

By setting $\{x\}$ equal to unity the stiffness matrix represents the force required to cause unit displacement.

For a uniform bar with two joints at each end, as shown in Figure 1, the stiffness matrix can be written as

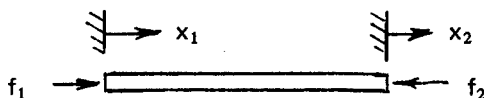


Figure 1. Uniform Bar with Two Nodes

*Fruehauf Corporation, Detroit, Michigan

$$[K] = \frac{EA}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \quad (2)$$

The stiffness matrix can be obtained by assuming a unit displacement in one degree of freedom (keeping all other displacements zero) and finding the force required to cause that unit displacement. Several textbooks on finite element method discuss in detail the calculation of stiffness matrices. The fundamentals have been explained thoroughly [1].

In dynamic analysis, two additional terms – mass and damping matrices – are needed. The mass matrix can be found in different ways. For example, if the mass m for a uniform bar is lumped at the two nodes (Fig. 2) the mass matrix becomes

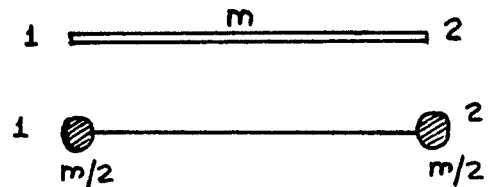


Figure 2. Lumped Mass of Uniform Bar

$$[M] = \begin{bmatrix} m/2 & 0 \\ 0 & m/2 \end{bmatrix} \quad (3)$$

If the bar is divided into two elements with three nodes or joints, the lumped mass assumption yields a mass matrix

$$[M] = \begin{bmatrix} m/3 & 0 & 0 \\ 0 & m/3 & 0 \\ 0 & 0 & m/3 \end{bmatrix} \quad (4)$$

Thus the lumped mass approach always gives a diagonal mass matrix. A diagonal matrix is one in which elements other than the main diagonal are zero. Such a matrix has several important advantages; computer dynamic analysis involves reducing non-diagonal matrices into diagonal ones. The lumped mass approach is not accurate, however, and the structure may have to be divided into a large

number of elements to yield reasonable results.

Another method for finding the mass matrix is the consistent mass approach, so called because the mass matrix is derived using the same displacement function as the stiffness. Take, for example, the longitudinal bar; using a consistent mass the mass matrix becomes

$$[M] = \begin{bmatrix} m/3 & m/6 \\ m/6 & m/3 \end{bmatrix} \quad (5)$$

This is a non-diagonal matrix and is a better representation of the actual mass distribution than a diagonal matrix. The mass matrices obtained either by lumped or consistent mass are independent of frequency.

Yet another method, called distributed mass, uses exact mathematical expressions for mass distribution. The method yields better results, but the mass and stiffness matrices are functions of frequency. They will therefore involve considerable computer costs and are thus not economical.

The general dynamic equations of motion for an n degree of freedom system in matrix form is

$$[M] \{\ddot{x}\} + [C] \{\dot{x}\} + [K] \{x\} = \{f(t)\} \quad (6)$$

The solution techniques depend on the nature of $f(t)$. The techniques have been described in detail [1]. Some particulars of those techniques are described below.

FREE VIBRATION OR MODAL ANALYSIS

Before describing the solution techniques for free vibration analysis or modal analysis, it is worthwhile to define modal analysis.

The term modal analysis has become especially popular with empirical vibration engineers. Modal analysis, either analytically or empirically, involves finding the natural frequencies and mode shapes of a structure under free-free conditions. (Free-free conditions can be obtained by supporting the structure on very soft springs.) Various types of test equipment are available to determine the modal

properties of a structure. Analytical modal analysis is discussed below; empirical modal analysis is also briefly explained.

The undamped free vibration equation of a system, using lumped or consistent mass, will be

$$[M] \{\ddot{x}\} + [K] \{x\} = 0 \quad (7)$$

using harmonic response

$$\{x\} = \{X\} e^{i\omega t} \quad (8)$$

the matrix equation becomes

$$(-\omega^2 [M] + [K]) \{X\} = 0 \quad (9)$$

For non-trivial solution of equation (9), the condition to be satisfied is that the determinant should vanish.

$$|-\omega^2 [M] + [K]| = 0 \quad (10)$$

This is called an eigenvalue problem; the vector $\{X\}$ associated with each frequency ω -- called the eigenvector -- is the mode shape.

Several solution techniques are available, the most common of which are determinant tracking, the Jacobi method, the Givens method, and the Householder method. In the determinant tracking method the value of the determinant in equation (10) is calculated for several trial frequencies. When there is a change in sign of the determinant, the determinant is recalculated using a new trial frequency until a specified tolerance level is reached. This method will work well except in some cases with closely spaced natural frequencies (Fig. 3).

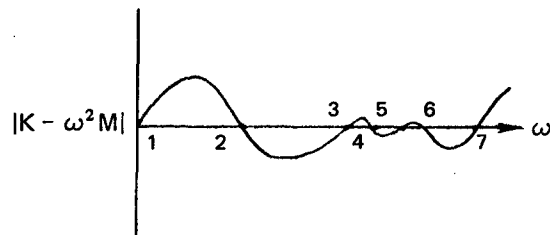


Figure 3. Determinant Tracking Method

One or two roots between 4, 5, and 6 may be missed. This difficulty is eliminated by using the Sturm sequence property, which determines the number of roots below any frequency. Actually, the determinant equation (10) is a polynomial equation, and the number of real roots between any two numbers, which are not roots, can be found. The method involves tri-diagonalization of the matrix $([K] - \omega^2 [M])$; i.e., maximum non-zero terms in a row is 3, one diagonal and two adjacent terms. The values of several pre-defined expressions are calculated, and the sign changes are noted. For example, if $N(a)$ is the number of sign changes for value 'a' and $N(b)$ is the number of sign changes for value 'b', the number of real roots between 'a' and 'b' is $N(a) - N(b)$. Therefore, closely spaced roots cannot be missed. However, the Sturm sequence does not recognize multiple or repeated roots.

The Jacobi method involves taking the largest absolute value of the non-diagonal matrix and applying several orthogonal transformations. The product of these transformation matrices reduces the original matrix to a diagonal matrix even if there are multiple roots. The sequence of transformations, sometimes called rotations, is infinite, though convergent, and the sequence can be terminated depending on the required precision. The eigenvalues will be the elements of the diagonalized matrix.

In the method of Givens, a finite sequence of orthogonal transformations is performed, but the original matrix is reduced to a tridiagonal form. A numerical technique is combined with the Sturm sequence property to obtain all the eigenvalues.

The method of Householder also produces a matrix of tri-diagonal form but with an increase in efficiency and economy as compared to Givens method. For an $n \times n$ matrix, $(n-2)$ transformations are required although each might involve more calculations than the Givens method.

SUBSTRUCTURING

In complex structures for which the finite element method is used, the number of equations to be solved is large and requires a large computer core. A few years ago Guyan developed a technique -- now known as the Guyan reduction -- to reduce the

number of equations by partitioning the stiffness and mass matrices.

For static analysis the matrix equation is

$$\{F\} = [K] \{x\} \quad (11)$$

Expanding $[K]$ into a 2×2 matrix

$$\begin{Bmatrix} F_1 \\ F_2 \end{Bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} \quad (12)$$

$$F_1 = K_{11}x_1 + K_{12}x_2 \quad (13)$$

$$F_2 = K_{21}x_1 + K_{22}x_2 \quad (14)$$

Solving for x_2 in equation (14)

$$x_2 = K_{22}^{-1} (F_2 - K_{21}x_1) \quad (15)$$

Substituting this value of x_2 in equation (13)

$$K_{11}x_1 + K_{12}K_{22}^{-1} (F_2 - K_{21}x_1) = F \quad (16)$$

$$(K_{11} - K_{12}K_{22}^{-1}K_{21})x_1 = F_1 - K_{12}K_{22}^{-1}F_2 \quad (17)$$

or

$$[K]^* \{x_1\} = \{F^*\} \quad (18)$$

where $[K]^*$ and $\{F^*\}$ are modified stiffness matrix and force vector respectively

$$[K]^* = K_{11} - K_{12}K_{22}^{-1}K_{21} \quad (19)$$

The matrix manipulations, like decomposition or inversion, must be performed on such smaller matrices as K_{11} , K_{12} , or K_{22} . Because computation time is directly proportional to the square of the number of terms in the matrix, the Guyan reduction results in an efficient, economical solution. In the stiffness matrix reduction, equation (19), there is no approximation involved.

The mass matrix can also be reduced in a similar fashion, but some approximation is involved, the effect of which should be negligible in the final results. In dynamic analysis, the reduction technique depends upon retaining a small proportion of the unknown nodal deflections, called masters. The remaining deflections, known as slaves, are reduced

out. Hence the order of the eigenvalue problem is reduced. With a careful choice of masters, the lower natural frequencies are preserved and can be accurately found.

The eigenvalue problem in matrix form is rewritten as

$$([K] - \omega^2 [M]) \{x\} = 0 \quad (20)$$

The matrices in partitioned form are

$$\left(\begin{bmatrix} K_{mm} & K_{ms} \\ \dots & \dots \\ K_{sm} & K_{ss} \end{bmatrix} - \omega^2 \begin{bmatrix} M_{mm} & M_{ms} \\ \dots & \dots \\ M_{sm} & M_{ss} \end{bmatrix} \right) \begin{Bmatrix} X_m \\ \dots \\ X_s \end{Bmatrix} = \begin{Bmatrix} 0 \\ \dots \\ 0 \end{Bmatrix} \quad (21)$$

X_m and X_s are master and slave degrees of freedom respectively.

In order to eliminate the slaves, it has been observed that, for low frequencies, the effects of inertia forces on the slave displacements are small compared with the effects of static forces. Therefore, the inertia forces arising due to the lower row of the mass matrix in the partitioned matrix, equation (21), are ignored. Expand equation (21) with this assumption

$$K_{mm}X_m + K_{ms}X_s - \omega^2 M_{mm}X_m - \omega^2 M_{ms}X_s = 0 \quad (22)$$

$$K_{sm}X_m + K_{ss}X_s = 0 \quad (23)$$

From equation (23)

$$X_s = -K_{ss}^{-1} K_{sm}X_m \quad (24)$$

Use equation (24)

$$\{X\} = \begin{Bmatrix} X_m \\ X_s \end{Bmatrix} = \begin{bmatrix} I \\ -K_{ss}^{-1} K_{sm} \end{bmatrix} \{X_m\} \quad (25)$$

The kinetic and strain energies in terms of master degrees of freedom system can be written as

$$\text{strain energy} = \frac{1}{2} \{X_m\}^T [K^*] \{X_m\} \quad (26)$$

$$\text{kinetic energy} = \frac{1}{2} \omega^2 \{X_m\}^T [M^*] \{X_m\} \quad (27)$$

where $[K^*]$ and $[M^*]$ are reduced stiffness and mass matrices respectively.

Strain energy and potential energy in terms of total degrees of freedom are

$$\text{strain energy} = \frac{1}{2} \{X\}^T [K] \{X\} \quad (28)$$

$$\text{Kinetic energy} = \frac{1}{2} \omega^2 \{X\}^T [M] \{X\} \quad (29)$$

Substituting equation (25) in equations (28) and (29)

$$[K^*] = K_{mm} - K_{sm} K_{ss}^{-1} K_{ms} \quad \text{and} \quad (30)$$

$$[M^*] = M_{mm} - K_{ss}^{-1} K_{sm} M_{sm} - M_{ms} K_{ss}^{-1} K_{sm} + K_{ss}^{-1} K_{sm} M_{ss} K_{ss}^{-1} K_{sm} \quad (31)$$

There is no approximation involved in equation (30).

But how to select the master degrees of freedom to obtain good accuracy? The criteria for the choice of an automatic master is based on the ratio of K_{ss} to M_{ss} terms. If one slave displacement is desired, the degree of freedom with the largest K_{ss} to M_{ss} ratio should be chosen. This is based on the assumption that mass terms corresponding to slave displacements have a negligible effect on mode shape. The method therefore involves scanning the leading diagonals of the $[K]$ and $[M]$ matrices to find the degrees of freedom that yield highest K_{ss} to M_{ss} ratios. The user then must decide only on the number of automatic masters required.

Substructuring is also useful in the building block approach, in which each component of a structure is separately analyzed and coupled at certain points. These connection points are the dynamic degrees of freedom or the master degrees of freedom. The components in the building block approach can be analyzed either analytically, using finite element techniques, or empirically. Experimental techniques have advanced in the past few years so that dynamic properties can be measured by exciting the structure by impact, or by random or swept sinusoidal loads.

The dynamic characteristics are determined through frequency response and mode shapes of the structure. The frequency response is obtained with a controlled excitation force; both force and response are measured. The response could either be displacement, velocity, or acceleration. Experimental frequency response techniques have reached such a

sophisticated stage mainly because of the algorithm for rapid Fourier Transform, which is commonly known as Fast Fourier Transform, or FFT.

Experimental modal analysis is important when damping is predominant. The analytical finite element method with damping is complex, and such assumptions as proportional damping must be made to include the contributions due to damping. Such an assumption is in general not realistic except in lightly damped structures. For heavily damped structures, the exact modal contribution of damping might be important.

The finite element solution involves considerable clerical work to keep track of the joint co-ordinates and element connectivity. For a large problem checking the geometry of the model will cost more than the actual computer processing! Several graphic techniques are available now. Using these techniques model creation time is considerably improved. Digitizer tablets are available that create a model from a drawing, thereby reducing the burden on the analyst.

Graphic techniques are also available to animate the vibrating shapes of structures. Color coded graphics are also available to plot stresses and strain energy levels.

The finite element technique has been used for structural analysis, and in such other areas as lubrication, fiber industry, panel flutter, and biomechanics. The buckling of structures is also an eigenvalue problem and a technique analogous to that described here has been used. Current extension of the finite element method involves finding the stress intensity factor and notch factor for fatigue and fracture mechanics analyses. Thus the capability for a complete evaluation of the useful life of a product will soon be available at the drawing stage, given the typical dynamic environment of the product and a finite element dynamic analysis.

REFERENCES

1. Seshadri, T.V., "Shock and Vibration Analyses Using Finite Element Techniques," Shock Vib. Dig. (July 1975).
2. Meirovitch, L., *Elements of Vibration Analysis*, McGraw Hill (1975).
3. Rodrigues, J.S., "Node Numbering Optimization in Structural Analysis," ASCE J. Struc. Div., 101 (ST2), p 361 (Feb 1975).
4. Grooms, H.R. and Rowe, J., "Substructuring and Conditioning," ASCE J. Struc. Div., 103 (ST3), p 507 (Mar 1977).
5. Fawzy, I., "A Theorem on the Free Vibration of Damped Systems," J. Appl. Mech., Trans. ASME, p 132 (Mar 1977).
6. Guyan, R.J., "Reduction of Stiffness and Mass Matrices," AIAA J., 3 (2), p 380 (1965).
7. Tolani, S.K. and Rocke, R.D., "Modal Truncation of Substructures Used in Free Vibration Analysis," ASME Paper No. 75-DET-82.
8. Henshell, R.D. and Ong, J.H., "Automatic Masters for Eigenvalue Extraction," Intl. J. Earthquake Engr. Struc. Dynam., 3, p 375 (1975).
9. DAGS Manual, Structural Dynamics Research Corporation, Cincinnati (May 1977).
10. Hooker, R.J. and O'Brien, D.J., "Natural Frequencies of Box-Type Structures by a Finite Element Method," J. Appl. Mech., Trans. ASME, p 363 (June 1974).
11. Meirovitch, L., "A Stationarity Principle for the Eigenvalue Problem for Rotating Structures," AIAA J., 14 (10), p 1387 (Oct 1976).
12. Chen, J.C. and Wada, B.K., "Matrix Perturbation for Structural Dynamic Analysis," AIAA J., 15 (8), p 1095 (Aug 1977).
13. Hasselman, T.K., "Damping Synthesis from Substructure Tests," AIAA J., 14 (10), p 1409 (Oct 1976).
14. Beliveau, J.-G., "Eigenrelations in Structural Dynamics," AIAA J., 15 (7), p 1039 (July 1977).
15. Rock, T. and Hinton, E., "Free Vibration and

- Transient Response of Thick and Thin Plates Using the Finite Element Method," *Intl. J. Earthquake Engr. Struc. Dynam.*, 3, p 51 (1974).
16. Mayes, R.L. and Mowbray, N.A., "The Effect of Coulomb Damping on Multidegree of Freedom Elastic Structures," *Intl. J. Earthquake Engr. Struc. Dynam.*, 3, p 275 (1975).
 17. Laurenson, R.M., "Modal Analysis of Rotating Flexible Structures," *AIAA J.*, 14 (10), p 1444 (Oct 1976).
 18. Hasselman, T.K., "Modal Coupling in Lightly Damped Structures," *AIAA J.*, 14 (11), p 1627 (Nov 1976).
 19. Ojalvo, I.U., Austin, F., and Levy, A., "Iterative Analysis Method for Structural Components with Diverse Stiffnesses," *AIAA J.*, 14 (9), p 1219 (Sept 1976).
 20. Cronin, D.L., "Approximation for Determining Harmonically Excited Response of Non-classically Damped Systems," *J. Engr. Indus., Trans. ASME*, p 43 (Feb 1976).
 21. Nelson, H.D. and McVaugh, J.M., "The Dynamics of Rotor-Bearing Systems Using Finite Elements," *J. Engr. Indus., Trans. ASME*, p 593 (May 1976).
 22. Nagarajan, S. and Popov, E.P., "Non-linear Finite Element Dynamic Analysis of Axi-symmetric Solids," *Intl. J. Earthquake Engr. Struc. Dynam.*, 3, p 385 (1975).
 23. Thomas, J. and Abbas, B.A.H., "Dynamic Stability of Timoshenko Beams by Finite Element Method," *J. Engr. Indus., Trans. ASME*, p 1145 (Nov 1976).
 24. Sweet, A.L., Genin, J., and Mlakar, P.F., "Determination of Column-Buckling Criteria from Vibratory Data," *Exptl. Mech.*, p 385 (Oct 1977).
 25. Gibson, R.F. and Plunkett, R., "A Forced-Vibration Technique for Measurement of Material Damping," *Exptl. Mech.*, p 297 (Aug 1977).
 26. Halvorsen, W.G. and Brown, D.L., "Impulse Technique for Structural Frequency Response Testing," *S/V, Sound Vib.*, p 8 (Nov 1977).
 27. Russell, R.H. and Deel, J.C., "Modal Analysis: Trouble-Shooting to Product Design," *S/V, Sound Vib.*, p 22 (Nov 1977).
 28. "Equipment, Simple and Sophisticated, Helps Pin-Point Harmful Vibrations," *Product Engr.*, (N.Y.), p 49 (Mar 1977).
 29. Taylor, J.E., "Scaling a Discrete Structural Model to Match Measured Modal Frequencies," *AIAA J.*, p 1647 (Nov 1977).
 30. Klosterman, A.L. and McClelland, W.A., "Combining Experimental and Analytical Techniques for Dynamic System Analysis," 1973 Tokyo Seminar on Finite Element Analysis (Nov 1973).
 31. Klosterman, A.L., McClelland, W.A., and Sherlock, J.E., "Dynamic Simulation of Complex Systems Utilizing Experimental and Analytical Techniques," *ASME Paper No. 75-WA/Aero-9*.
 32. Klosterman, A.L. and Zimmerman, R., "Modal Survey Activity Via Frequency Response Functions," *SAE Paper No. 750168*.
 33. Brigham, E.O., The Fast Fourier Transform, Prentice-Hall (1974).
 34. Aguiar, A.A., "Applications of Computer Graphics to Automotive Structural Analysis," *SAE Paper No. 760182*.
 35. Ladd, H.E., "Mechanism Design Using Animation," *J. Engr. Indus., Trans. ASME*, p 1324 (Nov 1976).
 36. Angus, G.D., Parmater, J.Q., and Smith, R.L., "Integration of Interactive Graphics into the Design Process," Fourth Annual Graphics Conf., *Engr. Soc. Detroit* (Apr 1978).
 37. Mei, C., "A Finite Element Approach for Non-Linear Panel Flutter," *AIAA J.*, 15 (8), p 1107 (Aug 1977).
 38. Singh, D.V., Sinhasan, R., and Ghai, R.C.,

"Static and Dynamic Analysis of Capillary Compensated Hydrostatic Journal Bearings by Finite Element Method," J. Lubric. Tech., Trans. ASME, p 478 (Oct 1977).

39. Eidelberg, B.E. and Booker, J.F., "Application of Finite Element Methods to Lubrication: Squeeze Films between Porous Surfaces," J. Lubric. Tech., Trans. ASME, p 175 (Jan 1976).
40. Willis, T. and Sheth, B., "An Application of the Finite Element Method to EHD Lubrication," ASLE Trans., 20 (4), p 340 (1976).
41. Kiparissides, C. and Vlachopoulos, J., "Finite Element Analysis of Calendering," Polymer Engr. and Sci., 16 (10), p 712 (Oct 1976).

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 aeroacoustics and plate vibrations. Dr. Arndt, Director of the St. Anthony Falls Hydraulic Laboratory, has prepared an interesting sketch on aeroacoustics: jet noise and noise from rotating blades.

Dr. Leissa of Ohio State University has prepared a review of the literature on recent research in plate vibrations. Dr. Leissa is the author of the popular monographs on plate and shell vibrations.

A SKETCH OF AEROACOUSTICS

R.E.A. Arndt*

Abstract - *This article reviews the state of the art in aeroacoustics. Aircraft noise sources are summarized. Two major noise sources -- jet noise and noise from rotating blades -- are described in detail. Research trends are mentioned.*

The general problems of noise reduction and acoustic fatigue fall within the general area of a new and challenging field called aeroacoustics -- an amalgam of aerodynamics and acoustics. Both are well developed disciplines; only in recent years has the aerodynamicist had much to do with acoustics and the acoustician with aerodynamics. The birth of aeroacoustics is often attributed to the classical publications of Lighthill [1] in 1952 and 1954. The theoretician would say that the propagation of low to medium intensity acoustical waves is but one example of a weakly perturbed compressible flow and that many features of high intensity acoustic waves or nonlinear acoustics are also known to the aerodynamicist. However, in practice, the acoustician is generally concerned with linear phenomena and with such properties of non-dispersive waves as transmission, reflection, refraction, and defraction. The aerodynamicist has been concerned mostly with such nonlinear phenomena as convective acceleration of fluid particles over bodies, vorticity, and turbulence in different types of flow fields. Classical acoustics is concerned with sound from such external forces as a loudspeaker, a vibrating violin or a blacksmith pounding an anvil with a hammer. Aeroacoustics is concerned with sound produced by the motion of fluids or bodies in the atmosphere and by such chemical processes as the combustion of jet fuel. Thus the intensity of sound from a given source is determined from aerodynamic considerations. The study of sound propagation is based on the principles of classical acoustics.

The discovery that the flow of a fluid or air over a body can create sound dates from the classical work of Strouhal [2] published in 1878. The foundations of propeller and helicopter rotor noise were laid down more recently. Gutin [3] demonstrated

in the late 1940s that the steady blade loads (relative to the propeller) associated with a thrusting rotor can produce sound. At about the same time Yudin [4] provided a way to study the noise due to unsteady propeller blade forces associated with vortex shedding phenomena. The classic work of Lighthill [1] provided the first firm theoretical basis for the study of noise due to a flowing medium in the absence of boundaries. Lighthill's work follows traditional lines in that he lumped the aerodynamics of the problem into an equivalent acoustic source strength. Crow [5] published an attempt to provide an integrated theory of jet noise in 1970. He formulated the aerodynamic sound emission problem in terms of matched asymptotic expansions; the inner solution provided a physical description of a compressible vortical flow (turbulence), and the outer solution consisted of a weakly perturbed wave-like motion (the acoustic radiation). In my opinion this paper is the basis for a unified approach to aeroacoustics and perhaps indicates the direction in which the future of aeroacoustics could be structured.

There is a need to train people to work in aeroacoustics. Active work dates back only about 25 years, yet the field has a firm theoretical foundation. The major developments are associated with aircraft noise, but possibilities in other fields are almost limitless. It is the aim of this paper to review the state of the art in aeroacoustics.

AIRCRAFT NOISE SOURCES

A typical jet engine is shown in Figure 1. Several internal rotating devices -- fan, compressor, and turbine -- generate noise that propagates from the inlet and discharge ducts. The burning of fuel in the engine is also a noise source, as are the discharges of hot gases from the turbine and of cold air from the fan that provide the engine thrust. The identification of a noise source and the study of noise propagation are complex. Various noise sources can contribute to the total noise problem. As a jet aircraft approaches

*Professor and Director, St. Anthony Falls Hydraulic Laboratory, Mississippi River at 3rd Avenue S.E., University of Minnesota, Minneapolis, Minnesota 55414

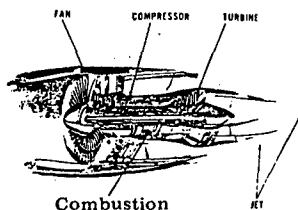


Figure 1. Jet Engine Noise Sources (After Sofrin)

an observer, the noise signature is dominated by noise propagating out the inlet (Fig. 2). As the aircraft passes overhead, the noise that has propagated out of the discharge ducts predominates; finally, as the aircraft leaves the observation point, the low frequency rumble of the jet exhaust dominates. Thus, many noise sources must be considered simultaneously in considering ways to decrease the overall noise level for a given aircraft.

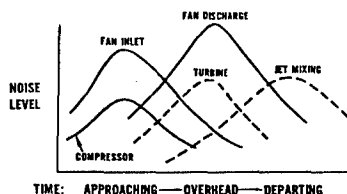


Figure 2. Flyover Noise History for a Jet Transport

Multiple noise sources are evident in Figure 3 which is a spectrum of noise from a typical helicopter. Both pure tone noise and broadband noise are present, and such components as the main rotor, tail rotor, power plant, and gearbox contribute to the noise signature.

Jet Noise

One major aircraft noise source is the fluctuating pressure field generated by the mixing of a high velocity jet with the atmosphere. Jet noise studies focus on the precise nature of the turbulence created by the mixing process, the exact nature of the sound generating mechanism -- including whether or not the major source involves the formation of a turbulent eddy or its decay -- whether or not some orderly structure in a turbulent jet tends to enhance the acoustic efficiency of turbulent noise sources, and the sound due to the interaction of turbulence

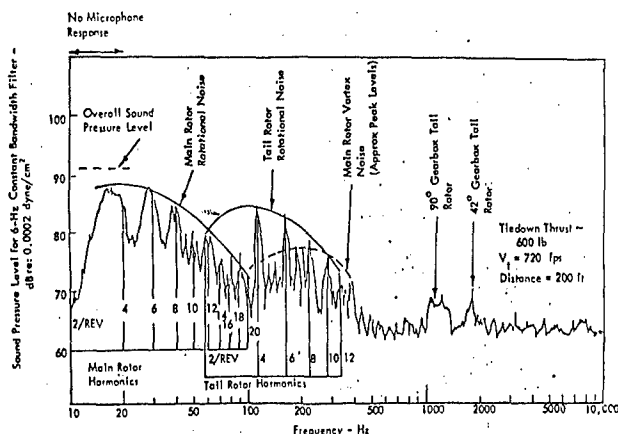


Figure 3. UH-1A External Noise Spectrum

and the shock structure in a turbulent jet. Jet suppressor technology has not yet been developed to the point that a rational approach to jet noise suppression is possible.

Much of what is known about jet noise has been deduced from a few basic principles that are briefly reviewed below. The Lighthill acoustic analogy was developed from the conservation of mass and momentum in a general fluid flow.

$$\frac{\partial^2 \rho}{\partial t^2} - a_0^2 \frac{\partial^2 \rho}{\partial x_i \partial x_i} = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_j} \quad (1)$$

$$T_{ij} \cong \rho_0 u_i u_j \quad (2)$$

In the equations ρ is the density, and a_0 the acoustic velocity in the undisturbed medium. A formal solution to equation (1) is given by

$$p' = \frac{1}{4\pi a_0^2} \frac{x_i x_j}{|\underline{x}|^3} \int_{\nabla} \frac{\partial^2 T_{ij}}{\partial t^2} [\underline{y}, t'] d\mathbf{y} \quad (3)$$

$$t' = t - \frac{r}{a_0}, \quad r = |\underline{x}| \quad (4)$$

In equation (3) p' is the pressure level at $\underline{x}$ due to a distribution of sound sources in the volume ∇ , and the position of each sound source is $\underline{y}$. Although the actual solution of equation (3) requires extensive measurement of the turbulent velocity field, Lighthill and others have suggested that many of the general features of jet noise can be inferred from

similarity principles.

Assume that the total sound at a given point is made up of the contribution of many uncorrelated sound sources within the jet. The sound from a volume of turbulence is then given by equation (5).

$$p' \cong \frac{x_j x_j V_e}{4\pi a_0^2 |x|^3} \ddot{T}_{ij} \left(t - \frac{r}{a_0} \right) \quad (5)$$

V_e is the volume over which a given sound source is correlated. The intensity I and total radiated power W are related to the square of the acoustic pressure.

$$I \cong \frac{p'^2}{\rho_0 a_0} \quad (6)$$

$$W \sim I |x|^2 \quad (7)$$

The total power radiated per unit volume of turbulence is therefore given by

$$\frac{W}{Vol} = \frac{V_e \omega^4 T_{ij}^2}{\rho_0 a_0^5} \quad (8)$$

Equation (8) assumes that differentiation with respect to time is proportional to a characteristic frequency ω . The variation of radiated acoustic power, the sound power per unit slice of jet, and the spectral characteristics of jet noise can be estimated from equation (8).

Detailed information is needed on the flow structure of turbulent jets; e.g., estimates for T_{ij} and V_e imply the need for turbulence measurements. In addition, two-point correlations are needed to estimate V_e , which can be said to be proportional to the cube of the integral scale. Figure 4 shows that a jet contains several different regions of flow. As the flow leaves the nozzle, a region of intense turbulent mixing is formed. The interchange in momentum between the core and the mixing regions decreases the core region. At about four diameters from the nozzle the potential core ceases to exist; further mixing shifts the region of maximum turbulence intensity toward the centerline. In the fully developed region the profiles of mean and fluctuating velocities are similar; the profiles attain a maximum at the jet centerline.

Figure 5 shows the results of correlation studies with a hot wire anemometer in the mixing zone of a jet. The data are plotted in terms of contours of constant

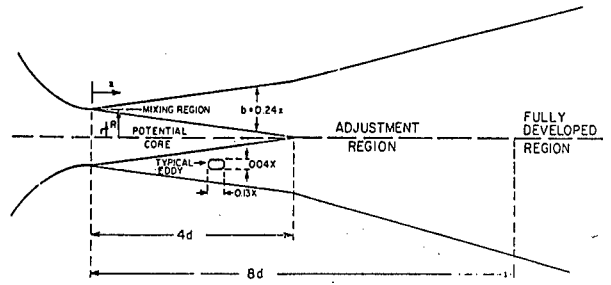


Figure 4. Flow Structure of Turbulent Jet

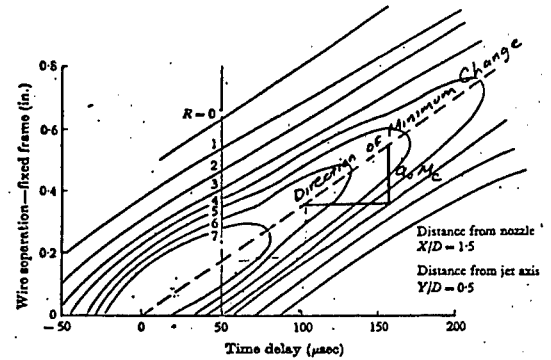


Figure 5. Correlation Studies in a Turbulent Jet [6]

correlation. A minimum change in correlation occurs in a certain direction in the space-time plane. The slope of this line is the convective speed of the eddies or acoustic sources in a jet because an observer moving with this speed sees the true time rate of change of the turbulent structure. It has been shown [6] that an autocorrelation in this frame of reference can be approximated by

$$R_\tau \sim \exp \left[-\frac{\tau}{T} \right] \quad (9)$$

$$T \cong \frac{4.5}{\frac{\partial \bar{u}}{\partial r}} \quad (10)$$

The turbulence intensity in the region is proportional to the mean shear $\frac{\partial \bar{u}}{\partial r}$ and the scale of the turbulence L .

$$u' \cong 0.2 \frac{\partial \bar{u}}{\partial r} L \quad (11)$$

Furthermore, the product of Tu' is proportional to the scale of the turbulence.

$$Tu' \cong 0.9L \quad (12)$$

Thus the characteristic frequency ω in equation (8) is given by

$$\omega \sim \frac{1}{T} = 1.1 \frac{u'}{L} \quad (13)$$

and in the mixing region

$$\frac{2\pi\omega d}{U_j} = 0.53 \left(\frac{x}{d}\right)^{-1} \quad (14)$$

A summary of measured and estimated turbulence data and the acoustic properties that can be inferred from these data is presented in Table 1. The estimates of acoustic properties are based on equation (8) and the following assumptions. The effective volume is assumed proportional to the cube of the eddy scale.

$$V_e \sim L^3 \quad (15)$$

Similarly the source strength T_{ij} is given by

$$T_{ij} \sim \rho_0 u'^2 \quad (16)$$

The sound power per unit slice of jet is estimated from

$$\frac{dW}{dx} \cong \frac{W}{Vol} \frac{Vol}{Slice} \quad (17)$$

where

$$\frac{Vol}{Slice} \sim d^2 \left(\frac{x}{d}\right) \quad \text{mixing region} \quad (18)$$

$$\sim d^2 \left(\frac{x}{d}\right)^2 \quad \text{fully developed} \quad (19)$$

In the adjustment region the estimate is

$$\frac{Vol}{Slice} \sim d^2 \left(\frac{x}{d}\right)^{3/2} \quad (20)$$

Table 1. Measured Functional Properties of Jet Turbulence and Inferred Acoustic Characteristics

Flow Property/Region	Mixing	Adjustment (estimated)	Fully Developed
$\frac{u'}{U_j}$	const	$\left(\frac{x}{d}\right)^{-1/2}$	$\left(\frac{x}{d}\right)^{-1}$
$\frac{L}{d}$	$\frac{x}{d}$	$\left(\frac{x}{d}\right)^{1/2}$	$\frac{x}{d}$
$\frac{a_o^5 d^5}{\rho_o U_j^8} \frac{W}{Vol}$	$\left(\frac{x}{d}\right)^{-1}$	$\left(\frac{x}{d}\right)^{-2/3}$	$\left(\frac{x}{d}\right)^{-9}$
$\frac{a_o^5}{\rho_o U_j^8 d} \frac{dW}{dx}$	const	$\left(\frac{x}{d}\right)^{-3}$	$\left(\frac{x}{d}\right)^{-7}$
$\frac{a_o^5}{\rho_o U_j^8 d^2} S$	$\sim \left(\frac{\omega d}{U_j}\right)^{-2}$	$\frac{\omega d}{U_j}$	$\left(\frac{\omega d}{U_j}\right)^2$

Similarly the spectrum of the acoustic signal is estimated from

$$S(\omega) \equiv \left| \frac{dW}{d\omega} \right| \quad (21)$$

and

$$\frac{dW}{d\omega} = \frac{dW}{dx} \frac{1}{\frac{d\omega}{dx}} \quad (22)$$

The total radiated power of a jet is given by

$$W = \int_0^\infty \frac{dW}{dx} dx \quad (23)$$

which is

$$W \sim \frac{\rho_0 U_j^8 d^2}{a_0^5} \quad (24)$$

From a design point of view equation (24) is probably the most significant result of the jet noise theory. The inherent advantages of the fan jet engine are apparent from this equation: significant noise reduction is possible at a given thrust level by moving larger quantities of air at a lower jet velocity. Propulsive efficiency is also increased.

Solutions of equation (24) are compared with data measured for several variables in Figure 6. The agreement is remarkable. The trend of noise spectra is compared with experimental results in Figure 7; the expected results are again remarkably reliable.

From equation (24) it can be shown that acoustic efficiency varies with the Mach number to the fifth power. There is a limit, however to acoustic efficiency. The intensity of acoustic radiation is altered by the effects of convection.

$$I \sim \frac{\rho_0 U_j^8}{a_0^5 r^2} \frac{1}{c^5} \quad (25)$$

C is a convection factor

$$C = \left\{ (1 - M_c \cos \theta)^2 + \frac{\omega^2 L^2}{\pi a_0^2} \right\}^{1/2} \quad (26)$$

Convection	Eddy
Effect	Decay
(Frozen	
Turbulence)	

As the eddy approaches supersonic speed, Mach waves form at an angle to the flow direction.

$$\theta_c = \cos^{-1} \frac{1}{M_c} \quad M_c > 1 \quad (27)$$

M_c is the convection Mach number. The implication of equation (27) is that very intense sound is focused at an angle θ_c to the jet. According to classical theory the sound would be very intense if the eddy were not decaying. Hence, when the eddies are convected supersonically, the convection factor C is not zero at θ_c but rather

$$C \cong \frac{\omega L}{a_0}, \quad \theta = \cos^{-1} \frac{1}{M_c} \quad (28)$$

The acoustic intensity is thus

$$I \sim \frac{\rho_0 U_j^8}{a_0^5 r^2} \frac{1}{\left(\frac{\omega L}{a_0} \right)^5} \quad (29)$$

Because $\omega L \sim U_j$, the intensity is

$$I \sim \frac{\rho_0 U_j^3}{r^2} \quad (30)$$

Equation (30) implies that acoustic efficiency is independent of Mach number. This result is in close agreement with observations of rocket noise.

Noise From Rotating Blades

One of the most common ways to impart or extract energy from a moving fluid is by aerodynamic lift in a rotating device. The most common devices in aerospace are propellers, helicopter rotors, fans, compressors, and turbines; all are important noise sources (see Table 2).

According to the theory of noise generation, the two fundamental types of noise sources are a dipole due to aerodynamic loading and a monopole due to the displacement that occurs when a blade of finite thickness is moving through the air. Turbulence created by the movement of the blades is an additional noise source. The major noise source common to all rotating devices, blade loading, is shown systematically in Figure 8. The relationship of the pressure field at x , due to a dipole at y moving relative to the observer with velocity $a_0 M_r$, is

$$P' = \frac{x_i - y_i}{4\pi a_0 r^2 (1 - M_r)^2} \left\{ \frac{\partial [F_i]}{\partial t} + \frac{[F_i]}{1 - M_r} \frac{\partial M_r}{\partial t} \right\} \quad (31)$$

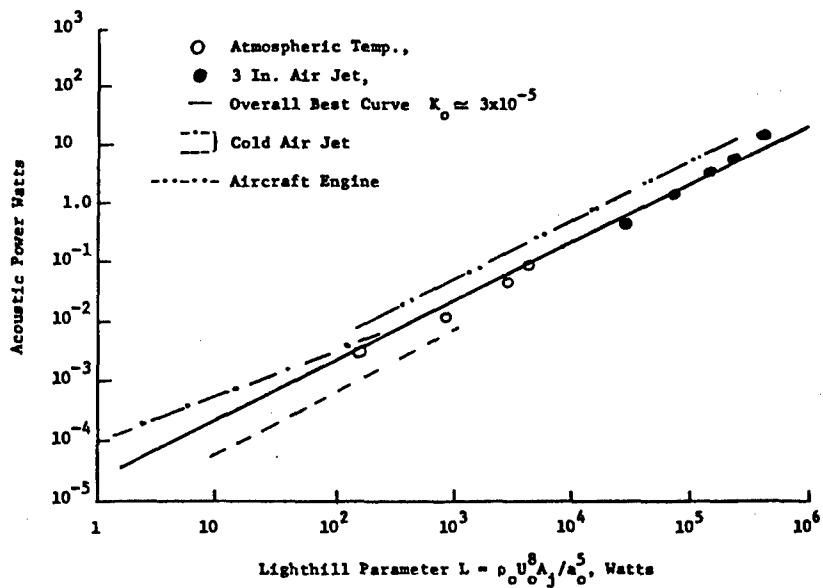


Figure 6. Acoustic Power as a Function of Lighthill Parameter

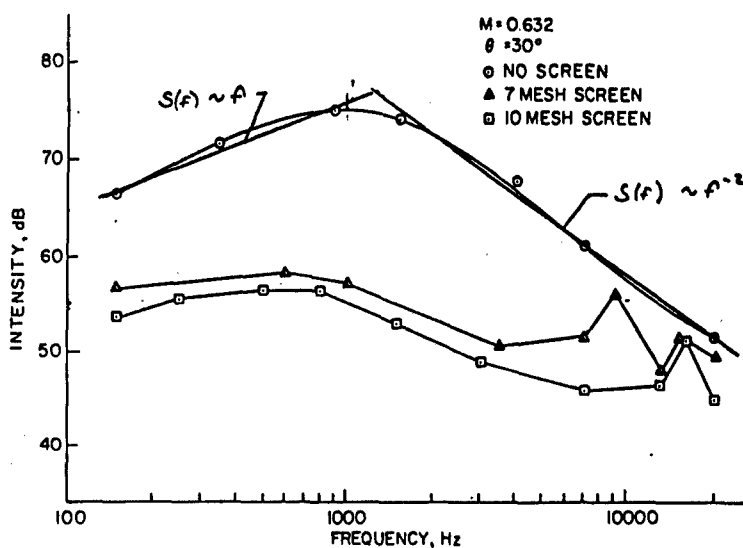


Figure 7. Frequency Spectrum of Jet Noise

Table 2. Typical Rotating Devices and Their Operating Conditions

Component	B	Chord Length (ft)	D (ft)	Tip Speed (ft/sec)	HP
Propellers	2-6	0.3-1	5-12	500-1000	50-5,000
Helicopter Rotors	2-6	0.3-2	5-70	500-900	50-10,000
Fans, Compressors Turbines	15-80	0.05-0.5	0.5-9	500-2000	50-50,000
Space System Impellers	2-10	0.02-0.05	0.05	200-400	0.1-1

Two Types:

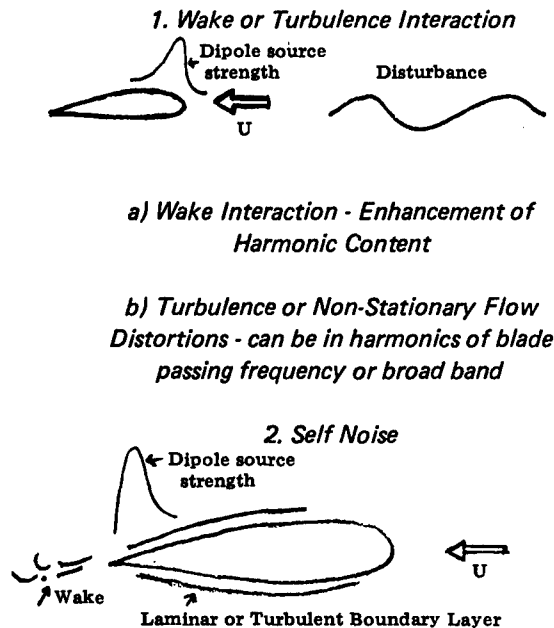


Figure 8. Schematic of Rotor Noise Blade Loading

Two contributors to the noise field are unsteady loads on the blade and acceleration of a steady load. Hence, if a propeller is operating with steady velocity in completely quiescent air, the blade load is steady and the first term in the brackets in equation (31) is zero. Only the steady load contributes to the sound field and is completely dependent on the centrifugal acceleration. Consideration of this

case resulted in the classical equation relating the noise level in each blade passing harmonic mB to the number of blades B , the thrust T , and the torque Q [3].

$$\langle SP_{mB} \rangle = \frac{mBN}{\sqrt{2}Ra_0} \left[T \cos \delta - \frac{Q}{r_e M_e} \right] J_{mB} (mB M_e \cos \delta) \quad (32)$$

$$M_e = \frac{2\pi N r_e}{a_0} \quad (33)$$

N is the rotational speed, and δ is the angle the observer makes with the thrust line. Equation (32) is useful in design for determining the relative effects of blade loading, the number of blades, and the rotational speed on the noise signature. All harmonics of pressure are due to a pressure field that rotates at the basic rotor speed N . Unsteadiness has a significant effect. For example, if a flow distortion results in an unsteady blade loading at a specific blade position, the pressure level is considerably enhanced in the higher harmonics ($mB > 1$). The problem is further complicated by the fact that the pressure level in each harmonic is made up of an infinite number of modes rotating with speeds

$$\omega_m = \frac{2\pi mBN}{mB \pm s} \quad (34)$$

Here s corresponds to the harmonic of blade loading

$$L = L_0 + \sum_{s=1}^{\infty} L_s \cos(s\psi - \theta_s) \quad (35)$$

L is the lift on each blade, and ψ is the blade position. A typical example of this type of loading is the effect of forward flight on a helicopter rotor; the velocity relative to the advancing blade is higher than that relative to the retreating blade. Another example is a compressor in which the rotor blades repeatedly slice through the wakes of the upstream stator vanes. The effects of such flow unsteadiness are shown in Figure 9.

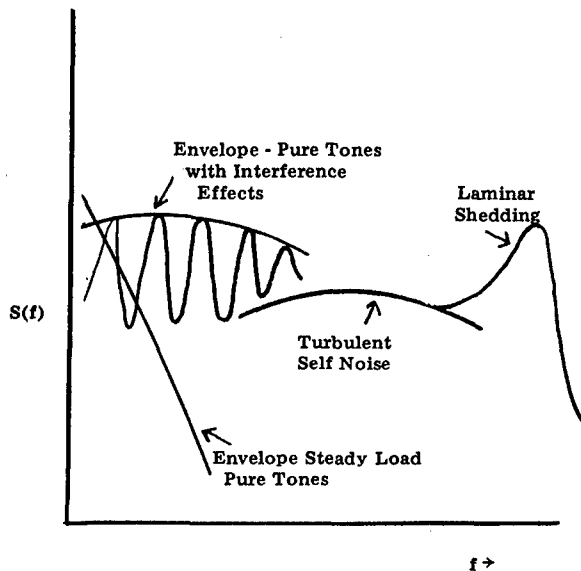


Figure 9. Schematic of Rotor Noise Spectrum

Changes in rotating modes are important when a rotor is placed in a duct -- the situation in a jet engine. According to theory a rotating pressure field propagates only in a thin annular duct of radius r_0 if the rotational Mach number is greater than unity.

$$\frac{2\pi N r_0}{a_0} > 1 \quad (36)$$

Thus, no noise propagates from a rotor rotating with subsonic tip speed in a circular duct if no flow distortion is occurring. If a rotor with B blades is operating behind a stator with V blades, an infinite number of rotational modes exist in each harmonic mB. Each mode rotates with a speed given by equation (34); in this case s is kV, k being any integer.

$$\omega_{\pm k} = \frac{2\pi m B N}{m B \pm k V} \quad (37)$$

The noise level in any harmonic is thus critically dependent on the number of stator and rotor vanes. The worst situation is a device with an equal number of rotor and stator vanes because, regardless of the tip speed, each harmonic of a blade passing frequency will propagate. As shown by equation (37), an integer k always exists that makes ω infinite. This very important point has resulted in the removal of the fan inlet guide vanes in the newest jet engines.

TRENDS

This review of jet and fan noise has described some of the factors that control the acoustic output from various aircraft components. It should be pointed out that most of the dramatic advances in aircraft noise control thus far have been based on a few relatively simple facts that have emerged from a considerable research effort.

However, as is true of any aspect of noise control, as one noise source is diminished, another becomes prominent. Efforts are being made to understand combustion noise; the propagation of internal noise sources through complex ducts, rotors, and guide vanes; the effect of rotation on the decay of rotor and stator wakes so that spacing for noise control can be optimal; and the noise due to turbulence ingestion either in the boundary layer along the wall of the inlet duct or in the atmosphere. Considerable effort is being expended to clarify the performance of acoustic liners in the presence of flow. The liner itself is a source of flow noise, and recent investigations have shown that the acoustic impedance of the liner is affected by the structure of the flow over the liner.

It should be mentioned that even if jet engine noise were completely masked, a typical jet transport would still be extremely noisy. Figure 10 shows that airframe noise is significant. If further improvements in jet engine noise control technology become a reality, airframe noise will become a significant problem, especially if noise control regulations are made more strict. A myriad of aeroacoustic noise sources are associated with airframe noise -- boundary layer noise, interaction of boundary layer turbulence with the trailing edges of wings and control surfaces, interaction of acoustic modes and shear layer instabilities at cut-outs such as wheel wells, and vortex shedding noise.

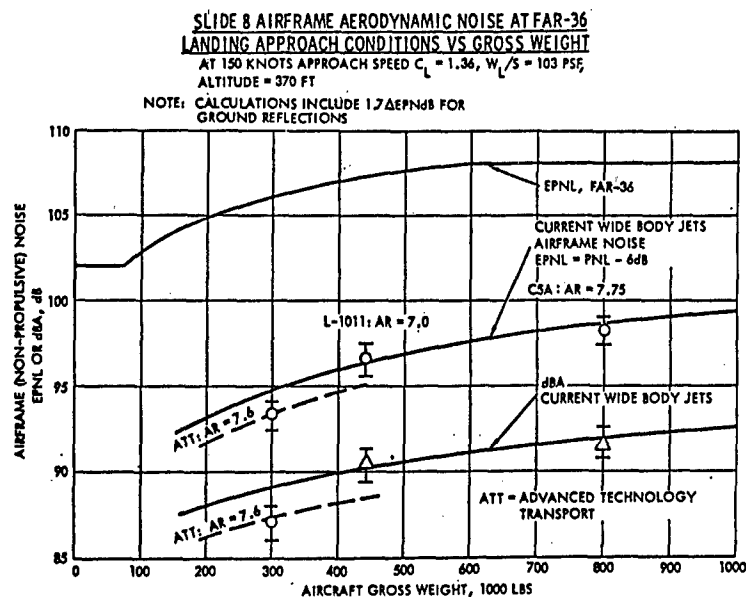


Figure 10. Predicted Airframe Noise

In addition, STOL and VTOL vehicles have special noise sources; e.g., blown flaps and jet flaps. It is of interest that these aeroacoustic problems touch on many areas in basic fluid mechanics as well as acoustics. For example, many recently published basic turbulence research results began as aeroacoustic problems.

Thus, although significant advances have been made in aircraft noise control, much remains to be done in the way of fundamental research, design, development of test facilities, development of sophisticated data processing techniques, and even in optimizing flight operational procedures for minimizing noise while maintaining a high degree of safety and performance.

ACKNOWLEDGMENTS

The preparation of this paper was partially supported by NASA under Grant No. NGR39-009-007 under the direct administration of Mr. James Stone. The visits to European research centers during the sabbatical leave of the author were made possible by a NATO Senior Scientist Fellowship Award and through support from the Office of Naval Research/London.

REFERENCES

1. Lighthill, M.J., Proc. Royal Soc. (London), 211, Ser. A, pp 564-587 (1952) and 222, pp 1-32 (1954).
2. Strouhal, V., Ann Phys. Chemie, New Ser., 5, pp 216-251 (1878).
3. Gutin, L., NACA TM 1195 (1948).
4. Yudin, E.Y., NACA TM 1136 (1947).
5. Crow, S.C., Studies in Appl. Math., MIT, XLIX, pp 21-44 (1970).
6. Davies et al, J. Fluid Mech., 15, pp 337-367 (1963).

RECENT RESEARCH IN PLATE VIBRATIONS. 1973 - 1976: COMPLICATING EFFECTS

A.W. Leissa*

This paper is a review of literature dealing with the complicating effects of free, undamped vibrations of plates that appeared from 1973-1975 and in part of 1976. Recent research dealing with the complicating effects of anisotropy, in-plane forces, variable thickness, surrounding media, large deflections, shear deformation, rotary inertia, and non-homogeneity (including layered plates) is summarized.

A previous paper [1] reviewed the recent literature of free vibrations of plates according to classical theory. Classical theory is governed by the equation of motion

$$D\nabla^4 w + \rho \frac{\partial^2 w}{\partial t^2} = 0, \quad (1)$$

That survey dealt with literature published from the beginning of 1973 through part of 1976; the present paper continues the survey and includes eight complicating effects, each of which requires generalization of equation (1) and increases the difficulty in obtaining analytical solutions for free vibration frequencies, nodal patterns, and mode shapes.

ANISOTROPIC PLATES

For plates having general anisotropy the term $D\nabla^4 w$ in equation (1) must be greatly expanded. Isotropic materials that have only two independent elastic coefficients -- usually taken as E (Young's modulus) and ν (Poisson's ratio) -- can be combined into a single flexural rigidity parameter, D . Definition of a generally anisotropic plate requires five independent rigidity parameters. Because of the number of additional parameters and terms required in equation (1), as well as further complications owing to coupling between derivatives, no results for the vibration of generally anisotropic plates are known to the author.

Orthotropic plates require the definition of three independent rigidity parameters. Thus, thorough

numerical studies require the variation of two parameters that are ratios of flexural rigidities. Furthermore, orthotropy can be defined with respect to various coordinate systems: the two most commonly used are polar and rectangular. Some recent work has also been done with skew orthotropy.

Polar Orthotropy

In the case of polar orthotropy equation (1) generalizes to

$$\begin{aligned} D_r \frac{\partial^4 w}{\partial r^4} + 2 \frac{D_{r\theta}}{r^2} \frac{\partial^4 w}{\partial r^2 \partial \theta^2} + \frac{D_\theta}{r^4} \frac{\partial^4 w}{\partial \theta^4} + 2 \frac{D_r}{r} \frac{\partial^3 w}{\partial r^3} \\ - 2 \frac{D_{r\theta}}{r^3} \frac{\partial^3 w}{\partial r \partial \theta^2} - \frac{D_\theta}{r^2} \frac{\partial^2 w}{\partial r^2} + \frac{2}{r^4} (D_\theta + D_{r\theta}) \frac{\partial^2 w}{\partial \theta^2} \\ + \frac{D_\theta}{r^3} \frac{\partial w}{\partial r} + \rho \frac{\partial^2 w}{\partial t^2} = 0 \end{aligned} \quad (2)$$

D_r , D_θ , and $D_{r\theta}$ are the appropriate flexural rigidity parameters [2]. Equation (2) permits separation of variables.

Axisymmetric vibrations of clamped circular plates have been analyzed [3]. Particular attention was given to the questionable meaning of polar orthotropy at the origin ($r=0$).

Ramaiah and Kumar [4, 5] made a thorough study of annular plates. The Ritz method was used with algebraic polynomial deflection functions [4] to obtain frequency parameters for all nine combinations of simple boundary conditions for various ratios of flexural rigidities and of boundary radii (b/a). Simple approximate formulas expressed the orthotropic frequencies in terms of flexural rigidity ratios and the frequencies of corresponding modes in the axisymmetric case. A simplified method based upon the assumption that the radial bending moment is small at a nodal circle [5] was shown to be especially useful for estimating frequencies of modes having a large number of nodal circles.

Orthotropic circular plates having concentric iso-

*Professor of Engineering Mechanics, Ohio State University, Columbus, Ohio

tropic cores have been analyzed [6, 7]. Axisymmetric frequencies were given for cases having clamped and simply supported boundaries. Annular corrugated disks have been represented by orthotropic plates [8] for the theoretical analysis of the case in which the outside boundary is free and the inside one clamped; theoretical results were compared with experimental ones.

Rubin [9] used the Frobenius method to study annular sector plates with radial edges simply supported. Numerical results were presented for a case with the inner boundary clamped and the outer one free. Vibrations of circular polar orthotropic plates have also been studied [10-13].

Rectangular Orthotropy

For rectangular orthotropy equation (1) becomes

$$D_x \frac{\partial^4 w}{\partial x^4} + 2D_{xy} \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} + \rho \frac{\partial^4 w}{\partial t^2} = 0 \quad (3)$$

D_x , D_y , and D_{xy} are the appropriate flexural rigidity parameters [2].

The six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solutions [2]. This procedure has been used [14-18] as a basis for comparison of approximate methods. Aksu and Ali [15] demonstrated a finite difference method using an unequal interval formulation; an optimum interval variation parameter was determined. Vijakumar [16] applied Bolotin's asymptotic method to obtain numerical results for five of the six cases. A finite-strip-difference technique was utilized and discussed [17, 18].

The rectangular orthotropic plate clamped on all edges has been studied [19-22]. Bauer and Reiss [19] used the perturbation method; the isotropic solution supplied the leading term in the perturbation expansion. King and Lin [22] used Bolotin's method to obtain results for the CFCF plate as well.

For plates of other shapes with rectangular orthotropy, an interesting reduction method has been demonstrated [23]. A frequency of one plate was estimated from that of another having a different shape. The method was demonstrated for the clamp-

ed ellipse (derived from results for the circle) and for the simply supported skew (parallelogram) plate (derived from the simply supported isotropic rectangular plate).

Maurizi and Laura [24] investigated rectangular plates having rectangular axes of orthotropy rotated through an angle ϕ with respect to the plate edges. The Galerkin method with algebraic polynomials was used to derive formulas for the first four frequencies of a clamped rectangular plate. Curves were plotted for an example representing a uni-directional boron-epoxy material.

Srinivasan and Munaswamy [25] studied the problem of the parallelogram plate having four free edges and supported at four interior points. The problem was solved by means of skew finite strips; extensive numerical results showing frequency parameters and mode shapes were presented [25].

Orthotropic parallelogram plates have also been treated [26], as have trapezoids [27]. Other references deal with free vibration of plates having rectangular orthotropy [28-30].

Skew Orthotropy

The case of a material with principal axes of orthotropy that are straight but not orthogonal has been investigated by Nair and Durvasula [31]. They used the Ritz method and presented extensive numerical results for square and skew plates having various combinations of boundary conditions. Orthotropic rhombic plates have also been studied [32].

IN-PLANE FORCES

The presence of in-plane forces during the vibration of a plate requires additional terms in equation (2); they are second derivatives of w . If the in-plane forces are constant with respect to the space variables, the additional terms will have constant coefficients. For example, one important case is that of hydrostatic normal stress -- i.e., constant normal stress in all directions -- for which equation (1) becomes

$$D \nabla^4 w - N \nabla^2 w + \rho \frac{\partial^2 w}{\partial t^2} = 0 \quad (4)$$

N is the constant tensile in-plane force per unit

length of boundary. Generally speaking, tensile in-plane forces increase the vibration frequencies, whereas compressive forces decrease them. Reduction of a frequency to zero yields a buckling load for the plate.

Circular Plates

Considerable recent research on the circular plate subjected to hydrostatic loading and supported elastically on the boundary has been done [33-37]. Both translational and rotational edge springs were considered [36]. A concentrated mass was added at the center [37]. Extensive results were presented [34].

The rotation about the polar axis as a cause of variable in-plane stresses, as well as thermal in-plane stresses, have been studied [38, 39]. Nieh and Note [38] compared experimental results with theoretical ones.

Some recent work has dealt with the annular plate [40-43]. Rosen and Libai [40, 41] studied the case in which the outer edge is simply supported and uniformly compressed, and the inner one is free. Simple one-term Rayleigh solutions were derived for the vibration modes having no internal nodal circles. Numerical results were compared with experimental ones. Loh [42] treated the case when the inner edge is simply supported and uniformly compressed, and the outer one is either simply supported or free and is free of in-plane loads. The disk is simultaneously spinning about its polar axis. The rotating disk has been studied [43, 44].

Rectangular Plates

It can be shown [2] that in rectangular coordinates the effects of in-plane forces are accounted for by adding the terms

$$N_x \frac{\partial^2 w}{\partial x^2} + 2 N_{xy} \frac{\partial^2 w}{\partial x \partial y} + N_y \frac{\partial^2 w}{\partial y^2} \quad (5)$$

to the right-hand sides of equations (1) or (3), where the N 's are the positive in-plane normal and shearing forces per unit length (either constant or variable). For the special case of hydrostatic loading equation (4) results.

For N_x and N_y constant, and $N_{xy} = 0$, the six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solu-

tions [2]. Cases of this type have been studied [14, 45, 46].

Dickinson [47] analyzed the orthotropic, clamped, square plate subjected to hydrostatic loading by means of Bolotin's method. Plates having two parallel edges clamped and the other two free have been discussed [48]. The effects of residual stresses upon frequencies of a free plate with a weld longitudinally along its center have been examined [49]. Extensive numerical results for simply supported plates having different rotational springs along various edges and subjected to biaxial in-plane loads (N_x and N_y) have been obtained by Laura and Romanelli [50]. Other references deal with rectangular plates having in-plane loads [51-53].

Other Shapes

Jones and Mazumdar [54] addressed the problem of the hydrostatically loaded, elliptical plate having clamped or simply supported edges. Numerical results were given for a wide range of loading parameters and for various aspect ratios. Natural frequencies of plates having elliptical holes have been studied [55]. Analytical results from the Galerkin method were compared with experimental ones. Rhombic (parallelogram) and trapezoidal plates have been treated, [32] and [27] respectively.

PLATES WITH VARIABLE THICKNESS

For plates having variable thickness the flexural rigidity (D) is no longer constant, and several terms containing variable coefficients must be added to equation (1) [2].

Circular Plates

Solid circular plates have been discussed [43, 56-59]. Kirkhope and Wilson [43] used annular finite elements to analyze free plates with parabolic thickness variation. They obtained extensive results for modes having 0 to 6 nodal diameters and 0 to 3 nodal circles. Polar orthotropic disks having exponential thickness variation were examined by Ghosh [56]. The axisymmetric modes of plates having linear and parabolic thickness variation have also been analyzed [57], as have plates with a single step in thickness [58].

Annular circular plates with linear thickness varia-

tions have been considered [60-63]. Ramaiah and Vijayakumar [60] made a thorough study for thickness variations, both increasing and decreasing with the radius; all nine possible combinations of simple edge conditions; various taper ratios and boundary radii ratios; and 0 to 2 nodal diameters. They used the Ritz method with nine trial functions in the radial direction, which should be sufficient to give accurate results. Soni and Amba-Rao [61, 62] examined the axisymmetric modes of plates having the inner edge clamped, the outer edge being clamped, simply supported, or free. The finite element method was used [63] to obtain the first two frequencies for the nine combinations of edge conditions except free-free.

The effects of in-plane forces acting on tapered circular plates have been investigated [39, 64].

Rectangular Plates

Rectangular plates having linear thickness variation along one of the directions parallel to an edge have been considered [65-72]. Eastep [65] used the perturbation method on the simply supported square plate. Simply supported orthotropic plates were studied by Sakata [66] for various taper ratios, aspect ratios, and ratios of orthotropic constants. Plates having two opposite sides simply supported and the other two either simply supported or clamped and subjected to thermal gradients were examined by Rao and Satyanarayana [67].

Other thickness variations have been considered [71-76]. Rectangular plates having the sides $y = 0$, b simply supported, and parabolic thickness variation in the x -direction have been studied [71]. The infinite strip of parabolic thickness variation in the transverse direction and its edges simply supported and/or clamped was treated by Tomar and Gupta [73]. Soni and Rao [74] analyzed plates having $y = 0$, b simply supported, $x = 0$ clamped, and $x = a$ clamped, simply supported or free, with exponential thickness variation in the x direction, for various taper ratios and aspect ratios. Wertz [72] used the perturbation method to investigate square, simply supported plates having linear thickness variation in two directions simultaneously (maximum or minimum thickness at center) and compared the results with finite difference, finite element, and experimental results. He also treated one case involving stepped thickness. Olhoff [75] considered the

problem of determining the plate thickness variation that maximizes the fundamental frequency for a given volume. The finite difference method was used on the resulting nonlinear partial differential equations.

Other Shapes

Chopra and Durvasula [77] addressed the problem of the rhombic plate with linearly varying thickness using the Ritz method with beam functions. Numerical results were obtained for the case when the opposite sides are simply supported and the other two are clamped and for various skew angles and taper ratios. Dokainish and Kumar [26] considered the completely clamped parallelogram having linearly varying thickness and orthotropic elastic constants in terms of orthogonal axes. The first two frequencies were found for various values of aspect ratio, skew angle, and taper ratio. Other results for the clamped parallelogram plate having linear thickness variation are also available [78]. Bailey and Greetham [27] examined trapezoidal plates having variable thickness with the additional complicating effects of thermal stress and orthotropy.

THE EFFECTS OF SURROUNDING MEDIA

Analytical solutions of free vibration problems are almost always based upon the assumption that the vibrating body is in a vacuum. Real problems and experimental simulations usually take place in air. Some references [2] have been made that deal with this difference, which can be significant. However, apparently no recent research has been done on this topic.

LARGE DEFLECTIONS

The term large deflections here refers to transverse deflections sufficiently large to cause additional stiffening of the plate due to membrane stretching at the midplane. This effect is usually significant for maximum deflections on the order of the plate thickness or more, and depends considerably on edge conditions. The simple governing equation of motion must be replaced by two coupled, nonlinear differential equations that include the effects of membrane stretching. A hypothesis due to Berger [79] simplifies the equations somewhat and is often

used. Much recent research has been done for large deflection vibrations of plates; brief descriptions are given below.

Circular Plates

Solid circular plates have been treated [80-88], including clamped [80-84], simply supported [80-83], elastically supported [85], and discontinuous [86, 87] boundary conditions. In addition, the effects of an elastic foundation [81] and of polar orthotropic material [82, 83, 87] have been studied. Notable for its good bibliography, especially from other countries, is the work of Sathymoorthy and Pandalai [88]. Vendham [84] made an interesting critical study of the Berger equations and compared them with the von Kármán equations; he found that the former do not give consistently accurate results and may even yield different mode shapes.

Annular plates have been considered [88-92]. Sandman and Walker [89] presented experimental results. Huang [90] included a concentric isotropic core. In one case [91] the annulus having its inner boundary clamped and outer free was considered for constant thickness and for thickness partly constant and partly linearly tapered.

Rectangular Plates

Large amplitude oscillations of rectangular plates have been widely studied [68, 81, 83, 88, 93-105]. Simply supported [81, 84, 93-97], clamped [81, 84, 93-95], and other plates having combinations of boundary conditions [68, 95, 98] have been investigated; it must be remembered that the in-plane, as well as transverse, edge constraint conditions must be defined in each problem. In addition, elastic edge constraints [99, 100], discontinuous edge conditions [101] -- square plates having portions of their boundaries clamped, other portions simply supported -- a concentrated mass [102], an elastic foundation [81, 103], orthotropic material [94, 104], and variable thickness [68] have been studied. Ramachandran and Reddy [68] were able to establish bounds on the nonlinear fundamental frequency.

Other Shapes

Parallelogram plates have been analyzed [78, 88, 106-108] for various edge conditions, including the effects of orthotropy [78, 107] and variable thickness [78]. Various shapes of triangular plates were also examined [84, 88, 93, 109, 110], including

the effects of orthotropy [110] and an elastic foundation [81, 109]. Elliptic plates have also been studied [88]. Datta [81] presented an interesting method using conformal mapping, along with the Galerkin procedure, which can accommodate a wide variety of shapes.

Other references deal with large amplitude vibrations of plates [111-115].

SHEAR DEFORMATION AND ROTARY INERTIA

For relatively thick plates ($h/l > 1/20$, where h is the plate thickness and l is an average length in its plane) the effects of shear deformation and rotary inertia become significant. The inclusion of shear deformation in the analysis of plate vibrations requires considerable generalization of equation (1). It is replaced by a sixth order set of equations; the most widely used in dynamic problems is that derived by Mindlin [116]. For this sixth order theory, three boundary conditions must be specified along an edge.

Circular Plates

The vibrations of thick, solid, circular plates have been studied [117-121]. Chandrasekaran and Kunukasseril [117] obtained results for the first 20 modes for four types of clamped and supported edge conditions. They compared the results of classical and sixth order theories. Isotropic plates having clamped or supported edges have also been investigated [118, 119]. The effects of orthotropy have been included [120, 121]. Soni and Amba-Rao [120] presented numerical results for the first five axisymmetric modes of an orthotropic plate having linear thickness variation.

Thick, annular plates have been considered [122, 123]. Rao and Prasad [122] reported extensive numerical results for the nine combinations of usual boundary conditions (clamped, simply supported, or free) for inner and outer circular boundaries. Results were reported for various ratios of thickness and of inner to outer radii.

Rectangular Plates

Triangular and quadrilateral finite elements have been used [124] to analyze simply supported and clamped rectangular plates. Finite elements have also been used [119]. The first 13 frequencies of

a simply supported rectangular plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ have been reported [125]. Orthotropic effects were also studied. The effects of in-plane stress have been included [126, 127]. Reismann and Tendorf [126] presented results for the simply supported plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ for the case of uniform in-plane stress (tension or compression) in one direction. Brunelle and Robertson [127] considered the effects of both axial stress N_x and axial moment M_x , with both bending and extensional deformation, upon a simply supported plate. In another paper [128] they treated transversely isotropic plates having the same types of in-plane stress. The effects of large deflections upon the vibration of thick plates have been investigated [129]. Results were given for the simply supported square.

Other work deals with thick plates [130-133]. Vibrations of thick orthotropic plates have been used to determine elastic properties experimentally [130].

NONHOMOGENEOUS PLATES

Material properties of a plate can vary with its length coordinates (say x or y) or with its thickness coordinate (z). The properties can vary continuously or in a step-wise manner. Examples of the former include materials that can vary widely in modulus of elasticity naturally (e.g., rubber, styrofoam) or as a result of severe thermal gradients [67]. Examples of the latter are layered plates, including those made of fibrous composite layers, which are of great importance in advanced plate design.

For layered plates the differential equation of motion (1) must be generalized by a piecewise integration of the forces and moments over the thickness of the plate, and, unless the layer arrangement is symmetrical with respect to the midplane of the plate, bending and stretching of the midplane are coupled during plate deformation. It has been shown by Reissner and Stavsky [134], Whitney and Leissa [135], and many others that the effect of the coupling is often significant with respect to vibration frequencies.

General problems of vibrating nonhomogeneous plates [67, 136-138] include the effects of materials

with continuously varying properties. Many recent publications have dealt with vibrations of layered (laminated) plates [119, 139-175]. The effects of initial, in-plane forces have been treated [139-143], and nonlinear (large deflection) vibrations have been studied [144-148]. Bert [149] wrote an excellent survey paper on the vibrations of layered plates, with special emphasis on the effects of damping.

SUMMARY

In the previous paper of this series [1] it was shown that considerable research in the vibration of plates is governed by classical plate theory. It was conjectured that probably more research on classical plate vibrations has been done and reported since the beginning of 1966 than in all time previous [2].

REFERENCES

1. Leissa, A.W., "Recent Research in Plate Vibrations, 1973-1976: Classical Theory," Shock Vib. Dig., 9 (10), pp 13-14 (Oct 1977).
2. Leissa, A.W., "Vibration of Plates," NASA SP-160, U.S. Govt. Printing Office (1969).
3. Prathap, G. and Varadan, T.K., "Axisymmetric Vibrations of Polar Orthotropic Circular Plates," AIAA J., 14 (11), pp 1639-1640 (1976).
4. Ramaiah, G.K. and Vijayakumar, K., "Natural Frequencies of Polar Orthotropic Annular Plates," J. Sound Vib., 26 (4), pp 517-531 (1973).
5. Ramaiah, G.F. and Vijayakumar, K., "Estimation of Higher Natural Frequencies of Polar Orthotropic Plates," J. Sound Vib., 32 (2), pp 265-278 (1974).
6. Woo, H.K., Kirmser, P.G., and Huang, C.L., "Vibration of Orthotropic Circular Plates with Concentric Isotropic Core," AIAA J., 11, pp 1421-1422 (1973).
7. Rao, K.S. and Ganapathi, K., "Vibration of Cylindrically Orthotropic Circular Plates,"

- J. Sound Vib., 36 (3), pp 433-434 (1974).
8. Rao, B.V.A. and Rama Bhat, B., "Vibrations of an Orthotropic Annular Disc Supported at the Inside Edge," J. Sound Vib., 42 (4), pp 510-514 (1975).
 9. Rubin, C., "Vibrating Modes for Simply Supported Polar-Orthotropic Sector Plates," J. Acoust. Soc. Amer., 58 (4), pp 841-845 (1975).
 10. Padovan, J. and Lestingi, J., "Natural Frequencies of Monoclinic Circular Plates," J. Acoust. Soc. Amer., 55 (4), pp 874-876 (1974).
 11. Imer, S. and Zimmermann, P., "Free Vibration of Polar-Orthotropic Disks," Ing. Arch., 42 (6), pp 395-410 (1973).
 12. Pardoen, G.C., "Vibration and Buckling Analysis of Axisymmetric Polar Orthotropic Circular Plates," Computers and Struc., 4 (5), pp 951-960 (1974).
 13. Zimmermann, P. and Imer, S., "Free Vibrations of a Polar Orthotropic Annular Plate," (In German), Zeitschrift f. Angewandte Math. und Mech., 54 (6), pp 366-369 (1974).
 14. Soni, S.R. and Rao, C.L.A., "Vibrations of Orthotropic Rectangular Plates under In-Plane Forces," Computers and Struc., 4 (5), pp 1105-1115 (1974).
 15. Aksu, G. and Ali, R., "Prediction of Dynamic Characteristics of Orthotropic Plates by Finite Difference Unequal Interval Formulation," J. Sound Vib., 35 (1), pp 119-128 (1974).
 16. Vijakumar, K., "Natural Frequencies of Rectangular Orthotropic Plates with a Pair of Parallel Edges Simply Supported," J. Sound Vib., 35 (3), pp 379-394 (1974).
 17. Sundarajan, C. and Reddy, D.V., "Finite Strip-Difference Calculus Technique for Plate Vibration Problems," Intl. J. Solids Struc., 11 (4), pp 425-435 (1975).
 18. Lowrey, M.J., "Discussion of: Finite Strip-Difference Calculus Technique for Plate Vibration Problems," Intl. J. Solids-Struc., 12, p 391 (1976).
 19. Bauer, L. and Reiss, E.L., "Flexural Vibrations of Clamped Orthotropic Plates," J. Acoust. Soc. Amer., 53 (5), pp 1360-1364 (1973).
 20. Elishakoff, I.B., "Vibration Analysis of Clamped Square Orthotropic Plate," AIAA J., 12 (7), pp 921-923 (1974).
 21. Ramachandra Rao, B.S., Narasimham, G.L., and Gopalacharyulu, S., "Eigenfunction Analysis for Bending of Clamped Rectangular, Orthotropic Plates," Intl. J. Solids Struc., 9 (4), pp 481-493 (1973).
 22. King, W.W. and Lin, C., "Applications of Bolotin's Method to Vibrations of Plates," AIAA J., 12, pp 399-401 (1974).
 23. Sakata, T., "A Reduction Method for Problems of Vibration of Orthotropic Plates," J. Sound Vib., 48 (3), pp 405-412 (1976).
 24. Maurizi, M.J. and Laura, P.A., "Vibration Analysis of Clamped Rectangular Plates of Generalized Orthotropy," J. Sound Vib., 26 (3), pp 299-305 (1973).
 25. Srinivasan, R.S. and Munaswamy, K., "Frequency Analysis of Skew Orthotropic Point Supported Plates," J. Sound Vib., 39 (2), pp 207-216 (1975).
 26. Dokainish, M.A. and Kumar, K., "Vibrations of Orthotropic Parallelogramic Plates with Variable Thickness," AIAA J., 11 (12), pp 1618-1621 (1973).
 27. Bailey, C.D. and Greetham, J.C., "Free Vibrations of Thermally Stressed Orthotropic Plates with Various Boundary Conditions," Ohio State Univ. Res. Foundation NASA-CR-2174 p 101 (1973).
 28. Aksu, G., "Dynamic Analysis of Orthotropic Plates Using a Finite Difference Formulation," Ph.D. Thesis, Loughborough Univ. (1974).
 29. Aksu, G. and Ali, R., "Finite Difference For-

- mulation for the Boundary Regions of Orthotropic Plates and Its Application to the Prediction of Their Dynamic Behavior," Dept. of Transport Technology, Loughborough Univ., Tech. Rept. No. TT 7310 (1973).
30. Yu, J.C.M. and Foster, W.A., Jr., "Unified Method for Determination of Fundamental Frequency of Orthotropic Plate with Arbitrary Boundary," Developments in Mechanics (Proc. 13th Midwest Mech. Conf., Pittsburgh, PA) 7, pp 721-732 (1973).
 31. Nair, P.S. and Durvasula, S., "Vibration of Generally Orthotropic Skew Plates," J. Acoust. Soc. Amer., 55 (5), pp 998-1002 (1974).
 32. Srinivasan, R.S. and Ramachandran, S.V., "Vibration of Generally Orthotropic Skew Plates," J. Acoust. Soc. Amer., 57 (5), pp 1113-1118 (1975).
 33. Laura, P.A.A. and Gelos, R., "Further Results on the Vibration and Stability of a Circular Plate Elastically Restrained Against Rotation," J. Sound Vib., 41 (3), pp 388-390 (1975).
 34. Laura, P.A.A., Luisoni, L.E., and Arias, A., "Antisymmetric Modes of Vibration of a Circular Plate Elastically Restrained Against Rotation and Subjected to a Hydrostatic State of In-Plane Stress," J. Sound Vib., 47 (3), pp 433-437 (1976).
 35. Laura, P.A.A., Diez, L., and Gianetti, C.E., Métodos Aproximados en la Mecánica Aplicada, Patagon, Bahía Blanca, Argentina (1975).
 36. Laura, P.A.A., Luisoni, L.E., and Lopez, J.J., "A Note on Free and Forced Vibrations of Circular Plates: The Effect of Support Flexibility," J. Sound Vib., 47 (2), pp 287-291 (1976).
 37. Laura, P.A.A., Arias, A., and Luisoni, L.E., "Fundamental Frequency of Vibration of a Circular Plate Elastically Restrained Against Rotation and Carrying a Concentrated Mass," J. Sound Vib., 45 (2), pp 298-301 (1976).
 38. Nieh, L.T. and Mote, C.D., Jr., "Vibration and Stability in Thermally Stressed Rotating Disks," Exptl. Mech., 15 (7), pp 258-264 (1975).
 39. Ghosh, N.C., "Thermal Effect on Transverse Vibration of Spinning Disk of Variable Thickness," J. Appl. Mech., Trans. ASME, 42 (2), pp 358-362 (1975).
 40. Rosen, A. and Libai, A., "Stability Behaviour and Vibrations of an Annular Plate Under Uniform Compression," Technion, Israel Inst. of Tech., Haifa, Israel, Dept. Aero Engrg., Rept. No. TAE-229 (1974).
 41. Rosen, A. and Libai, A., "Transverse Vibrations of Compressed Annular Plates," J. Sound Vib., 40 (1), pp 149-153 (1975).
 42. Loh, H.C., "Vibration and Stability of a Spinning Annular Plate Reinforced with Edge Beams," Ph.D. Thesis, Univ. Connecticut (1975).
 43. Kirkhope, J. and Wilson, G.J., "Vibration and Stress Analysis of Thin Rotating Discs Using Annular Finite Elements," J. Sound Vib., 44 (4), pp 461-474 (1976).
 44. Ghosh, N.C., "Transverse Vibration of Spinning Disk Clamped Partially Between the Hubs of Equal Radii," Czech. J. Phys., B, 24 (7), pp 781-785 (1974).
 45. Dokmeci, M.G. and Boley, B.A., "Vibration Analysis of a Rectangular Plate," J. Franklin Inst., 296 (5), pp 305-321 (1973).
 46. Koshor, B., "On the Natural Frequencies of Transverse Vibrations of an Elastic Plate (with Inplane Forces) Resting on a Winkler Foundation," J. Appl. Mech., Trans. ASME, 40 (2), pp 607-608 (1973).
 47. Dickinson, S.M., "Bolotin's Method Applied to the Buckling and Lateral Vibration of Stressed Plates," AIAA J., 13 (1), pp 109-110 (1975).
 48. Bassily, S.F. and Dickinson, S.M., "Corrigen-

- dum: Buckling and Lateral Vibration of Rectangular Plates Subject to Inplane Loads - a Ritz Approach," *J. Sound Vib.*, 29 (4), pp 505-508 (1973).
49. Porter Goff, R.F.D., "The Effect of Self-Equilibrating Stresses on the Natural Frequencies of a Free-Free Rectangular Plate," *J. Sound Vib.*, 47 (1), pp 85-94 (1976).
 50. Laura, P.A.A. and Romanelli, E., "Vibrations of Rectangular Plates Elastically Restrained Against Rotation Along All Edges and Subjected to a Biaxial State of Stress," *J. Sound Vib.*, 37 (3), pp 367-377 (1974).
 51. Kumai, T., "Effect of Edge Thrust on the Natural Frequency of Flexural Vibration of Rectangular Plates," *Rept. Res. Inst. for Appl. Mech.*, 20 (66), pp 73-76 (1973).
 52. Bassily, S.F. and Dickinson, S.M., "Vibration of Plates Subject to Arbitrary In-Plane Loads - A Perturbation Approach," *J. Appl. Mech.*, *Trans. ASME*, 40, pp 1023-1028 (1973).
 53. MacBain, J.C., "Vibratory Behavior of Twisted Cantilevered Plates," *J. Aircraft*, 12 (4), pp 343-349 (1975).
 54. Jones, R. and Mazumdar, J., "Transverse Vibration of Elliptic Plates with In-Plane Forces," *Proc. Noise, Shock, Vibr. Conf.*, Monash Univ., Melbourne, Australia, pp 107-112 (1974).
 55. Datta, P.K. and Carlson, R.L., "Buckling and Vibration of a Thin Tensioned Sheet with an Elliptical Hole," *Exptl. Mech.*, 13 (7), pp 280-286 (1973).
 56. Ghosh, N.C., "The Vibration of Rotating Aeolotropic Elastic Disk of Variable Thickness," *Indian J. Phys. and Proc. Indian Assoc. Cultivation Sci.*, 47 (11), pp 693-700 (1973).
 57. Banjaree, M.M., "On the Nonlinear Vibrations of Elastic Circular Plates of Variable Thickness," *J. Sound Vib.*, 47 (3), pp 341-346 (1976).
 58. Gallego, J.J.A., "Axisymmetric Vibrations of Circular Plates with Stepped Thickness," *J. Sound Vib.*, 26 (3), pp 411-416 (1973).
 59. Chen, S.S.H., "Bending and Vibration of Plates of Variable Thickness," *J. Engr. Indus.*, *Trans. ASME*, 98 (1), pp 166-170 (1976).
 60. Ramaiah, G.K. and Vijayakumar, K., "Vibrations of Annular Plates with Linear Thickness Profiles," *J. Sound Vib.*, 40 (2), pp 293-298 (1975).
 61. Soni, S.R. and Amba-Rao, C.L., "Axisymmetric Vibrations of Annular Plates of Variable Thickness," *J. Sound Vib.*, 38 (4), pp 465-473 (1975).
 62. Soni, S.R., "Quintic Splines in Vibrations of Nonuniform Annular Plates," *Computers and Struc.*, 4 (6), pp 1269-1279 (1974).
 63. Raju, I.S., Prakasa Rao, B., and Venkateswara Rao, G., "Axisymmetric Vibrations of Linearly Tapered Annular Plates," *J. Sound Vib.*, 32 (4), pp 507-512 (1974).
 64. Takahashi, S., Suzuki, K., and Nakamura, Y., "The Vibrations of a Circular Plate with Uniformly Distributed Load Around Its Outer Periphery," *Bull. JSME*, 16, pp 714-722 (1973).
 65. Eastep, F.E., "Estimation of the Fundamental Frequency of Beams and Plates with Varying Thickness," *AIAA J.*, 14 (11), pp 1647-1649 (1976).
 66. Sakata, T., "Natural Frequencies of Orthotropic Plates with Varying Thickness," *J. Acoust. Soc. Amer.*, 60 (4), pp 844-847 (1976).
 67. Rao, C.K. and Satyanarayana, B., "Effect of Thermal Gradient on Frequencies of Tapered Rectangular Plates," *AIAA J.*, 13 (8), pp 1123-1126 (1975).
 68. Ramachandran, J. and Reddy, D.V., "Nonlinear Vibrations of Rectangular Plates with Linearly Varying Thickness," *Appl. Sci. Res.*, 31 (1), pp 67-80 (1975).
 69. Horwat, J.W., "Experimental Investigation of

Natural Frequencies of Plates with Variable Thickness," Air Force Inst. Tech., Rept. No. GCE/MC/74-14 (1975).

70. Venkateswara Rao, G. and Raju, I.S., "A Comparative Study of Variable and Constant Thickness High Precision Triangular Plate Bending Elements in the Analysis of Variable Thickness Plates," Nucl. Engr. Des., 26 (2), pp 299-304 (1974).
71. Jain, R.K. and Soni, S.R., "Free Vibrations of Rectangular Plates of Parabolically Varying Thickness," Indian J. Pure Appl. Meth., 4, pp 267-277 (1973).
72. Wertz, F.H., "Approximate Solutions for the Fundamental Frequency of Square Plates with Variable Thickness," Air Force Inst. Tech., School Engrg., MS Thesis (1974).
73. Tomar, J.S. and Gupta, D.C., "Free Vibrations of an Infinite Plate of Parabolically Varying Thickness on Elastic Foundation," J. Sound Vib., 47 (1), pp 143-145 (1976).
74. Soni, S.R. and Rao, K.S., "Vibrations of Nonuniform Rectangular Plates: A Spline Technique Method of Solution," J. Sound Vib., 35 (1), pp 35-45 (1974).
75. Olhoff, N., "Optimal Design of Vibrating Rectangular Plates," Intl. J. Solids Struc., 10 (1), pp 93-109 (1974).
76. Chopra, I., "Vibration of Stepped Thickness Plates," Intl. J. Mech. Sci., 16 (6), pp 337-344 (1974).
77. Chopra, I. and Durvasula, S., "Vibration of Tapered Skew Plates," Revue Roumaine des Sciences Techniques, Serie de Mécanique Appliquée, 18 (5), pp 925-938 (1973).
78. Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Vibration of Variable Thickness Skew Plates," Proc. Noise, Shock, Vibr. Conf., Monash Univ., Melbourne, Australia, pp 99-106 (1974).
79. Berger, H.M., "A New Approach to the Analyses of Large Deflection of Plates," J. Appl. Mech., Trans. ASME, 22 (4), p 465 (1955).
80. Ramachandran, J., "Nonlinear Vibrations of Circular Plates with Linearly Varying Thickness," J. Sound Vib., 38 (2), pp 225-232 (1975).
81. Datta, S., "Large Amplitude Free Vibrations of Irregular Plates Placed on an Elastic Foundation," Intl. J. Nonlin. Mech., 11 (5), pp 337-345 (1976).
82. Pal, M.C., "Static and Dynamic Nonlinear Behavior of Heated Orthotropic Circular Plates," Intl. J. Nonlin. Mech., 8 (5), pp 489-504 (1973).
83. Venkateswara Rao, G., Kanaka Raju, K., and Raju, I.S., "Finite Element Formulation for Large Amplitude Flexural Vibrations of Beams and Orthotropic Circular Plates," Computers and Struc., 6 (3), pp 169-172 (1976).
84. Vendhan, C.P., "A Study of Berger Equations Applied to Non-Linear Vibrations of Elastic Plates," Intl. J. Mech. Sci., 17 (7), pp 461-468 (1975).
85. Ramachandran, J., "Large Amplitude Vibrations of Elastically Restrained Circular Plates," J. Acoust. Soc. Amer., 55 (4), pp 880-882 (1974).
86. Ramachandran, J., "Large Amplitude Vibrations of Circular Plates with Mixed Boundary Conditions," Computers and Struc., 4 (4), pp 871-877 (1974).
87. Nowinski, J.L., "Some Static and Dynamic Problems Concerning Nonlinear Behavior of Plates and Shallow Shells with Discontinuous Boundary Conditions," Intl. J. Nonlin. Mech., 10 (1), pp 1-14 (1975).
88. Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Vibrations of Certain Deformable Bodies. Part 2: Plates and Shells," J. Aero. Soc. India, 25 (1), pp 1-10 (1973).
89. Sandman, B.E. and Walker, H.S., "An Ex-

- perimental Observation in Large Amplitude Plate Vibrations," J. Appl. Mech., Trans. ASME, 40 (2), pp 633-634 (1973).
90. Huang, C.-L., "Finite Amplitude Vibrations of an Orthotropic Circular Plate with an Isotropic Core," Intl. J. Nonlin. Mech., 8 (5), pp 445-457 (1973).
 91. Huang, C., Woo, H.K., and Walker, H.S., "Non-Linear Flexural Oscillations of a Partially Tapered Annular Plate," Intl. J. Nonlin. Mech., 11 (2), pp 89-97 (1976).
 92. Huang, C.-L. and Woo, H.K., "Large Oscillations of an Orthotropic Annulus," Developments in Mech. (Proc. 13th Midwest Mech. Conf., Pittsburgh, PA) 7, pp 1027-1039 (1973).
 93. Vendhan, C.P., "Modal Equations for the Nonlinear Flexural Vibration of Plates," AIAA J., 13 (8), pp 1092-1094 (1975).
 94. Kanaka Raju, K. and Venkateswara Rao, G., "Non-linear Vibrations of Orthotropic Plates By a Finite Element Method," J. Sound Vib., 48 (2), pp 301-303 (1976).
 95. Venkateswara Rao, G., Raju, I.S., and Raju, K.K., "A Finite Element Formulation for Large Amplitude Flexural Vibrations of Thin Rectangular Plates," Computers and Struc., 6 (3), pp 163-167 (1976).
 96. Alekseeva, N.K., "Approximate Method of Determining the Natural Frequencies of a Nonlinear Rectangular Plate," (In Russian), Prikladnaya Mekhanika, 9 (6), pp 68-72 (1973).
 97. Crawford, J. and Atluri, S., "Nonlinear Vibrations of a Flat Plate with Initial Stresses," J. Sound Vib., 43 (1), pp 117-129 (1975).
 98. Mei, C., "Finite Element Displacement Method for Large Amplitude Vibrations of Beams and Plates," Computers and Struc., 3, pp 163-174 (1973).
 99. Ramachandran, J., "Large Amplitude Vibrations of Elastically Restrained Rectangular Plates," J. Appl. Mech., Trans. ASME, 40, pp 811-813 (1973).
 100. Ramachandran, J., "Nonlinear Vibrations of Elastically Restrained Rectangular Orthotropic Plates," Nucl. Engr. Des., 30 (3), pp 402-407 (1974).
 101. Ramachandran, J., "Large Amplitude Natural Frequencies of Rectangular Plates with Mixed Boundary Conditions," J. Sound Vib., 45 (2), pp 295-297 (1976).
 102. Ramachandran, J., "Non-Linear Vibrations of Rectangular Plates Carrying a Concentrated Mass," J. Appl. Mech., Trans. ASME, pp 630-632 (1973).
 103. Kishor, B. and Rao, J.S., "Nonlinear Vibration Analysis of a Rectangular Plate on a Viscoelastic Foundation," Aeronaut. Quart., 25 (1), pp 37-46 (1974).
 104. Vendhan, C.P. and Das, Y.C., "Application of Rayleigh-Ritz and Galerkin Methods to Nonlinear Vibration of Plates," J. Sound Vib., 39 (2), pp 147-157 (1975).
 105. Bayles, J.D., Lowery, R.L., and Boyd, D.E., "Nonlinear Vibration of Rectangular Plates," ASCE J. Struc. Div., 99 (ST 5), pp 853-864 (1973).
 106. Sathyamoorthy, M. and Pandalai, K.A.V., "Vibration of Simply-Supported Clamped Skew Plates at Large Amplitudes," J. Sound Vib., 27 (1), pp 37-46 (1973).
 107. Sathyamoorthy, M. and Pandalai, K.A.V., "Nonlinear Vibration of Elastic Skew Plates Exhibiting Rectilinear Orthotropy," J. Franklin Inst., 296 (5), pp 359-369 (1973).
 108. Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Flexural Vibration of Simply Supported Skew Plates," AIAA J., 11 (9), pp 1279-1282 (1973).
 109. Sircar, R., "Vibration of Rectilinear Plates on Elastic Foundation at Large Amplitude," Bull. Acad. Polon. Sci., Ser. Sci. Tech., 22 (4), pp 197-203 (1974).

110. Vendhan, C.P. and Dhoopar, B.L., "Nonlinear Vibration of Orthotropic Triangular Plates," *AIAA J.*, 11 (5), pp 704-709 (1973).
111. Rehfield, L.W., "Nonlinear Free Vibrations of Elastic Structures," *Intl. J. Solids Struc.*, 9 (5), pp 581-590 (1973).
112. Westbrook, D.R., "Small Strain Non-Linear Dynamics of Plates," *J. Sound Vib.*, 44 (1), pp 75-82 (1976).
113. Harari, A., "Generalized Non-Linear Free Vibration of Prestressed Plates and Shells," *Intl. J. Nonlin. Mech.*, 11 (3), pp 169-181 (1976).
114. Ramachandran, J., "Vibration of Variable Thickness Plates of Large Amplitudes," *J. Franklin Inst.*, 299 (5), p 359 (1975).
115. Pandalai, K.A.V., "A General Conclusion Regarding the Large Amplitude Flexural Vibration of Beams and Plates," *Israel J. Tech.*, 11 (5), pp 321-324 (1973).
116. Mindlin, R.D., "Influence of Rotary Inertia and Shear on Flexural Motions of Isotropic, Elastic Plates," *J. Appl. Mech., Trans. ASME*, 18 (1), pp 31-38 (1951).
117. Chandrasekaran, K. and Kunukkasseril, V.X., "Forced Axisymmetric Response of Circular Plates," *J. Sound Vib.*, 44 (3), pp 407-417 (1976).
118. Chandrasekaran, K. and Kunukkasseril, V.X., "Frequency Spectra of Circular Plates," *J. Sound Vib.*, 33 (3), pp 376-378 (1974).
119. Cheung, Y.K. and Kwok, W.L., "Dynamic Analysis of Circular and Sector Thick, Layered Plates," *J. Sound Vib.*, 42 (2), pp 147-158 (1975).
120. Soni, S.R. and Amba-Rao, C.L., "On Radially Symmetric Vibrations of Orthotropic Non-Uniform Disks, Including Shear Deformation," *J. Sound Vib.*, 42 (1), pp 57-63 (1975).
121. Kunukkasseril, V.X. and Swamidas, A.S.J., "Vibration of Continuous Circular Plates," *Intl. J. Solids Struc.*, 10 (6), pp 603-619 (1974).
122. Rao, S.S. and Prasad, A.S., "Vibrations of Annular Plates Including the Effects of Rotary Inertia and Transverse Shear Deformation," *J. Sound Vib.*, 42 (3), pp 305-324 (1975).
123. Kanaka Raju, K. and Venkateswara Rao, G., "Axisymmetric Vibrations of Circular Plates Including the Effects of Geometric Nonlinearity, Shear Deformation and Rotary Inertia," *J. Sound Vib.*, 47 (2), pp 179-184 (1976).
124. Narayanaswami, R., "New Triangular and Quadrilateral Plate Bending Finite Elements," NASA, Langley Res. Ctr., Rept. No. NASA-TN-D-7407 (1974).
125. Rock, T.A. and Hinton, E., "A Finite Element Method for the Free Vibration of Plates Allowing for Transverse Shear Deformation," *Computers and Struc.*, 6 (1), pp 37-44 (1976).
126. Reismann, H. and Tendorf, Z.A., "Dynamics of Initially Stressed Plates," *J. Appl. Mech., Trans. ASME*, 43 (2), pp 304-308 (1976).
127. Brunelle, E.J. and Robertson, S.R., "Vibrations of an Initially Stressed Thick Plate," *J. Sound Vib.*, 45 (3), pp 405-416 (1976).
128. Brunelle, E.J. and Robertson, S.R., "Initially Stressed Mindlin Plates," *AIAA J.*, 12 (8), pp 1036-1045 (1974).
129. Singh, P.N., Sundararajan, V., and Das, Y.C., "Large Amplitude Vibration of Some Moderately Thick Structural Elements," *J. Sound Vib.*, 36 (3), pp 375-387 (1974).
130. Ryll-Nardzewski, J., "Application of the Property of Resonant Circular Plates to the Determination of Elastic Constants," (In Polish), *Polish Acad. Sci., Warsaw Rept. No.* 44/1973 (1973).
131. Cornwell, P.E. and Yen, D.H.Y., "Boundary Value Problems in the Improved Theory of Elastic Plates. 1: Existence of Eigenvibra-

- tions for Plates of Arbitrary Shape," SIAM J. Appl. Math., 30 (3), pp 469-482 (1976).
132. Rock, T. and Hinton, E., "Free Vibration and Transient Response of Thick and Thin Plates Using the Finite Element Method," Intl. J. Earthquake Engr. Struc. Dynam., 3, pp 51-63 (1974).
 133. Venkateswara Rao, G., Venkataramana, J., and Prakasa Rao, B., "Vibrations of Thick Plates Using a High Precision Triangular Element," Nucl. Engr. Des., 31 (1), pp 102-105 (1974).
 134. Reissner, E. and Stavsky, Y., "Bending and Stretching of Certain Types of Heterogeneous Anisotropic Elastic Plates," J. Appl. Mech., Trans. ASME, 28 (3), pp 402-408 (1961).
 135. Whitney, J.M. and Leissa, A.W., "Analysis of Heterogeneous Anisotropic Plates," J. Appl. Mech., Trans. ASME, 36 (2), pp 261-267 (1969).
 136. Dunninger, D.R., "A Lower Bound for the First Eigenvalue of a Vibrating Nonhomogeneous Plate," Z. Angew. Math. und Phys., 25 (3), pp 422-424 (1974).
 137. Rao, G.V., Rao, B.P., and Raju, I.S., "Vibrations of Inhomogeneous Thin Plates Using a High Precision Triangular Element," J. Sound Vib., 34 (3), pp 444-445 (1974).
 138. Komkov, V., "On Lower Bounds of the Natural Frequencies of Inhomogeneous Plates," Quart. Appl. Math., 31 (4), pp 395-401 (1974).
 139. Biot, M.A., "Buckling and Dynamics of Multi-Layered and Laminated Plates under Initial Stress," Intl. J. Solids Struc., 10 (4), pp 419-451 (1974).
 140. Bradford, L.G. and Dong, S.B., "Elastodynamic Behavior of Laminated Orthotropic Plates under Initial Stress," Intl. J. Solids Struc., 11 (2), pp 213-230 (1975).
 141. Chandra, R. and Basava Raja, B., "Large Amplitude Vibration of Cross Ply Laminated Composite Plates," Fibre Sci. Tech., 8, pp 243-263 (1975).
 142. Rao, Y.V.K.S. and Sinha, P.K., "Vibrations of Sandwich Plates under Uniaxial Compression," AIAA J., 12 (9), pp 1282-1283 (1974).
 143. Sinha, P.K. and Rath, A.K., "Frequencies of Free Vibration of Axially Compressed Orthotropic Sandwich Plates," J. Sound Vib., 35 (4), pp 541-547 (1974).
 144. Chandra, R., "Nonlinear Vibration of Laminated Composite Panels," M.S. Thesis, Indian Inst. Tech., Madras (1975).
 145. Chandra, R. and Basava Raju, B., "Large Deflection Vibration of Angle Ply Laminated Plates," J. Sound Vib., 40 (3), pp 393-408 (1975).
 146. Chandra, R., "Large Deflection Vibration of Cross-Ply Laminated Plates with Certain Edge Conditions," J. Sound Vib., 47 (4), pp 509-514 (1976).
 147. Shahin, R.M., "Nonlinear Vibrations of Multi-layer Sandwich Plates," Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 43, Pt. 2, pp 43-53 (1973).
 148. Shahin, R.M., "Nonlinear Vibrations of Multi-layer Orthotropic Sandwich Plates," J. Sound Vib., 36 (3), pp 361-374 (1974).
 149. Bert, C.W., "Damping of Composite and Sandwich Panels," Shock Vib. Dig., Part I, 8 (10), pp 37-48 (1976); Part II, 8 (11), pp 15-24 (1976).
 150. Bert, C.W., "Non-Linear Vibration of a Rectangular Plate Arbitrarily Laminated of Anisotropic Material," J. Appl. Mech., Trans. ASME, 40, pp 452-458 (1973).
 151. Clary, R.R. and Cooper, P.A., "Vibration Characteristics of Aluminum Plates Reinforced with Boron-Epoxy Composite Material," J. Composite Matl., 7 (3), pp 348-365 (1973).
 152. Durocher, L.L. and Solecki, R., "Bending and

- Vibration of Transversely Isotropic Two-Layer Plates," AIAA J., 13 (11), pp 1522-1524 (1975).
153. Herman, H. and Kirchner, R.P., "Fundamental Frequency Approximation Methods," J. Acoust. Soc. Amer., 55 (6), pp 1225-1231 (1974).
 154. Jones, R.M., "Buckling and Vibration of Unsymmetrically Laminated Cross-Ply Rectangular Plates," AIAA J., 11 (12), pp 1626-1632 (1973).
 155. Kao, W.-T., "Thermally Induced Vibration of Laminated Composite Plates," Ph.D. Thesis, Univ. Nebraska (1973).
 156. Kao, W.T. and Pao, Y.C., "Thermally-Induced Vibration of Simply Supported Symmetric Cross-Ply Plates," Developments Theor. Appl. Mech. (Proc. 8th SECTAM, Blacksburg, VA) 8, pp 331-348 (1976).
 157. Khatua, T.P. and Cheung, Y.K., "Bending and Vibration of Multilayer Sandwich Beams and Plates," Intl. J. Numer. Methods Engr., 6 (1), pp 11-24 (1973).
 158. Kwok, W.L. and Cheung, Y.K., "Analysis of Circular and Annular Laminated Plates," Proc. Intl. Conf. Finite Element Methods in Engrg., Univ. New South Wales, Sydney, Australia (1974).
 159. Lin, C.-C., "Free Transverse Vibrations of Rectangular Laminated Plates," Ph.D. Thesis, Georgia Inst. Tech., Atlanta (1973).
 160. Lin, C.-C. and King, W.W., "Free Transverse Vibrations of Rectangular Unsymmetrically Laminated Plates," J. Sound Vib., 36 (1), pp 91-103 (1974).
 161. Mau, S.-T. and Pian, T.H.H., "Linear Dynamic Analyses of Laminated Plates and Shells by the Hybrid-Stress Finite-Element Method," Mass. Inst. Tech., Aeroelastic Struc. Res. Lab., Rept. No. ASRL-TR-172-2 (1973).
 162. Mau, S.-T., Pian, T.H.H., and Tong, P., "Vibration Analysis of Laminated Plates and Shells by a Hybrid Stress Element," AIAA J., 11 (10), pp 1450-1452 (1973).
 163. McCullers, L.A. and Naberhaus, J.D., "Automated Structural Design and Analysis of Advanced Composite Wing Models," Computers and Struc., 3 (4), pp 925-935 (1973).
 164. Minich, M.D. and Chamis, C.C., "Analytical Displacements and Vibrations of Cantilevered Unsymmetric Fiber Composite Laminates," NASA, Lewis Res. Ctr., Rept. No. NASA-TM-X-71699 (1975).
 165. Minnich, M.D. and Chamis, C.C., "Cantilevered Unsymmetric Fiber Composite Plates," AIAA J., 14 (3), pp 299-300 (1976).
 166. Mirza, S. and Singh, A.V., "Axisymmetric Vibration of Circular Sandwich Plates," AIAA J., 12 (1), pp 1418-1420 (1974).
 167. Nelson, R.B. and Dong, S.B., "High Frequency Vibrations and Waves in Laminated Orthotropic Plates," J. Sound Vib., 30 (1), pp 33-44 (1973).
 168. Noor, A.K., "Mixed Finite Difference Scheme for Analysis of Simply-Supported Thick Plates," Computers and Struc., 3, pp 967-982 (1973).
 169. Noor, A.K., "Free Vibrations of Multilayered Composite Plates," AIAA J., 11 (7), pp 1038-1039 (1973).
 170. Rao, Y.V.K.S. and Nakra, B.C., "Theory of Vibratory Bending of Unsymmetrical Sandwich Plates," Arch. Mech. Stosowane, 25 (2), pp 213-225 (1973).
 171. Sierakowski, R.L. and Sun, C.T., "Experimental Investigation of the Dynamic Response of Cantilever Anisotropic Plates," Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 44, Pt. 5, pp 89-98 (1974).
 172. Solecki, R., "Oscillations of Rectangular Sandwich Plates with Concentrated Masses," J. Sound Vib., 33 (3), pp 295-303 (1974).

173. Sun, C.-T. and Whitney, J.M., "Forced Vibrations of Laminated Composite Plates in Cylindrical Bending," J. Acoust. Soc. Amer., 55 (5), pp 1003-1008 (1974).
174. Steinberg, D.S., "Avoiding Vibration in Odd-Shaped Printed Circuit Boards," Des., 48 (12), pp 116-119 (1976).
175. Thomas, C.R., "Flexural and Extensional Vibrations of Simply Supported Laminated Rectangular Plates," J. Acoust. Soc. Amer., 57 (3), pp 655-659 (1975).

ANNUAL ARTICLE INDEX

FEATURE ARTICLES

	ISSUE	PAGES
Murphy, G. Scaling and Modeling for Experiment	1	5-13
Lyon, R.H. Recent Developments in Statistical Energy Analysis	2	3-7
Hales, F.D. Ride Handling Dynamics of Road Vehicles (A Review of Recent Literature)	3	3-8
Dubey, R.N. Vibration of Overhead Transmission Lines	4	3-6
Bernard, J.E. Computer Programs for the Directional Response of Highway Vehicles	5	3-8
Drenick, R.F. and Wang, P.C. System Reliability Assessments Using Critical Excitations	6	3-7
Attenborough, K. Sound Attenuation Over Ground Cover	7	3-13
Beards, C.F. Damping Overhead Transmission Line Vibration	8	3-8
Stadelbauer, D.G. Balancing Machines Reviewed	9	3-9
Romilly, N. Guided Sound Transmission Through Layers	10	3-7
Ulsoy, A.G. and Mote, C.D., Jr. Band Saw Vibration and Stability	11	3-15
Seshadri, T.V. Shock and Vibration Analysis Using Finite Element Techniques	12	3-9

LITERATURE REVIEWS

	ISSUE	PAGES
Ibrahim, R.A. and Barr, A.D.S. Parametric Vibration. Part I: Mechanics of Linear Problems	1	15-29
Dix, R.C. Dynamic Analysis for Rigid-Link Mechanisms	1	31-33
Ibrahim, R.A. and Barr, A.D.S. Parametric Vibration. Part II: Mechanics of Nonlinear Problems	2	9-24
Scott, R.A. Linear Elastic Wave Propagation. An Annotated Bibliography: Part I	2	25-41
Scott, R.A. Linear Elastic Wave Propagation. An Annotated Bibliography: Part II	3	11-39
Ibrahim, R.A. Parametric Vibration. Part III: Current Problems (1)	3	41-57
Massoud, M. and Pastorel, H. Impedance Methods for Machine Analysis	4	9-18
Ibrahim, R.A. Parametric Vibration. Part IV: Current Problems (2)	4	19-47
De, S. On Seismic Waves. Part I: Introduction	5	11-16
Ibrahim, R.A. and Roberts, J.W. Parametric Vibration. Part V: Stochastic Problems	5	17-38
De, S. On Seismic Waves. Part II: Surface Waves and Guided Waves	6	9-14
Mote, C.D., Jr. and Szymani, R. Circular Saw Vibration Research	6	15-30
DiMaggio, F.L. Recent Research on the Dynamic Response of Fluid-Filled Shells	7	15-19
De, S. On Seismic Waves. Part III: Mathematical Methods	7	21-43
De, S. On Seismic Waves. Part IV: Mathematical Methods (2)	8	11-26
Venancio Filho, F. Finite Element Analysis of Structures Under Moving Loads	8	27-35

LITERATURE REVIEWS (CONTINUED)

	ISSUE	PAGES
Platzer, M.F. Transonic Blade Flutter: A Survey of New Developments	9	11-20
Jones, N. Recent Progress in the Dynamic Plastic Behavior of Structures. Part I	9	21-33
Nielsen, L.E. Mechanical Damping of Filled Plastics	10	9-11
Jones, N. Recent Progress in the Dynamic Plastic Behavior of Structures. Part II	10	13-19
Chung, T.J. Thermomechanical Vibrations	11	17-25
Ramamurti, V., Sathikh, S., and Chari, R.T. Transmission Line Vibrations	11	27-31
Arndt, R.E.A. A Sketch of Aeroacoustics	12	11-19
Leissa, A.W. Recent Research in Plate Vibrations. 1973-1976: Complicating Effects	12	21-35

BOOK REVIEWS

COMPUTING IN APPLIED MECHANICS

R.F. Hartung, Editor
The American Society of Mechanical Engineers
New York, 1976

This book is a collection of nine papers that were presented at the ASME Winter Annual Meeting in New York in December 1976. The papers comprised a symposium organized by the Applied Mechanics Division's Committee on Computing to highlight various aspects of computerized analysis in applied mechanics.

Schaeffer's paper has to do with the advances in computer hardware, numerical analysis, and computer science and discusses his perception of future finite element analysis codes using NASTRAN as a base line. He identifies developments required in supporting technological areas and discusses the concept of a National Software Center to disseminate valuable software resources.

Smith and Craig consider the role of the minicomputer in experimental mechanics. They describe appropriate hardware and software and provide examples of effective systems.

Vanderplaats considers the role of the computer in design synthesis. He describes numerical optimization techniques and discusses methods of coupling these techniques with analysis procedures to achieve fully automated design capability.

MacCormic's paper is concerned with the field of computational fluid mechanics. He presents a new numerical technique for solving such systems of equations as the time-dependent Navier-Stokes equations at high Reynolds numbers.

Gartling reviews recent developments in the use of the finite element to solve problems of viscous incompressible flow. He also discusses the coupled fluid/thermal problem and presents problem formu-

lations, solution methods, and example problems.

The paper by Egan et al discusses interesting applications of the computer to environmental studies. Two broad categories are defined: computer simulation in the analysis of air pollution and data acquisition and storage for environmental studies.

Tong describes computational methods used to analyze dynamic problems associated with ground transportation. The four specific problem areas discussed are vehicle crashworthiness prediction, rail vehicle dynamics, and train handling and track wear.

Belytschko considers methods for computer analysis of wave propagation and shock. The methods are categorized as methods of characteristics, semi-discretization methods, and hybrid methods.

Finally Bathe surveys the computational methods for analysis of problems in structural dynamics. He presents the numerical formulation and discusses methods appropriate for linear and nonlinear analyses.

The book contains a brief summary of each paper by Hartung; the symposium organizer; he draws the following general conclusions.

- The computer, coupled with computer-oriented computational schemes, has been instrumental in achieving the level of sophistication that exists in many areas of applied mechanics.
- Further advances in computational applied mechanics will depend more upon advances in computer technology and numerical analysis than upon breakthroughs in applied mechanics.
- Computational methods are a common ingredient in work being done in most areas of applied mechanics. At the computational level many of the different areas begin to look similar.

The computer may well serve the purpose of promoting more interdisciplinary work within applied mechanics.

- The use of the computer in design (as opposed to analysis) remains limited, primarily because of high computer costs. As more powerful computing hardware becomes available, the computer will become an important design tool in applied mechanics.
- Dynamic problems are common to many areas of applied mechanics, and their solution is presently receiving much attention. New numerical integration methods that are being developed will lead to more solutions per computer dollar.
- A vast national resource exists in the many computer programs that have been developed in applied mechanics and other fields of technology. No one has yet found a satisfactory solution for disseminating, maintaining, and providing technical support for these programs.
- The use of computers for data acquisition, data reduction, and control of experiments has become more common with the advent of low cost, high power minicomputers.

Harry G. Schaeffer
Schaeffer Analysis
Kendall Hill Road
Mont Vernon, NY 03057

THE COMPONENT ELEMENT METHOD IN DYNAMICS

S. Levy and J.P.D. Wilkinson
McGraw-Hill Book Company, New York, NY

Many dynamics books are published, but this is one of the more outstanding ones because it contains topics concerned with current design problems. Subjects usually found only in specialized volumes are included: finite elements, structurally-induced vibrations, vehicle dynamics, turbine bucket analysis under centrifugal loads, and earthquake design. The nine chapters progress from elementary to more advanced vibration topics.

Chapter I is concerned with force, mass, damping, and stiffness; forced response is included, as is a good discussion of the Newmark, Houbolt, and Wilson

methods applied to the dynamic response of linear and nonlinear systems.

Chapter II has to do with the dynamics of single-mass systems and nonlinearities of springs and dampers. A fully detailed computer program used by the authors in the past few years is included.

Chapter III describes multi-degree-of-freedom systems in matrix notation and applies the information to beam dynamics and forced responses of linear and nonlinear systems. The stiffness matrix of a beam with shear deformation is considered, and an extensive computer program developed by the authors is given.

Chapter IV begins with basic linear and nonlinear problems and goes on to applied engineering problems; i.e., vehicle dynamics, aircraft landings, locomotive dynamics, car (train) dynamics, and air-cushion vehicle dynamics. This information is not available in any other book.

In the reviewer's opinion Chapter V on finite elements is excellent. Few dynamics books even discuss finite elements. The simple spring is described first, then two-dimensional elastic continuum and isoparametric elements. Three-dimensional solid elements are described for the first time in a book on dynamics.

Chapter VI, a continuation of the previous chapter, includes information on the direct use of Eigenvalue solutions via Jacobi's method, the Eigenvalue economizer method, and more modern iterative approaches. The reviewer commends the authors for their inclusion of the dynamics of a turbine blade subjected to centrifugal forces -- another first in a dynamics book and also a practical engineering problem in stiffness matrix form.

Chapter VII applied the methods from Chapter VI to the direct response of composite aircraft fan blades and includes a description of impact loading.

Chapter VIII considers the study of seismic response of power plants with finite elements. Design response spectra, generation of artificial design response spectra, substructuring, and soil-structure interaction are included. There is a good section on component mode synthesis.

The final chapter discusses vibration of structural components submerged in water. The subject is directly applicable to reactor internals, marine design, and heat exchanger design. The study of fluid dynamics using finite elements is briefly discussed.

In summary, the book is well written and contains much information not found in many dynamics books. The reviewer would have liked a section on random vibrations and a section on variational methods. The transfer matrix method is not discussed even though many engineers use this version of dynamic analysis. Nevertheless, the book is recommended to persons involved in dynamics.

Herb Saunders
General Electric Company
Building 41, Room 319
Schenectady, NY 12345

BOOK REVIEWS: 1978

Bartlett, J.H., Classical and Modern Mechanics, The University of Alabama Press, University, AL; 1975, Reviewed by M. Taylor, SVD, 10 (10), p 21 (Oct 1978)

Bathe, K.-J. and Wilson, E.L., Numerical Methods in Finite Element Analysis, Prentice-Hall, Inc., Englewood Cliffs, NJ; Reviewed by H. Saunders, SVD, 10 (9), pp 34-35 (Sept 1978)

Blevins, R.D., Flow-Induced Vibration, Van Nostrand-Reinhold; 1977, Reviewed by R.H. Scanlon, SVD, 10 (6), p 33 (June 1978)

Bolotin, V.V., Application of Methods of Theory of Probability and Theory of Reliability to Analysis of Structures, AD 776115, Reviewed by H. Saunders, SVD, 10 (11), pp 32-33 (Nov 1978)

Bolt, B.A., Nuclear Explosions and Earthquakes, The Parted Veil, W.H. Freeman and Company, San Francisco; 1976, Reviewed by H.C. Pusey, SVD, 10 (8), p 36 (Aug 1978)

Byrne, R., ed., Symposium on Railroad Equipment Dynamics, The American Society of Mechanical Engineers, New York, NY; 1976, Reviewed by A.B. Perlman, SVD, 10 (9), p 36 (Sept 1978)

Campbell, J.D., Dynamic Plasticity of Metals, Springer-Verlag; 1972, Reviewed by J. Lipkin, SVD, 10 (3), p 58 (Mar 1978)

Chen, P., Thermodynamic Effects in Wave Propagation; Reviewed by T.C.T. Ting, SVD, 10 (11), p 32 (Nov 1978)

Cheremisinoff, P.N. and Cheremisinoff, P., Industrial Noise Control Handbook, Ann Arbor Science, Ann Arbor, MI; 1977, Reviewed by R.J. Peppin, SVD, 10 (7), pp 46-47 (July 1978)

Eringen, A.C. and Suhubi, E.S., Elastodynamics, Volume 1. Finite Motions, Academic Press, New York and London; 1974, Reviewed by K.S. Pister, SVD, 10 (9), p 35 (Sept 1978)

Evan-Iwanowski, R.M., Resonance Oscillations in Mechanical Systems, Elsevier Scientific Pub., The Netherlands; 1976, Reviewed by C.L. Dym, SVD, 10 (7), p 46 (July 1978)

Harris, C.M. and Crede, C.E., eds., Shock and Vibration Handbook, (2nd Edition), McGraw-Hill Book Company, New York; 1976, Reviewed by H. Saunders, SVD, 10 (1), p 34 (Jan 1978)

Harris, C.M. and Crede, C.E., eds., Shock and Vibration Handbook, (2nd Edition), McGraw-Hill Book Company, New York; 1976, Reviewed by R.H. Volin, SVD, 10 (1), pp 35-36 (Jan 1978)

Hartung, R.F., ed., Computing in Applied Mechanics, The American Society of Mechanical Engineers, New York; 1976, Reviewed by H.G. Schaeffer, SVD, 10 (12), pp 39-40 (Dec 1978)

Hartung, R.F., ed., Integrated Design and Analysis of Aerospace Structures, The American Society of Mechanical Engineers, New York; 1975, Reviewed by R.L. Dreisbach, SVD, 10 (2), pp 44-45 (Feb 1978)

- Hult, J., ed., Mechanics of Visco-Elastic Media and Bodies, Springer-Verlag; 1975, Reviewed by P.J. Chen, SVD, 10 (7), pp 45-46 (July 1978)
- Kalnins, A. and Dym, C.L., eds., Vibration: Beams, Plates and Shells, Halsted Press; 1976, Reviewed by J.E. Goldberg, SVD, 10 (10), pp 21-22 (Oct 1978)
- Levy, S. and Wilkinson, J.P.D., The Component Element Method in Dynamics, McGraw-Hill Book Co., New York; Reviewed by H. Saunders, SVD, 10 (12), pp 40-41 (Dec 1978)
- Lomakin, V.A., Statistical Problems in Mechanics of Solid, Deformable Bodies (Statisticheskie zadachi mekhaniki tverdykh deformiruemyykh tel), Moscow, Izdatelstvo Nauka; 1970, Reviewed by Z. Sobotka, SVD, 10 (1), p 36 (Jan 1978)
- Lumb, P., ed., Statistics and Probability in Civil Engineering, Hong Kong, University Press; 1972, Reviewed by S.M. Holzer, SVD, 10 (4), p 48 (Apr 1978)
- Mallett, R.H., ed., Limit Analysis Using Finite Elements, Symp. Proc.; Reviewed by P.G. Hodge, Jr., SVD, 10 (7), pp 44-45 (July 1978)
- Medearis, K.G., Structural Response to Explosion-Induced Ground Motions, ASCE, New York; 1975, Reviewed by V.H. Neubert, SVD, 10 (4), p 49 (Apr 1978)
- Miller, R.K., Handbook of Industrial Noise Management, The Fairmont Press, Inc.; 1976, Reviewed by G. Schweitzer, SVD, 10 (2), p 43 (Feb 1978)
- Naudascher, E., ed., Flow-Induced Structural Vibration, Springer-Verlag, Berlin, Heidelberg, New York; Reviewed by H. Saunders, SVD, 10 (10), pp 20-21 (Oct 1978)
- Nowacki, W., Dynamic Problems of Thermoelasticity, Noordhoff International Publishing, Leyden, The Netherlands; 1975, Reviewed by W.D. Pilkey, SVD, 10 (8), p 38 (Aug 1978)
- Price, W.G. and Bishop, R.E.D., Probabilistic Theory of Ship Dynamics, Halsted Press, New York; Reviewed by H. Saunders, SVD, 10 (6), p 32 (June 1978)
- Reismann, H. and Pawlik, P.S., Elastokinetics, West Publishing Company, St. Paul, Minnesota; Reviewed by H. Saunders, SVD, 10 (5), pp 40-41 (May 1978)
- Rikards, R.B. and Teters, G.A., Stability of Shells Made of Composite Materials (Ustoichivost obolchek iz kompozitnykh materialov), Riga, Izdatelstvo "Zinatne"; 1974, Reviewed by W.A. Nash, SVD, 10 (2), p 42 (Feb 1978)
- Saczalski, K., Measurement and Prediction of Structural and Biodynamic Crash-Impact Response, American Society of Mechanical Engineers, New York; 1976, Reviewed by H. Armen, Jr., SVD, 10 (8), pp 36-37 (Aug 1978)
- Syndararajan, C., Dynamic Analysis of Pressure Vessel and Piping Components, American Society of Mechanical Engineers, New York; 1977, Reviewed by P.S. Chopra, SVD, 10 (11), p 33 (Nov 1978)
- Thoma, J.U., Introduction to Bond Graphs and Their Applications, Pergamon Press; 1975, Reviewed by D. Karnopp, SVD, 10 (3), p 59 (Mar 1978)

Wasley, R.J., Stress Wave Propagation in Solids. An Introduction, Marcel Dekker, Inc., New York; 1973, Reviewed by W. Herrman, SVD, 10 (5), pp 39-40 (May 1978)

Development of the Mechanics of Gyroscopic and Inertial Systems (Razvitie mekhaniki giroskopicheskikh inertialnykh sistem), Moscow, Izdatelstvo "Nauka"; 1973, Reviewed by V. Chobotov, SVC, 10 (2), pp 42-43 (Feb 1978)

Developments in Mechanics, Volume 8, Proceedings of the 14th Midwestern Mechanics Conf.; Reviewed by L.Y. Bahar, SVD, 10 (8), pp 37-38 (Aug 1978)

SHORT COURSES

DECEMBER

MACHINE PROTECTION AND MALFUNCTION DIAGNOSIS

Dates: December 11-15, 1978

Place: Carson City, Nevada

Objective: Topics to be covered include: Measuring and monitoring parameters for predictive maintenance; Eddy current probe and proximity theory of operation; Installation procedures and common pitfalls; Permanent machine monitoring systems; System calibration procedures; Thrust position measurements; Troubleshooting the system; Transducer polarity rules; Hazardous area considerations; Introduction to machine data acquisition; Oscilloscope theory and operation; Oscilloscope cameras; Tunable filters, Vector filter-phase meter; Tape recorders; Keyphasor theory; and Electrical runout.

Contact: Training Manager, Bently Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611.

1979

JANUARY

NONDESTRUCTIVE EXAMINATION

Dates: Repeated continuously through-out the year (1 day to 3 weeks)

Place: Los Angeles, CA

Objective: For those requiring qualification and certification, theory and practical application courses are available for either one or all of the basic techniques; Ultrasonics, Radiographic, Magnetic Particle, Liquid Penetrant, Eddy Current and Helium Leak. Also Special Radiation Safety and Radiographic Film Interpretation courses for Level II and Level III training are presented. The selection of courses is also applicable to those who require engineering understanding, supervision training or state-of-the-art development.

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

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: January 8-12, 1979

Place: The George Washington University

Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including step-wise refinement, program correctness, and top-down system development.

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

ENVIRONMENTAL ACOUSTICS

Dates: January 10 to March 21, 1979
(Wednesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA

Objective: This course will cover acoustic measurements, noise metrics and human criteria, sound propagation and attenuation, vehicle and aircraft noise, sound in rooms, acoustic properties of materials, transmission loss, ducts and mufflers, sound transmission in buildings, vibration control and impact isolation, sound reinforcement, noise law and environmental impact.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

SHOCK AND VIBRATION ENGINEERING FOR AEROSPACE SYSTEMS

Dates: January 9 to March 20, 1979
(Tuesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA
Objective: This course will cover each facet of shock and vibration engineering in aerospace systems.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

FEBRUARY

VIBRATION AND LOOSE PARTS MONITORING SYSTEMS AND TECHNOLOGY

Dates: February 5-8, 1979
Place: Los Angeles, California
Objective: A course designed for users, utility designers specifying systems, installers, operators, and analysts of Vibration and Loose Parts Monitoring Systems. Classroom instruction in theory, installation, calibration, alarms and location, signature analysis, noise analysis, and troubleshooting and servicing. Practical demonstration includes student "hands-on" operation of equipment.

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

FLOW-INDUCED VIBRATION PROBLEMS AND THEIR SOLUTIONS IN PRACTICAL APPLICATIONS: TURBOMACHINERY, HEAT EXCHANGERS AND NUCLEAR REACTORS

Dates: February 12-16, 1979
Place: The University of Tennessee Space Inst.
Objective: The aim of the course is to provide practicing engineers engaged in design, research and service, an in-depth background and exposure to various problems and solution techniques developed in recent years. Topics to be covered will be the fundamental principles of unsteady fluid flow, structural vibration and their interplay; review of the morphology of flow-induced vibration; state-of-the-art discussion upon theory, experimental techniques and their interaction; methodology of alleviation.

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

MACHINERY VIBRATIONS COURSE

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

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

MARCH

MACHINERY VIBRATION SEMINAR

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

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

MEASUREMENT SYSTEMS ENGINEERING

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

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 19-23, 1979
Place: Phoenix, Arizona
Objective: Program emphasis is on how to increase

productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists, and managers in industrial, governmental, and educational organizations. Electrical measurements of mechanical and thermal quantities are the major topics.

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

APPLICATIONS OF THE FINITE ELEMENT METHOD TO PROBLEMS IN ENGINEERING

Dates: March 12-16, 1979

Place: The University of Tennessee Space Inst.

Objective: This course will concentrate on material developed recently and provide a solid foundation for those relatively new to the field. Topics to be covered are the treatment of mixed type equations which occur in transonic flow and wave motion in nonlinear solids, mixed type elements which are of importance in systems such as the Navier-Stokes equations, the interrelationship between the equation formation and the iterative scheme needed to solve any of the nonlinear equations, the advantages of hybrid elements, and the use of interactive graphics as an aid to problem solution.

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

APRIL

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: April 16-20, 1979

Place: UCLA

Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct

dynamics test programs.

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

MAY

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: May 21-25, 1979

Place: The George Washington University

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

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

JUNE

ACOUSTIC EMISSION STRUCTURAL MONITORING TECHNOLOGY

Dates: June 18-19, 1979

Place: Los Angeles, California

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

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

NEWS BRIEFS

news on current
and Future Shock and
Vibration activities and events

CALL FOR PAPERS

Design and Applications: Advanced Composite Materials

The Mechanical Failure Prevention Group (MFPG) sponsored by the National Bureau of Standards; Office of Naval Research, Department of the Navy; Department of Energy; and NASA Goddard Space Flight Center will hold its 29th Symposium at the National Bureau of Standards, Gaithersburg, Maryland on May 22-24, 1979. Papers are desired in the following areas: Applications in land, marine, and aerospace systems; Analytical techniques; Fabrication techniques; Non-destructive testing; Failure modes; Environmental effects; and Materials. Proceedings in the form of extended abstracts, 2-4 typewritten pages, will be published by the National Bureau of Standards. Closing date for initial abstracts is January 1, 1979 and for extended abstracts, April 30, 1979. Abstracts should be sent to Jesse E. Stern, Code 721, Goddard Space Flight Center, Greenbelt, Maryland 20771 - (301) 982-2657.

VIBRATION OF BEARINGS

The book Vibration of Bearings by K.M. Ragulskis, A.Y. Jurkauskas, V.V. Atstupenas, A.Y. Vitkute, and A.P. Kulvec has been translated into English by NASA (Rept. No NASA-TT-F-17449; TT-75-52090, 517 pp (Dec 1977)[Engl. transl. of "Vibratsiya podshipnikov" Vilnius, Lit. SSR: Mintis Publishers; 1974, 391 pp]). It contains analytical determination of vibrations and friction torque due to rotation taking into account the hydrodynamic action of a lubricating oil film. Determination of the elastic and damping characteristics of bearings and bearing assemblies are some of the problems considered in this book. The methodology and techniques of measuring the dynamic characteristics of bearings are presented. Experimental data and the methodology of statistical analysis are also given. The Russian version of the book was reviewed in the December 1977 issue of the DIGEST.

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog
Computation
Analytical Methods
Dynamic Programming
Impedance Methods
Integral Transforms
Nonlinear Analysis
Numerical Analysis
Optimization Techniques
Perturbation Methods
Stability Analysis
Statistical Methods
Variational Methods
Finite Element Modeling
Modeling
Digital Simulation
Parameter Identification
Design Information
Design Techniques
Criteria, Standards, and
Specifications
Surveys and Bibliographies
Tutorial
Modal Analysis and Synthesis

COMPUTER PROGRAMS

General
Natural Frequency
Random Response
Stability
Steady State Response
Transient Response

ENVIRONMENTS

Acoustic
Periodic
Random
Seismic
Shock
General Weapon
Transportation

PHENOMENOLOGY

Composite
Damping
Elastic
Fatigue
Fluid
Inelastic
Soil
Thermoelastic
Viscoelastic

EXPERIMENTATION

Balancing
Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers
Shafts
Beams, Strings, Rods, Bars
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames, Arches
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs

Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural
Tires

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Electrical
Foundations and Earth
Helicopters
Human
Isolation
Material Handling
Mechanical
Metal Working and Forming
Off-Road Vehicles
Optical
Package
Pressure Vessels
Pumps, Turbines, Fans,
Compressors
Rail
Reactors
Reciprocating Machine
Road
Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

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 51	PHENOMENOLOGY 62	Pipes and Tubes 76
Analytical Methods 51	Damping 62	Plates and Shells 77
Nonlinear Analysis 51	Fatigue 64	Structural 80
Numerical Analysis 51	Fluid 65	Tires 81
Optimization Techniques . .52	Soil 65	SYSTEMS 82
Statistical Methods 52	Viscoelastic 66	Absorber 82
Finite Element Modeling . .52		Noise Reduction 82
Modeling 53	EXPERIMENTATION 66	Aircraft 83
Parameter Identification . .53	Balancing 66	Building 86
Design Techniques 54	Diagnostics 66	Construction 87
Criteria, Standards, and	Equipment 67	Foundations and Earth . .87
Specifications 54	Instrumentation 67	Human 87
Surveys and	Techniques 67	Isolation 87
Bibliographies 55		Mechanical 88
Modal Analysis and	COMPONENTS 67	Metal Working and
Synthesis 56	Absorbers 67	Forming 88
COMPUTER PROGRAMS 56	Shafts 68	Off-Road Vehicles 89
General 56	Beams, Strings, Rods, Bars .68	Pumps, Turbines, Fans,
ENVIRONMENTS 58	Bearings 70	Compressors 89
Acoustic 58	Blades 71	Rail 90
Random 60	Controls 72	Reactors 90
Seismic 60	Cylinders 73	Reciprocating Machine . .91
Shock 62	Ducts 73	Road 91
General Weapon 62	Frames, Arches 73	Rotors 92
Transportation 62	Gears 74	Self-Excited 94
	Linkages 75	Spacecraft 94
	Mechanical 75	Transmissions 94
		Turbomachinery 94

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1820)

78-1700

Eigenvalue Bounds for Damped Linear Systems

D.W. Nicholson

Goodyear Research, The Goodyear Tire and Rubber Co., Akron, OH, Mech. Res. Comm., 5 (3), pp 147-152 (1978) 4 refs

Key Words: Free vibration, Boundary value problems, Linear systems, Damped structures

Lower bounds are obtained on the real and imaginary parts of the eigenvalues of a damped linear system in free vibration. A condition for subcritical damping in all modes is obtained. The bounds have a close relation to the eigenvalue of a one degree-of-freedom system.

78-1701

Methods for Oscillating Problems

L. Petzold and G.W. Gear

Dept. of Computer Science, Illinois Inst. of Tech., Chicago, IL, Rept. No. C00-2383-45; UILU-ENG-77-1752, 36 pp (Oct 1977)
N78-23826

Key Words: Boundary value problems

Initial-value problems for ordinary differential equations with highly oscillatory solutions are considered. A solution method, applicable to linear or nonlinear oscillations, is discussed.

NONLINEAR ANALYSIS

78-1702

A Boundary Tracking Optimization Algorithm for Constrained Nonlinear Problems

J.Y. Morado and M. Pappas

Dept. of Mech. Engrg., Newark College of Engrg. of

the New Jersey Inst. of Technology, Newark, NJ, J. Mech. Des., Trans. ASME, 100 (2), pp 292-296 (Apr 1978) 1 fig, 4 tables, 13 refs

Key Words: Nonlinear programming, Optimization

A new procedure for numerical optimization of constrained nonlinear problems is described. The method makes use of an efficient "boundary tracking" strategy to move on the constraint surfaces. In a comparison study it was found to be an effective method for treating nonlinear mathematical programming problems particularly those with difficult nonlinear constraints.

NUMERICAL ANALYSIS

78-1703

Numerical Solutions of the Unsteady Transonic Small-Disturbance Equations

M.M. Hafez, M.H. Rizk, E.M. Murman, and L.C. Wellford

Flow Research Co., Kent, WA, Rept. No. FLOW-RR-83, AFFDL-TR-77-100, 68 pp (Oct 1977)
AD-A054 036/9GA

Key Words: Numerical analysis, Fluid mechanics, Perturbation theory, Harmonic waves, Finite element technique

Three problems pertinent to the numerical solution of the unsteady transonic small-disturbance equation are studied. The first problem is the numerical instabilities arising in the solution of the harmonic perturbation potential equation. Several remedies that have been tested are suggested. The second problem is the movement of unsteady shock waves in the harmonic perturbation approach. A formulation and computed example are presented. The third problem is a finite-element formulation for unsteady transonic flow. Preliminary calculations are given.

78-1704

Dynamic Analysis of Structures Containing Nonlinear Springs

L.D. Hofmeister

Systems Dev. Corp., 2500 Colorado Blvd., Santa Monica, CA 90406, Computers Struct., 8 (5), pp 609-614 (May 1978) 1 fig, 5 tables, 11 refs

Key Words: Linear systems, Nonlinear springs, Iteration

An efficient algorithm is presented for the solution of the dynamics problem of a linear structure containing springs

with nonlinear force-deflection characteristics. The method is based upon the Newmark direct integrator, and uses an iterative procedure in each time step to account for the nonlinear spring behavior. Convergence criteria are derived for the iteration.

OPTIMIZATION TECHNIQUES

(Also see Nos. 1789, 1804, 1821)

78-1705

Sensitivity Analysis and Optimization of Structures for Dynamic Response

E.J. Haug, J.S. Arora, and T.T. Feng

Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (2), pp 311-318 (Apr 1978) 6 figs, 5 tables, 12 refs

Key Words: Optimum design, Earthquake resistant structures, Blast resistant structures

A state space method of optimal design of structures under transient dynamic excitation is developed and three problems are solved. It is shown that exploitation of the mathematical form of the equations of structural dynamics leads to significant computational efficiencies. A factor of five reduction in computing time is shown to be achievable, relative to more conventional nonlinear programming methods.

STATISTICAL METHODS

(Also see No. 1819)

78-1706

Statistics of Normal Mode Amplitudes in a Random Ocean. II. Computations

L.B. Dozier and F.D. Tappert

Courant Inst., New York Univ., New York, NY 10012, J. Acoust. Soc. Amer., 64 (2), pp 533-547 (Aug 1978) 8 figs, 1 table, 19 refs

Key Words: Elastic waves, Normal modes, Statistical analysis, Monte Carlo method

Numerical acoustic propagation theory in a canonical model of a random ocean is evaluated and compared to the results of a large-scale Monte Carlo computer simulation. At each of the acoustic frequencies 50, 100, 200, 500, and 1000 Hz, 100 independent realizations of the random acoustic model are obtained.

FINITE ELEMENT MODELING

(Also see No. 1721)

78-1707

Linear Constraint Equations for Continuous Support Conditions in Finite Element Analysis

D.D. Pfaffinger

Fides Trust Co., Zurich, Switzerland, Computers Struc., 8 (5), pp 553-562 (May 1978) 11 figs, 3 tables, 12 refs

Key Words: Plates, Elastic foundations, Finite element technique

Discretized structural models such as by finite elements imply discretized support conditions. In some cases such as plates on elastic foundation or slabs on large interacting columns an improved formulation of the continuous support conditions is desirable. This can be achieved by means of linear constraint equations. The numerical treatment of linear constraints is discussed for the method of elimination of variables as well as for the method of Lagrange multipliers. Then specific constraint equations for different accuracy requirements are derived, which can be used to constrain rectangular flat shell elements of arbitrary shape functions. The effect on the strain energy of a square shell element is shown for the different constraint equations. As an application, the linear constraints are used to represent the continuous interaction of columns with the plate in a flat slab structure. Comparison of the finite element solutions with analytical results shows that the derived constraint equations allow a considerably improved formulation of continuous support conditions.

78-1708

Finite-Element Analysis of Coupled Thermoviscoelastic Structures Undergoing Sustained Periodic Vibrations

T.L. Cost and J.M. Heard

Univ. of Alabama, Tuscaloosa, AZ, AIAA J., 16 (8), pp 795-799 (Aug 1978) 5 figs, 10 refs

Key Words: Forced vibration, Periodic response, Finite element technique, Thermoviscoelasticity theory, Computer programs

A general method is presented for analyzing the effects of internal heating in geometrically complex viscoelastic structures due to exposure to sustained periodic vibratory loads. The analysis employs the finite-element method for both transient displacement and temperature determinations and utilizes "complex" viscoelastic material property functions. The method is demonstrated by application to a problem involving longitudinal oscillations of a linear visco-

elastic rod. General agreement is obtained with the results of Huang and Lee which appear in the literature. The method is applicable to geometrically complex, linear viscoelastic structures of the thermorheologically simple type undergoing small deformations. Existing computer codes that model linear elastic materials can be used, with minor modifications, to obtain linear viscoelastic results.

MODELING

78-1709

Dynamic System Simplification: A Time Domain Criterion

R.G. Leonard and E.D. Ward

Automatic Control Center, School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 59 (1), pp 15-21 (July 8, 1978) 6 figs, 1 table, 2 refs

Key Words: Mathematical models, Dynamic systems

This paper explores the conditions under which second and third order dynamic systems can be reduced to systems of lower order. The performance criterion chosen is the 2% settling time in response to a step input to the system. Graphical results are presented which depict the conditions for the valid reduction of second order systems to first order dominant, third order systems to first order dominant, and third order systems to second order dominant.

78-1710

Model Verification of Mixed Dynamic Systems

J.D. Chrostowski, D.A. Evensen, and T.K. Hasselman
Engrg. Mechanics Dept., J.H. Wiggins Co., Redondo Beach, CA, J. Mech. Des., Trans. ASME, 100 (2), pp 266-273 (Apr 1978) 6 figs, 3 tables, 15 refs

Key Words: Mathematical models, Dynamic systems

A general method is presented for using experimental data to verify math models of "mixed" dynamic systems. The term "mixed" is used to suggest applicability to combined systems which may include interactive mechanical, hydraulic, electrical, and conceivably other types of components. Automatic matrix generating procedures are employed to facilitate the modeling of passive networks (e.g., hydraulic, electrical). These procedures are augmented by direct matrix input which can be used to complement the network model. The problem of model verification is treated in two parts; verification of the basic configuration of the model and determination of the parameter values associated with that configuration are addressed sequentially. Statistical param-

eter estimation is employed to identify selected parameter values, recognizing varying degrees of uncertainty with regard to both experimental data and analytical results. An example problem, involving a coupled hydraulic-mechanical system, is included to demonstrate application of the method.

78-1711

Stored Response Modeling

J. Eichler

Dept. of Mech. Engrg., Ben-Gurion Univ. of the Negev, Beer-Sheva, Israel, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 132-139 (June 1978) 6 figs, 2 tables, 6 refs

Key Words: Mathematical models, System identification technique, Stored response modeling

A direct "brute force" method of system identification is presented. The method is based on the definition of a deterministic system and applicable to nonlinear nonstationary systems with measurement noise. The approach is to discretize the state of the system (or equivalent measurable state), the input vector and time (in the case of a nonstationary system). An optimal control problem is solved using the SRM model.

PARAMETER IDENTIFICATION

(Also see Nos. 1711, 1868)

78-1712

Instrumental Variables Algorithm for Modal Parameter Identification in Flutter Testing

W. Johnson and N.K. Gupta

Ames Res. Center, NASA, Moffett Field, CA, AIAA J., 16 (8), pp 800-806 (Aug 1978) 4 figs, 1 table, 12 refs

Key Words: Aircraft, Flutter, Testing techniques, Parameter identification technique

An instrumental variables algorithm for modal parameter identification is derived in the frequency domain, and an example of its use in aeroelasticity testing is given. Basically the algorithm fits a set of poles and zeros to the measured transfer function of a linear, time-invariant system. An instrumental variables estimate is similar to a least-squared-error estimate but without the bias of the latter for noisy data. The algorithm was implemented for on-line data reduction using a minicomputer-based analysis system, with less core and computation time requirements than the data acquisition process. With the instrumental variables algo-

rithm, accurate and reliable stability estimates can be obtained from a reasonable length of data.

DESIGN TECHNIQUES

(See No. 1799)

CRITERIA, STANDARDS, AND SPECIFICATIONS

78-1713

Practice and Principle in Environmental Noise Rating

D.W. Robinson

National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-81, 24 pp (Apr 1977)

N78-23885

Key Words: Noise measurement, Standards

The possibility to derive a comprehensive noise index was studied to abandon established practices. Some classes of noise evaluation and planning problems are soluble only within a unified system. These are outlined, together with brief reviews of progress on standardization in UK, USA, and ISO. The scale of noise measurement on which such progress is possible is the A-weighted equivalent continuous sound level, Leq.

78-1714

The Ramifications of Noise Control in Food Plants

W.W. Carey

Nestle Enterprises, Inc., White Plains, NY, S/V, Sound Vib., 12 (7), pp 22-24 (July 1978) 2 figs, 1 table, 5 refs

Key Words: Noise control, Standards and codes

Current OSHA requirements for engineering control of worker noise exposure conflict with both FDA and USDA sanitation requirements and GMP's for food manufacturing facilities. A comparison of these conflicting requirements is made and examples provided which indicate both the difficulties and magnitude of costs faced by those who must comply with these standards. Approaches being practiced by many processors are reviewed and future actions pertaining to resolution of the Agency conflict are discussed.

78-1715

Locomotive In-Cab Noise -- Towards a Standardized

Measurement Methodology

R.M. Clarke, R.D. Kilmer, and D.S. Blomquist
National Bureau of Standards, Washington, D.C.,
In: NOISE-CON Conf. on Noise Control Engrg.,
Langley Res. Center, NASA, Hampton, VA, pp 431-442 (Oct 1977)

Sponsored by the Federal Railroad Administration
PB-280 396/3GA

Key Words: Locomotives, Noise measurement, Measurement techniques, Measuring instrumentation, Standards and codes

The U.S. Federal Railroad Administration, in cooperation with the Association of American Railroads, is currently sponsoring efforts by the National Bureau of Standards to collect locomotive in-cab noise level data. The purpose of the program is to develop a simplified stationary test procedure which will correlate with operational duty cycle, crew exposure, and noise level data, and which is based on current OSHA hearing conservation regulations. This paper describes the measurement methodology and instrumentation system developed for this program. The data and conclusions presented are preliminary in nature. The program is scheduled for completion in early 1978.

78-1716

The National Measurement System for Acoustics

D.S. Pallett and M.A. Cadoff

National Bureau of Standards, Washington, D.C.,
Sound and Vibration 11, No. 10, pp 20-25, 27-31
(Oct 1977)

Key Words: Noise measurement, Measurement techniques, Standards and codes

Many recent acoustical measurement processes have been motivated by societal concern over noise and have broad relevance to our contemporary technological society. The emphasis of the study of the National Measurement for Acoustics has been to determine the adequacy of these important physical measurements and to promote improvements within the measurement system. The relevant physical quantities are indicated, and the interactions occurring between participants as well as the roles of acoustical standardization institutions are specified. Finally, the status and trends of the system and the NBS role in adapting to changing technology are discussed.

78-1717

Earthquake Ordinances for the City of Los Angeles, California. A Brief Case Study

K.A. Solomon, D. Okrent, and M. Rubin

Dept. of Chemical, Nuclear and Thermal Engrg.,
California Univ., Los Angeles, CA., Rept. No. UCLA-
ENG-7765, NSF/RA-770485, 62 pp (Oct 1977)
PB-280 763/4GA

Key Words: Buildings, Earthquake-resistant structures,
Regulations

The objective of this paper is to illustrate some of the difficulties in dealing with decisions involving the building code revisions designed to protect against earthquake hazards. Discussed are: the history of earthquakes in the Los Angeles area; recent proposed earthquake ordinances; public sentiment regarding earthquake ordinances (as depicted in newspaper editorials); and comparisons of earthquakes risk for unimproved and improved pre-1933 structures. An appendix contains a brief UCLA report on the situation, as perceived in April 1976, and a copy of a briefing given to Governor Brown by the U.S. Geological Survey in March 1976.

SURVEYS AND BIBLIOGRAPHIES

78-1718

Structural Mechanics Software. Volume 2. May 1975 - May 1978 (A Bibliography with Abstracts)

G.W. Reimherr

National Technical Information Service, Springfield,
VA., 219 pp (June 1978)
NTIS/PS-78/0551/8GA

Key Words: Bibliographies, Computer programs, NASTRAN (computer program), EPSOLA (computer program), SUPERSCEPTRE (computer program), SINGER (computer program)

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, deformation, etc. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPERSCEPTRE, and SINGER. (This updated bibliography contains 213 abstracts, 63 of which are new entries to the previous edition.)

78-1719

Highway Traffic Noise (A Bibliography with Abstracts)

E. Kenton

National Technical Information Service, Springfield,
VA, 190 pp (June 1978)
NTIS/PS-78/0634/2GA

Key Words: Bibliographies, Traffic noise

The citations relate to many aspects of highway noise and its reduction. Studies include transportation noise models, environmental aspects, noise sources, tire-pavement studies, noise barrier design, noise levels, and research in the field. The bibliography also covers highway planning and Government policies in connection with noise pollution abatement and control strategies. Central city investigations are in general excluded.

78-1720

Stability Tests for One, Two, and Multidimensional Linear Systems

E.I. Jury

Dept. of Electrical Engrg. and Computer Sciences,
Electronics Res. Lab., Univ. of California, Berkeley,
CA 94720, J. Dyn. Syst., Meas. and Control, Trans.
ASME, 100 (2), pp 105-109 (June 1978) 39 refs

Key Words: Reviews, Stability, Linear systems

This paper reviews analytical stability tests for one-dimensional linear systems since the early tests of E.J. Routh in his famous Adams Prize essay of 1877. The historical background of Routh's stability test and criterion, as well as Fuller's conjecture on its simplification, will be mentioned. In this historical review, the works of Hermite, Sylvester, Maxwell and others as related to the stability problem are also discussed. This review provides the context for a discussion of recent stability tests obtained for two-dimensional and multidimensional linear systems. These tests are described and their computational complexity is discussed in detail. In addition, the applications of stability testing to the study of two- and multidimensional digital filters, numerical analysis of stiff-differential equations, realization of mixed lumped and distributed parameter systems, and the design of output feedback systems will be briefly mentioned. Comments on future research in this area concludes the paper.

78-1721

Finite Element Analysis of Structures Under Moving Loads

F.V. Filho

Faculty of Civil Engrg., COPPE, Federal University
of Rio de Janeiro, Brazil, Shock Vib. Dig., 10 (8),
pp 27-35 (Aug 1978) 5 figs, 2 tables, 36 refs

Key Words: Reviews, Finite element technique, Moving loads

This review is concerned with the utilization of the finite

element method to obtain stiffness (or flexibility) properties and the properties of the mass of the structural system and of the mass of the loading due to a moving vehicle. A general equation is formulated and specific cases and their methods of solution are described. Significant contributions are reviewed and related whenever possible to work involving continuous or approximate approaches. Areas of further research are indicated.

78-1722

On Seismic Waves. Part IV: Mathematical Methods (2)

S. De

Old Engrg. Office (Qrs.), Santinketan, Birbhum, West Bengal, India, Shock Vib. Dig., 10 (8), pp 11-26 (Aug 1978) 173 refs

Key Words: Reviews, Seismic waves, Earthquake prediction

This second article on mathematical methods includes a brief discussion about earthquake prediction. Suggestions for future research are given in this final section.

78-1723

Damping Overhead Transmission Line Vibration
C.F. Beards

Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7 2BX, UK, Shock Vib. Dig., 10 (8), pp 3-8 (Aug 1978) 17 refs

Key Words: Reviews, Cables (ropes), Transmission systems, Suspended structures

Aeolian vibration of overhead transmission lines can cause line failure through fatigue of the conductor, clamps, or supports. Controlling the vibration to keep dynamic stresses at acceptable levels is essential. The cause of aeolian vibration is reviewed, and several methods for controlling it are presented.

MODAL ANALYSIS AND SYNTHESIS

(See Nos. 1742, 1844, 1889, 1890)

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1718, 1739)

78-1724

Computer Program for Vibration Prediction of Fighter Aircraft Equipments

R.W. Sevy and M.N. Haller

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-101, 218 pp (Nov 1977)

AD-A054 598/8GA

Key Words: Aircraft equipment, Vibration prediction, Computer programs

This study details in-house efforts that culminate in a computer program for the prediction of vibration inputs to equipments mounted in fighter aircraft. Program inputs specify flight conditions, aircraft structural classes, equipment weight, equipment locational coordinates, and mounting categories in order to characterize vibration inputs of fighter aircraft equipments during flight attitudes ranging from straight and level states to a variety of significant flight maneuvers and phases. Program outputs, digital and graphical, are designed to provide the direct spectral information necessary to assemble sequential vibration histories corresponding to fighter aircraft mission profiles.

78-1725

General Aviation Airplane Structural Crashworthiness User's Manual. Volume II. Input-Output Techniques and Applications

M.A. Gamon, G. Wittlin, and W.L. LaBarge

Lockheed-California Co., Burbank, CA, Rept. No. LR-28307-VOL-2, FAA-RD-77-189-VOL-2, 185 pp (Feb 1978)

AD-A054 317/3GA

Key Words: Computer programs, Collision research (aircraft)

This document provides a comprehensive description of program KRASH as modified. Included in this Volume of the User's Manual are the following sections: user's guide, math model development; KRASH data requirements; and Typical Model Arrangements.

78-1726

General Aviation Airplane Structural Crashworthiness User's Manual. Volume III. Related Design Information

G. Wittlin

Lockheed-California Co., Burbank, CA, Rept. No. LR-28307-3, FAA/RD-77/189-3, 121 pp (Feb 1978)

AD-A054 266/2GA

Key Words: Computer programs, Collision research (aircraft)

General information is presented in this report to assist the general aviation airplane industry designer in developing improved structural crashworthiness designs. This report is initiated for the purpose of providing the General Aviation Manufacturers Association (GAMA) members with the basis for understanding the types of procedures, methods and data that are available with regard to structural crashworthiness. This document contains the following sections: (1) General Aviation Airplane Operational and Structural Characteristics; (2) Crash Environment; (3) Occupant Injury Assessment; (4) Structural Data and Methods; and (5) Structural Crashworthiness Design and Compliance Methods.

78-1727

The Digital Calculation of the Operating Parameters of the Mercedes-Benz Accident Simulator (Die digitale Berechnung der Betriebsparameter des Mercedes-Benz Unfallsimulators)

E. Decker and J. Arneemann

Meisenweg 5, 7257 Ditzingen 5, Automobiltech. Z., 80 (6), pp 293-294 (June 1978) 3 figs

Key Words: Collision research (automotive), Computer programs

This paper describes the development of a mathematical model for the accident simulator used at Daimler-Benz, Sindelfingen. The digital computer program predicts the response of the testing for a given set of parameters and will be explained by a practical example.

78-1728

Revision of Simulation Model of Automobile Collisions Computer Program: Investigation of New Integration Algorithm

M. Chi, E. Neal, and J.R. Tucker

Chi Associates, Inc., Arlington, VA., Rept. No. DOT-HS-803 294, 142 pp (May 20, 1977)
PB-280 753/5GA

Key Words: Computer programs, Collision research (automotive)

SMAC (Simulated Model of Automobile Collisions) is a computerized program which recreates collision events between two automobiles. Its purpose is to provide a data bank from which information on the causes and consequences of these accidents can be drawn and to aid highway planners and the public in general to avoid unnecessary accidents and mitigate the effects of those which are unavoidable. Based on preliminary investigation of the new pro-

cedure, significant progress has been recorded in reducing computer execution time.

78-1729

Users' Manual for Asymmetric Wheel/Rail Contact Characterization Program

R. Heller and N.K. Cooperrider

Dept. of Mech. Engrg., Arizona State Univ., Tempe, AZ, Rept. No. FRA/ORD-78/05, 103 pp (Dec 1977)
PB-279 707/4GA

Key Words: Interaction: rail-wheel, Computer programs

Wheel/rail geometric constraint relationships, such as the effective conicity and gravitational stiffness, strongly influence the lateral dynamics of railway vehicles. The principal curvatures of wheel and rail profiles are important parameters in the determination of creep coefficients used in rail vehicle models. In general, these geometric constraints and profile curvatures are nonlinear functions of the wheel-set lateral displacement. This report is a users manual for a computer program written in Fortran IV that uses iterative procedures to determine these nonlinear functions for arbitrary wheel and rail profiles. The program computes the wheel/rail contact positions, geometric constraint functions, and profile curvatures for any given wheel profile, rail profile, rail cant angle, and rail gauge for an asymmetric wheelset on asymmetric rails. Analytical methods used and program input and output are described. Results are in the form of printout, punched cards and drum plotter plots. The users manual includes program listings, sample deck set-ups, and sample run output.

78-1730

The Inclusion of Coulomb Friction in Mechanisms Programs with Particular Reference to DRAM

D.C. Threlfall

Central Electricity Generating Board, Berkeley Nuclear Labs., Berkeley, Gloucestershire, UK, Mech. Mach. Theory, 13 (4), pp 475-483 (1978) 12 figs, 6 refs

Key Words: Computer programs, Mechanisms, Coulomb friction

This paper discusses some properties of friction and critically assesses several possible methods of incorporating these into automatic mechanism programs. The method selected, its compromises and its incorporation into a particular computer program DRAM (Dynamic Response of Articulated Machinery) are described in detail. This method is shown to be a successful compromise between theoretical studies of friction and the avoidance of large computational overheads in their application.

78-1731

THIN - A Computer Program for Analyzing the Axisymmetric Behavior of Thin Spherical Shells

H.E. Williams

Naval Weapons Center, China Lake, CA, Rept. No. NWC-TP-5785, GIDEP-E053-0467
AD-B007 306/4GA

Key Words: Computer programs, Spherical shells

The computer program THIN obtains the solution of the equations of equilibrium governing the small deflections of thin spherical shells using an algorithm called "Dynamic Relaxation." It is assumed that the material properties of the shell are constant and that the shell is closed at the apex. The conditions at the outer edge can be chosen to be either clamped, simply-supported or supported on a transverse rollerskate. This report describes the input/output requirements of the program, the behavior of the "Dynamic Relaxation" algorithm and estimates the accuracy of the program by comparing numerical results obtained using THIN with either exact analytical solutions or analytical solutions where accuracy can be assessed.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1714, 1715, 1716, 1719, 1833, 1845, 1846, 1847, 1849, 1850, 1851, 1852, 1853, 1859, 1870)

78-1732

Classifying Road Vehicles for the Prediction of Road Traffic Noise

P.M. Nelson and R.J. Piner

Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-752, 26 pp (1977)
PB-280 864/0GA

Key Words: Traffic noise, Noise prediction, Noise measurement

The accuracy of traffic noise predictions obtained using the TRRL computer model of traffic noise depends to a considerable extent on the degree of simplification adopted in categorizing vehicles according to their sound output and speed in the traffic stream. This report examines and summarizes the available data on the acoustic classification of vehicles in traffic streams for predicting traffic noise. Measurements of speed, noise level and vehicle type have been

made in road conditions ranging from fairly congested urban situations with speeds around 20 km/h to free flow on motorways with speeds over 100 km/h. The measurements have been used to construct approximate vehicle noise levels and speed characteristics over the speed range 20-100 km/h for up to 6 vehicle categories, and used as input in the TRRL computer model of traffic noise.

78-1733

Traffic Noise in a High-Rise City

N.W.M. Ko

Dept. of Mech. Engrg., Univ. of Hong Kong, Hong Kong, Appl. Acoust., 11 (3), pp 225-239 (July 1978) 3 figs, 3 tables, 16 refs

Key Words: Traffic noise, Urban noise, Noise measurement

Extensive results of traffic noise measured at 258 roadside sites in the high-rise city of Hong Kong are reported. From the results of this investigation the measurement sites can be very simply classified into three categories: enclosed, semi-enclosed and open. Distinct differences were found in the sound pressure levels L_{10} , L_{50} and L_{90} and in the standard deviations obtained at the enclosed site and at the semi-enclosed and open sites.

78-1734

Multiple-Reflection Diffuse-Scattering Model for Noise Propagation in Streets

H.G. Davies

Dept. of Mech. Engrg., Univ. of New Brunswick, Fredericton, New Brunswick, Canada, J. Acoust. Soc. Amer., 64 (2), pp 517-521 (Aug 1978) 4 figs, 5 refs

Key Words: Urban noise, Sound propagation, Acoustic scattering

The sound field generated by an omnidirectional point source in an infinitely long, straight street is considered. The field is assumed to be the sum of a multiply-specularly reflected field and a diffuse field that is fed from scattering at the walls at each reflection of the specular field. It is shown that scattering is important close to the source. The sound level depends on the width of the street and the height of the walls and on the reflection and scattering coefficients of the walls.

78-1735

Noise Transmission Through Plates into an Enclosure

W.B. McDonald

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

Rept. No. NASA-TP-1173; L-11906, 44 pp (May 1978)
N78-23877

Key Words: Plates, Sound transmission, Enclosures

An analytical model is presented to predict noise transmission through elastic plates into a hard-walled rectangular cavity at low frequencies, that is, frequencies up through the first few plate and cavity natural frequencies. One or several nonoverlapping and independently vibrating panels are considered. The effects on noise transmission of different external-pressure excitations, plate boundary conditions, fluid parameters, structural parameters, and geometrical parameters were investigated.

78-1736

Measurements with an Intensity Meter of the Acoustic Power of a Small Machine in a Room

F.J. Fahy

Inst. of Sound and Vib. Research, Southampton Univ., Southampton SO9 5NH, UK, Rept. No. ISVR-TR-94, 27 pp (Sept 1977)
N78-23884

Key Words: Machinery noise, Noise measurement, Measurement techniques

A technique which employs two closely spaced pressure microphones, a special purpose circuit, and a sound level meter to measure acoustic intensity in octave bands, is used to estimate the intensity distribution around a small, 1200 electrical watt, machine situated in a room. The total acoustic power estimated therefrom is compared with that obtained by the conventional direct field method. The technique, which appears to be accurate over the range 250-4000 Hz, produces values of intensity and power which are generally less than the direct field values. The difference tends to increase with frequency. A potential for source location application is indicated.

78-1737

Jet Noise Modelling by Geometric Acoustics. Part 1: Theory and Prediction Outside the Cone of Silence

C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-91-Pt-1, 174 pp (Sept 1977)
N78-23881

Key Words: Jet noise, Noise prediction, Mathematical models

The generation of noise by the turbulent mixing process downstream of a round jet nozzle is investigated and a geometric acoustics model for jet noise radiation outside the cone of silence is developed. For isothermal jets the turbulence is represented as acoustically equivalent to a volume displacement distribution of quadrupole order. For non-uniform density flows (heated jets) the dominant radiation at low Mach numbers is modeled as acoustically equivalent to a volume displacement distribution of dipole order. A volume displacement monopole distribution is also considered as a possible additional source of noise in heated jets. The effect of mean flow-acoustic interaction is modeled separately from the sources. Source non-compactness and convection effects are included in the source description. A jet noise prediction scheme valid for radiation angles outside the cone of silence is developed from the source master spectra and turbulence parameters inferred from rear arc jet noise measurements, using the geometric acoustics model. Agreement between predictions in the forward arc and measured results is very good.

78-1738

Jet Noise Modelling by Geometric Acoustics. Part 2: Theory and Prediction Inside the Cone of Silence

C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-92-Pt-2, 84 pp (Oct 1977)
N78-23882

Key Words: Jet noise, Noise prediction, Mathematical models

A geometric acoustics model of jet mixing noise is extended to describe far-field radiation within the cone of silence. The relevant acoustic-mean flow interactions are modeled by an approximation to the WKB type solution. The original monopole solution is generalized to yield high-frequency solutions for the dipole and quadrupole sources used to model jet mixing noise. The exponential decay factor encountered within the cone of silence is theoretically predicted to be almost proportional (in decibels) to the shear layer thickness. Analysis of a wide range of isothermal jet noise data leads to inferred values of the ratio of shear layer thickness at the source location to the nozzle diameter, as a function of Strouhal number. These are in excellent agreement with the results of source location and flow profile measurements.

78-1739

Jet Noise Modelling by Geometric Acoustics. Part 3: A Computer Program for the Prediction of Jet Mixing Noise

C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-93-Pt-3, 29 pp (Oct 1977)
N78-23883

Key Words: Jet noise, Noise prediction, Computer programs

A prediction program for far-field jet mixing noise is documented. The theory is based upon Morfey's geometric acoustics model of jet mixing noise. The program is valid for radiation angles greater than 30 deg to the jet axis and for any jet static temperature ratio. Any velocity ratio may be predicted outside the cone of silence, but there is at present an upper limit inside the cone of silence. Sound pressure levels in 1/3 octave bands are predicted for a source Strouhal number range of 0.1 to 3.16, corresponding to a frequency range of 5 octaves centered approximately on the peak 1/3 octave frequency.

78-1740

Noise Suppression in Jet Inlets

B. Zinn, W.L. Meyer, and W.A. Bell
School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA., Rept. No. AFOSR-TR-78-0696, 52 pp (Feb 1978)
AD-A054 173/0GA

Key Words: Jet noise, Geometric effects, Numerical analysis, Computer programs

This report summarizes the work performed during the first year of a research effort to determine the sound fields associated with jet engine inlet configurations. A solution approach for axisymmetric bodies based upon the integral formulation of the wave equation has been developed. This solution approach circumvents the uniqueness problems which normally occur at certain frequencies when 'straight-forward' solutions of the integral equation are obtained. A numerical method and a computer program for solving for the acoustic field associated with general inlet configurations and boundary conditions have also been developed. To evaluate the numerical method, computed and exact results are compared for a sphere and a finite length cylinder. For continuous boundary conditions, the agreement is within ten per cent over a range of nondimensional frequencies from one to ten. For discontinuous boundary conditions, the numerical errors increased by a factor of two. This report presents results for a given inlet configuration and the computed and exact solutions are shown to agree to within ten per cent over the nondimensional frequency range from one to ten.

78-1741

Experimental Measurements of Acoustic Scattering

by Rows of Cylindrical Obstacles

S. Liao and W. Sachse
Dames & Moore, Cranford, NJ 07016, J. Acoust. Soc. Amer., 64 (2), pp 563-570 (Aug 1978) 11 figs, 14 refs

Key Words: Underwater sound, Acoustic scattering, Cylinders

Experiments were performed in a shallow two-dimensional water tank to determine the effects of diameter, spacing, and material properties on acoustic scattering by rows of cylindrical obstacles. Cylinder diameters ranged from 0.17 to 0.39 times the wavelength, and center-to-center spacings up to 1.2 wavelengths were investigated. In the limit of small spacings, multiple scattering was found to be characteristically similar to sound wave transmission through walls. Analysis of the experimental data indicated that the acoustic properties and microstructure of the scatterers could be distinguished by the transmissivity response of the arrays.

RANDOM

(See Nos. 1781, 1782)

SEISMIC

(Also see Nos. 1705, 1717, 1722, 1799, 1828, 1858, 1876)

78-1742

Simulation of Strong-Motion Displacements Using Surface-Wave Modal Superposition

H.J. Swanger and D.M. Moore
Dept. of Geophysics, Stanford Univ., Stanford, CA 94305, Bull. Seismol. Soc. Amer., 68 (4), pp 907-922 (Aug 1978) 10 figs, 4 tables, 27 refs

Key Words: Ground motion, Simulation, Modal synthesis

Synthetic seismograms constructed by addition of surface-wave modes in a layered half-space are compared to Cagniard-de Hoop calculations of Heaton and Helmberger (1977, 1978) and to ground displacement recordings near El Centro, California to examine the applicability of modal superposition as a means of simulating ground motion of possible engineering interest. Ground displacement recordings of El Centro from the 1968 Borrego Mountain earthquake are modeled using a multi-layered geological structure and a source model based on independent studies.

78-1743

New Discrete Models and Their Application to Seismic Response Analysis of Structures

T. Kawai

Inst. of Industrial Science, Univ. of Tokyo, 22-1, Roppongi 7 Chome, Minato-ku, Tokyo 106, Japan, Nucl. Engr. Des., 48 (1), pp 207-229 (June 1978) 34 figs, 2 tables, 14 refs

Key Words: Lumped parameter methods, Seismic response

New discrete models and their application to seismic response analysis of structures is proposed in this paper. These models consist of finite number of small rigid bodies connected with springs distributed over the contact area of two neighboring bodies. In general size of stiffness matrices of these elements are at most (6×6) which are equal to or even smaller than $\frac{1}{2}$ of those of conventional finite elements so that considerable reduction of computing time can be expected. Effectiveness of these elements in nonlinear structural analysis, especially dynamic response analysis of structures are demonstrated by several numerical examples.

78-1744

Torsional Spectrum for Earthquake Motions

W.K. Tso and T.-I. Hsu

Dept. of Civil Engrg. and Engrg. Mechanics, McMaster Univ., Hamilton, Ontario, Canada, Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 375-382 (July/Aug 1978) 6 figs, 1 table, 7 refs

Key Words: Seismic excitation, Earthquake response, Torsional response, Spectrum analysis, Buildings

A computational scheme is presented to construct torsional spectra due to the rotational component of seismic ground motions. The rotational component of ground motion is estimated from the measured earthquake acceleration records. In contrast to previous studies, no differentiation of acceleration records is involved in the present scheme. The torsional spectrum of the 1940 El Centro earthquake is computed and compared with previous results. An average and a mean plus one standard deviation torsional spectrum is presented for design purposes. These spectra are results based on four historical records (1934 El Centro, 1940 El Centro, 1949 Olympia and 1952 Taft) normalized to the 1940 El Centro intensity.

78-1745

High Earthquake Risk Buildings in New Zealand

R. Shepherd

Univ. of Auckland, New Zealand, Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 383-395 (July/Aug 1978) 9 figs, 2 tables, 8 refs

Key Words: Seismic design, Buildings

Many existing buildings in seismically active areas were constructed prior to the acceptance of any design criteria specifically intended to produce earthquake resistance in the structure. Although such buildings are typically fifty or more years old they still constitute a large proportion of occupied domestic and commercial accommodation. Since almost all these structures comprise greater hazards than more recent constructions they are referred to as High Earthquake Risk buildings. The problems of identification, assessment and alleviation of the deficiencies have received increasing attention in recent years. In this paper some New Zealand experience is recounted.

78-1746

A Reconnaissance Report for the Romanian Earthquake of 4 March 1977

S.S. Tezcan, V. Yerlici, and H.T. Durgunoglu

Bogazici Univ., Istanbul, Turkey, Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 397-421 (July/Aug 1978) 26 figs, 1 table, 15 refs

Key Words: Earthquake damage, Buildings

The engineering aspects of the 4 March 1977 Romanian earthquake are presented. They are based upon a field investigation conducted by the writers in Bucharest and in southern Romania in collaboration with members of the Building Research Institute of Romania, during the period 25-31 March 1977. This report covers general observations, data and evaluation on the character of the earthquake, structural damage inflicted by it, performance of different types of buildings during the earthquake and relief operations.

78-1747

A Model for Formulating Seismic Design Provisions

C. Culver

National Bureau of Standards, Washington, D.C., 10 pp (June 1977)
PB-280 397/1GA

Key Words: Buildings, Earthquake resistant structures

The paper describes a program currently underway in the United States to develop improved seismic design provisions for buildings. Organization of the activity, the form of the provisions and the technical areas included are discussed. Important aspects of the provisions dealing with: design ground motion, structural design, architectural and mechanical-electrical design, and existing buildings are summarized.

SHOCK

(Also see Nos. 1705, 1725, 1726, 1727, 1728,
1797, 1854, 1855, 1881)

78-1748

Evaluation of the Shock Block Technique for Generating Underwater Plane Waves

A.L. Florence and C.M. Romander

Sri International, Menlo Park, CA., Rept. No. DNA-4447Z, AD-E300 169, 33 pp (Oct 1977)

AD-A053 419/8GA

Key Words: Underwater explosions, Shock wave propagation

Underwater Explosions Research Division has developed a shock block technique for generating underwater plane waves for the Defense Nuclear Agency. The technique was designed to produce a pulse that would simulate the pulse generated by an underwater nuclear explosion and was developed to improve the current method of loading submarine sections in which the energy source is concentrated as either a large sphere or a single line of explosive. This report discusses our work and recommends improvements. Examination of the experimental results revealed that the pulse generated by the equally spaced array of horizontal strands of Primacord explosive forming the shock block was of much shorter duration than predicted by superposition of the pulses from the individual strands. Instead of the required long rectangular pulse, the technique produces a short half-sine wave pulse. The work suggested the use of a helical coil of Primacord wrapped on a disposable cylindrical mandrel as an alternative to the straight strand of Primacord. The coil axis is horizontal and the pitch is the smallest that allows reliable detonation of the complete strand forming the helix without appreciable displacement.

78-1749

Duration of Nuclear Explosion Ground Motion

W.W. Hays, K.W. King, and R.B. Park

U.S. Geological Survey, Denver Federal Center, Denver, CO 80225, Bull. Seismol. Soc. Amer., 68

(4), pp 1133-1145 (Aug 1978) 15 figs, 29 refs

Key Words: Nuclear explosion effects, Ground motion

This paper evaluates the duration of strong ground shaking that results from nuclear explosions and identifies some of the problems associated with its determination. Knowledge of the duration of horizontal ground shaking is important out to the epicentral distances of about 44 km and 135 km, the approximate distances at which the ground shaking level falls to 0.01 g for nuclear explosions having yields of about 100 kt and 1,000 kt, respectively. Evaluation of the strong ground motions recorded from the event

STRAIT ($M_L = 5.6$) on a linear array of five, broad-band velocity seismographs deployed in the distance range 3.2 to 19.5 km provides information about the characteristics of the duration of ground shaking.

78-1750

Mode and Bound Approximation Methods for Large Deflections of Dynamically Loaded Structures with Plastic and Viscoplastic Behavior

P.S. Symonds

Div. of Engrg., Brown Univ., Providence, RI, 16 pp (Apr 15, 1978)

AD-A054 277/9GA

Key Words: Structural response, Pulse excitation, Plastic properties, Viscoplastic properties

The research aimed at finding and developing methods for estimating the main features of response of engineering structures subjected to severe dynamic loading of pulse type, with emphasis put on methods valid both for large deflections and for structures of materials exhibiting strong strain rate sensitivity in the plastic range. Problem types of practical importance include explosive loading, either external due to military attack or internal for example due to disruptive accident in a pressure vessel or containment structure; various types of vehicular impact; wave impact on ship or offshore structures; and high energy rate forming. Preliminary applications have been made of the methods under investigation in the program presently being reviewed in all but the last of the above areas.

GENERAL WEAPON

(See No. 1807)

TRANSPORTATION

(See No. 1732)

PHENOMENOLOGY

DAMPING

(Also see Nos. 1700, 1770, 1836, 1837,
1838, 1839, 1856, 1891)

78-1751

An Experimental Study of the Steady-State Response of Oil-Film Dampers

R.K. Sharma and M. Botman

Pratt & Whitney Aircraft of Canada, Ltd., Longueuil, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 216-221 (Apr 1978) 12 figs, 7 refs

Key Words: Fluid-film damping, Oil film bearings, Periodic response

Oil-film dampers are an integral feature of most high-speed, lightweight turbo engines, in which they are used to suppress undesirable shaft dynamic responses. They are generally located at the antifriction main bearings. An experimental study of the steady-state response of an oil-film damper at a main bearing was conducted on the high-speed rig developed for this purpose. The rig and some typical test results on a damper with a discrete number of oil-inlet ports were described in an earlier publication. In this paper, the experimental results are presented on dampers with different geometries and oil-supply arrangements. The results are presented in terms of transmissibility, deflection and damping coefficient plots. The response of the damper with radial springs to simulate gravity effects in a vertical rotor arrangement is compared to that without radial springs.

78-1752

Experimental and Analytical Investigation of Squeeze Film Bearing Damper Forces Induced by Offset Circular Whirl Orbits

P.N. Bansal and D.H. Hibner

Structures Technology Group, Commercial Products Div., Pratt & Whitney Aircraft Group, Div. of United Technologies Corp., East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 549-557 (July 1978) 10 figs, 19 refs

Key Words: Squeeze-film dampers, Hydrodynamic excitation, Whirling

A basic research program was conducted to investigate the hydrodynamic forces of a squeeze film bearing damper. These forces were induced by controlled offset circular whirl orbits of the damper journal. The orbits were mechanically produced by eccentric damper rings and cams in a specially designed, end sealed test rig. Aircraft engine damper geometry and operating conditions were simulated. The instantaneous circumferential pressure profiles, for specific orbits, were measured by eight high response pressure transducers. These test values are required to compare theory with test. Since the data reduction for offset orbits is extremely complicated, this simple method was found to be very useful in analyzing the test results. Test results for pressure profiles as well as damper forces were compared

with theoretical predictions. The analysis is based on "long bearing" solution of Reynolds equation and includes the effect of inlet and cavitation pressures. For the cavitated oil film, inlet pressure was shown to have important effect on damper forces.

78-1753

Analysis and Experimental Investigation of the Stability of Intershaft Squeeze Film Dampers - Part 2: Control of Instability

D.H. Hibner, P.N. Bansal, and D.F. Buono

Pratt and Whitney Aircraft, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 558-562 (July 1978) 8 figs, 5 refs

Key Words: Stability, Squeeze-film dampers, Rotor-bearing systems

A comprehensive stability analysis is used to study the stability of the test rig which incorporates a modified intershaft bearing support. The analysis is applicable to large multi-mass, rotor-bearing systems and includes the effects of gyroscopic moments, shear deformation, bearing support flexibility, and damping. The results of the stability analysis are presented in the form of system stability maps which clearly indicate the effectiveness of the modification in improving the instability onset speed of the system. Also presented are the results of an experimental investigation which substantiate the analytical predictions.

78-1754

Squeeze Film Damper Characteristics for Gas Turbine Engines

R.A. Marmol and J.M. Vance

Government Products Div., Pratt and Whitney Aircraft Group, West Palm Beach, FL, J. Mech. Des., Trans. ASME, 100 (1), pp 139-146 (Jan 1978) 12 figs, 9 refs

Key Words: Squeeze-film dampers, Gas turbine engines, Mathematical models

A mathematical model for squeeze film dampers is developed, and the solution results are compared with data from four different test rigs. A special feature of the analysis is the treatment of several different types of end seals and inlets, with inlet feedback included. A finite difference method is used to solve the Reynolds equation, with a banded matrix inversion routine. The test data are taken from a new high-speed free-rotor rig, and from three previously tested controlled-orbit rigs.

78-1755

The Dynamic Characteristics of O-Rings

A.J. Smalley, M.S. Darlow, and R.K. Mehta
Mechanical Technology, Inc., Latham, NY, J. Mech.
Des., Trans. ASME, 100 (1), pp 132-138 (Jan 1978)
12 figs, 6 refs

Key Words: Elastomeric dampers, Experimental data

Stiffness and damping characteristics for O-rings are presented and discussed. These characteristics have been determined as a function of frequency and the effect of the following test parameters have been investigated: O-ring material, O-ring cross-section diameter, temperature, amplitude, squeeze, stretch, and groove width. The base excitation, resonant mass method, has been used in conjunction with a computerized system for data acquisition and reduction. Generally consistent data has been obtained and the trends resulting from the parameter changes are, qualitatively, as would be expected.

78-1756

Extinction of Predominantly Subharmonic Oscillations in a Non Linear Dynamic Damper with Two Degrees of Freedom

R. Riganti
Inst. for Rational Mechanics, Polytechnic of Turin, Italy, Mech. Res. Comm., 5 (3), pp 113-119 (1978)
5 figs, 10 refs

Key Words: Nonlinear damping

Following previous studies on the subharmonic response of forced non linear systems, the steady-state, 1/3 subharmonic oscillations of a dynamic damper with two degrees of freedom, sinusoidal forcing function and viscous dampings are examined. From the analysis, easy theoretical conditions are derived, regarding the limiting values of the various parameters needed to destroy the predominantly subharmonic component in the periodical oscillations of the damper. The results deduced from the proposed conditions are compared with the ones obtained by numerical integration of the equations of motion of the dynamical system.

78-1757

Damping Materials Provide Low-Cost Solutions to Vibration Problems

S/V, Sound Vib., 12 (8), pp 4-7 (Aug 1978)

Key Words: Material damping, Aircraft engines, Airframes

The use of damping materials in aircraft engines and airframes to prevent cracking as a result of vibration is described.

78-1758

Design Evaluation of Layered Viscoelastic Damping Treatments

A.D. Nashif and W.G. Halvorsen
Anatrol Corp., Cincinnati, OH, S/V, Sound Vib., 12 (7), pp 12-15 (July 1978) 9 figs, 3 refs

Key Words: Viscoelastic damping, Beams, Structural elements

Design procedures are presented for predicting the performance of viscoelastic vibration damping treatments for application to structures. The results presented are based primarily on the application of damping treatments to simple beams. However, similar procedures have been developed for more complicated systems such as plates and stiffened structures. Correlation between the predicted and measured results using the approach described in the article is very good.

FATIGUE

78-1759

Fatigue Life Prediction of Complex Structures

B.N. Leis
Battelle Columbus Labs., Columbus, OH, J. Mech. Des., Trans. ASME, 100 (1), pp 2-9 (Jan 1978)
4 figs, 52 refs

Key Words: Fatigue life

Because of the complex nature of the fatigue process, it is only recently that reasonably effective analysis procedures for predicting finite-fatigue life for simple notched coupons have evolved. One of the more vexing problems in adapting these procedures to making life predictions for complex components and structures is that of the multiplicity of crack initiation sites and mechanisms which determine the fatigue life of such structures. It has been observed that which of the many potential initiation sites and mechanisms controls failure depends on the service environment and the magnitude and character of the service loading. The present paper critically examines available technology for fatigue analysis of complex structures in which the multiplicity of initiation sites and mechanisms control the structure's life.

78-1760

Dynamic Severity Criterion for Designing Against High Cycle Fatigue

G.S.A. Shawki

Faculty of Engrg., Cairo Univ., Cairo, Egypt, J. Mech. Des., Trans. ASME, 100 (1), pp 10-15 (Jan 1978) 12 figs, 33 refs

Key Words: Fatigue (materials)

A novel approach to the interpretation of material behavior under cyclic loading is presented. In this approach a non-dimensional criterion, featuring the dynamic severity of applied load, is put forward with a view to the provision of simple though confident assessment of component performance under dynamic load. The fatigue diagram based on the proposed criterion displays significant merits over previous diagrams, the presented approach thus providing an effective tool for designing against high cycle fatigue with due consideration to maximum utilization of material.

FLUID

(Also see Nos. 1795, 1810, 1811, 1813, 1875)

78-1761

Aeroelastic Instability of Rectangular Cylinders in a Heaving Mode

K. Washizu, A. Ohya, Y. Otsuki, and K. Fujii
Dept. of Aeronautics, Univ. of Tokyo, Tokyo, Japan,
J. Sound Vib., 59 (2), pp 195-210 (July 22, 1978)
16 figs, 11 refs

Key Words: Cylinders, Rectangular bodies, Aeroelasticity, Fluid-induced excitation

This paper deals with wind tunnel experiments on the aeroelastic instability in a heaving mode of two-dimensional rectangular cylinders in a uniform two-dimensional flow. Both the free oscillation method and the forced oscillation method are employed for the experiments. Emphasis is placed on finding the effect of the ratio c/d , which is the ratio of the lengths of the sides of the rectangle, to the aeroelastic instability phenomena in the vicinity of the resonance speed. Emphasis is also placed on finding possible limitations in the application of the quasi-steady aerodynamic theory to the analysis of the aeroelastic characteristics.

78-1762

Extremes of Morison-Type Wave Loading on a Single Pile

G. Moe and S.H. Crandall
Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, 100 (1), pp 100-104 (Jan 1978) 3 figs, 9 refs

Key Words: Offshore structures, Piles, Water waves, Fluid-induced excitation

A statistical estimate of the extreme wave force per unit length acting on a section of a fixed cylindrical pile in a random sea-state is derived. The random motion of the sea is described by a spectrum of wave heights in conjunction with linear wave theory. The wave force is assumed to depend linearly on the water particle acceleration and nonlinearly on the water velocity according to the Morison formula. The interaction of the velocity and acceleration contributions and the contribution of a small steady current are accounted for by an asymptotic approximation valid for large forces. The expected rate of occurrences of extremes based on a simple peak definition agrees satisfactorily with a more elaborate result based on a true maximum definition. The formulas derived here provide a basis for a design-force procedure which could provide an improvement over the design-wave procedure commonly used for the analysis of offshore structures.

SOIL

78-1763

The Spring Method for Embedded Foundations

E. Kausel, R.V. Whitman, J.P. Morray, and F. Elsabee
Stone and Webster Engrg. Corp., 245 Summer St., Boston, MA 02107, Nucl. Engr. Des., 48 (2/3), pp 377-392 (Aug 1978) 16 figs, 34 refs

Key Words: Interaction: soil-structure, Spring method

The paper presents simplified rules to account for embedment and soil layering in the soil-structure interaction problem, to be used in dynamic analyses. The relationship between the spring method, and a direct solution (in which both soil and structure are modeled with finite elements and linear members) is presented. It is shown that for consistency of the results obtained with the two solution methods, the spring method should be performed in three steps.

78-1764

Some Aspects of the Ground Vibration Problem

T.G. Gutowski, L.E. Wittig, and C.L. Dym
Noise Control Engr., 10 (3), pp 94-100 (May-June 1978) 8 figs, 24 refs

Key Words: Ground vibration

The topic of ground vibration involves many disciplines; pertinent work has been done in the areas of seismology, civil engineering, acoustics, noise control, and biomechanics, to mention a few. The purpose of this paper is to draw

together some of these results and to show their applicability to solving ground vibration problems.

78-1765

Soil-Structure Interaction. A Background Discussion for the Swedish Council for Building Research

S. Hansbo and G. Karrholm

Swedish Council for Building Res., Stockholm, Sweden, Rept. No. ISBN-91-540-2719-5; D10:1977, 30 pp (1977)
PB-280 181/9GA

Key Words: Interaction: soil-structure, Reviews

The report investigates damages caused by improper consideration of soil-structure interaction, mechanical properties of soils, mechanical properties of superstructures, computation models, and surveys of research problems.

VISCOELASTIC

(See Nos. 1758, 1796)

EXPERIMENTATION

BALANCING

(Also see No. 1769)

78-1766

Turbine Engine Rotor Dynamic Evaluation. Volume II. Engine and Test Rig Balancing

J. Davis, J. Tessarzik, and R.A. Rio

Mechanical Technology, Inc., Latham, NY, Rept. No. MTI-76TR41-VOL-2, AFAPL-TR-76-81-VOL-2, 52 pp (Jan 1978)
AD-A054 533/5GA

Key Words: Balancing techniques, Turbine engines

Balancing demonstrations were performed to show the applicability of combining dynamic characteristics and advanced balancing techniques to effectively reduce the vibration of production type machinery. Trim balancing procedures were performed on the TF30, TF41 and F100

jet engines which are currently in use on military aircraft. A very sensitive high-speed experimental test apparatus called the 'Rub Rig' was also used to show the benefits of multi-plane-multispeed balancing using influence coefficients.

DIAGNOSTICS

78-1767

Detection of Rolling Element Bearing Damage by Statistical Vibration Analysis

D. Dyer and R.M. Stewart

Mech. Engrg. Labs., G.E.C. Power Engrg., Whetstone, Leicester, UK, J. Mech. Des., Trans. ASME, 100 (2), pp 229-235 (Apr 1978) 9 figs, 16 refs

Key Words: Housings, Bearings, Diagnostic techniques

A new method is presented for predicting rolling element bearing condition from measurements of bearing housing vibration. This method is based on a statistical parameter Kurtosis, that remains constant for an undamaged bearing irrespective of load and speed, yet changes with damage. The extent of damage can be assessed from the distribution of this statistical parameter in selected frequency ranges. An assessment of bearing condition can thus be made with minimum recourse to historical information. Most other damage detection techniques rely heavily on the trend analysis of data and so this new method may prove to be a significant advance in bearing fault detection technology, at least when viewed within the original objective to provide a simple and cheap technique. As with most other simple detection techniques, the precise nature of the fault cannot be defined and for such information it is necessary to use the more sophisticated diagnostic methods.

78-1768

An Evaluation Technique for Determining the Cost Effectiveness of Condition Monitoring Systems

P.T. George and A.T. Parker

Pratt & Whitney Aircraft Group, East Hartford, CT, ASME Paper No. 78-GT-166

Key Words: Diagnostic techniques

A technique for analyzing the cost-effectiveness of condition monitoring systems has been developed both to provide a quantitative assessment of the value of condition monitoring and to guide the selection of items to be monitored by the system. The technique uses historical data combined with catalog cost estimating to estimate both the life cycle cost of the condition monitoring system and the potential cost savings offered by the system for commercial engines. The results are obtained in a form that can be easily con-

verted to any of the primary cost-effectiveness parameters in current use by industry.

78-1769

Turbine Engine Automated Trim Balancing and Vibration Diagnostics

R. McTasney, R.A. Rio, and W.A. Troha
Oklahoma City Air Logistics Center, Oklahoma City, OK, ASME Paper No. 78-GT-129

Key Words: Turbine engines, Balancing techniques, Diagnostic techniques

After turbine engine is overhauled at Oklahoma City Air Logistics Center (OC-ALC) or at San Antonio Air Logistic Center (SA-ALC), it is run in the test cell before shipment. While in the test cell, final adjustments are made to the engine. One of these adjustments is the dynamic vibration balance of the engine. This adjustment is referred to as a trim balance. The current trim balance procedures in use at OC-ALC require the engine to be in the test cell from 4 to 6 hours.

78-1770

Signature Analysis of Acoustic Emissions From Composites. Final Report. 1 Oct 1975 - 30 Mar 1978

E.G. Henneke, II

Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., Rept. No. NASA-CR-145373, 79 pp (May 19, 1978) N78-23148

Key Words: Acoustic signatures, Fracture properties, Composite materials

Acoustic emission data were obtained from a series of tensile tests on specially designed graphite-epoxy unidirectional laminates. The design was such that the specimens would preferentially fail first by fiber breakage and later by matrix splitting. The AE signals for each of these events was analyzed and some typical results are reported. Patterns characteristic of each failure mechanism were noted for both the time signatures and the corresponding frequency spectra.

EQUIPMENT

(See Nos. 1724, 1837)

INSTRUMENTATION

(Also see No. 1715)

78-1771

Frequency Spectrum Analyzer

M.J. Post, R.E. Cupp, and R.L. Schwiesow
Wave Propagation Lab., National Oceanic and Atmospheric Administration, Boulder, CO, Rept. No. NOAA-TR-ERL-392, WPL-51, 8 pp (Oct 1976) PB-280 941/6GA

Key Words: Frequency analyzers

The report describes an electronic apparatus that analyzes Doppler returns from an infrared lidar system. By processing each spectral frequency channel with a 100 percent duty cycle rather than with a swept filter analyzer, considerably better S/N is obtained.

78-1772

Industrial Sound Level Meter Environmental Testing

R.J. Koshut

Testing and Certification Branch, National Inst. for Occupational Safety and Health, Morgantown, WV, Rept. No. NIOSH/TC/P-015, 35 pp (Apr 1978) PB-280 028/2GA

Key Words: Sound level meters, Environmental effects

This test procedure checks the effect on an industrial sound level meter when it is subjected to environmental conditions of temperature and humidity. Included is a list of equipment needed to perform the test and the configuration in which the equipment is to be used.

TECHNIQUES

(See Nos. 1713, 1715, 1736)

COMPONENTS

ABSORBERS

78-1773

Physical and Acoustical Properties of Urethane Foams

E. O'Keefe

Specialty Composites Corp., Newark, DE, S/V, Sound Vib., 12 (7), pp 16-21 (July 1978) 7 figs, 3 tables, 12 refs

Key Words: Foams, Acoustic properties, Vibration dampers, Acoustic absorption, Noise barriers

The basic processes governing the manufacturing of acoustical foams, as well as the physical properties which affect their use as an acoustic absorber, barrier, or vibration damper are described. Some of the properties which determine the acoustical properties are the flow resistance, thickness, type of facing, stiffness, and even temperature. The relevance of different methods for determining acoustical performance are discussed, and methods are recommended for specifying some of the important acoustic parameters of acoustical foams.

SHAFTS

(See Nos. 1834, 1892)

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1723, 1789)

78-1774

The Dynamics and Control of Large Flexible Space Structures. Part A: Discrete Model and Modal Control

P.M. Bainum and R. Sellappan

Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156975, 59 pp (May 1978)

N78-23139

Key Words: Spacecraft, Beams, Mathematical models, Lumped parameter methods, Modal control technique

Attitude control techniques for the pointing and stabilization of very large, inherently flexible spacecraft systems were investigated. The attitude dynamics and control of a long, homogeneous flexible beam whose center of mass is assumed to follow a circular orbit was analyzed. First order effects of gravity gradient were included. A mathematical model which describes the system rotations and deflections within the orbital plane was developed by treating the beam as a number of discretized mass particles connected by massless, elastic structural elements. The uncontrolled dynamics of the system are simulated and, in addition, the effects of the control devices were considered. The concept of distributed modal control, which provides a means for controlling a system mode independently of all other modes, was examined. The effect of varying the number of modes in the model as well as the number and location of the control devices were also considered.

78-1775

The Dynamics and Control of Large Flexible Space Structures. Part B: Development of Continuum Model and Computer Simulation

P.M. Bainum, V.K. Kumar, and P.K. James

Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156976, 116 pp (May 1978)

N78-23140

Key Words: Spacecraft, Beams, Mathematical models, Computerized simulation, Equations of motion

The equations of motion of an arbitrary flexible body in orbit were derived. The model includes the effects of gravity with all its higher harmonics. As a specific example, the motion of a long, slender, uniform beam in circular orbit was modeled. The example considers both the inplane and three dimensional motion of the beam in orbit. In the case of planar motion with only flexible vibrations, the pitch motion is not influenced by the elastic motion of the beam. For large values of the square of the ratio of the structural modal frequency to the orbital angular rate the elastic motion was decoupled from the pitch motion. However, for small values of the ratio and small amplitude pitch motion, the elastic motion was governed by a Hill's 3 term equation. Numerical simulation of the equation indicates the possibilities of instability for very low values of the square of the ratio of the modal frequency to the orbit angular rate. Also numerical simulations of the first order nonlinear equations of motion for a long flexible beam in orbit were performed. The effect of varying the initial conditions and the number of modes was demonstrated.

78-1776

On the Multiplicity of Solutions of the Inverse Problem for a Vibrating Beam

V. Barcilon

Dept. of Geophysical Sciences, Chicago, Univ., IL, 19 pp (Apr 1978)

AD-A054 248/0GA

Key Words: Beams, Spectrum analysis

The 2 to the N-1 power fold multiplicity of solutions found by Boley and Golub in their study of the inverse problem for $N \times N$ symmetric, pentadiagonal matrices contrasts with the unicity of the solution of the inverse problem for an inhomogeneous, discrete beam.

78-1777

Minimum Mass Structures with Specified Natural Frequencies

A. Miele
Aero-Astronautics Group, Rice Univ., Houston, TX,
Rept. No. AAM-WP-1, AFOSR-TR-78-0751, 27 pp
(1976)
AD-A053 727/4GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated numerically. The mass distribution that minimizes the total mass for a given fundamental frequency constraint is determined using both the sequential ordinary gradient-restoration algorithm (SOGRA) and an ad hoc modification of the modified quasilinearization algorithm (MQA).

78-1778

Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Miele, A. Mangiavacchi, B.P. Mohanty, and A.K. Wu
Aero-Astronautics Group, Rice Univ., Houston, TX,
Rept. No. AAR-138, AFOSR-TR-78-0723, 64 pp
(1977)
AD-A053 725/8GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated both analytically and numerically. The mass distribution that minimizes the total mass for a given value of the frequency parameter β is determined using both the sequential ordinary gradient-restoration algorithm (SOGRA) and the modified quasilinearization algorithm (MQA). Concerning the minimum value of the mass, SOGRA leads to a solution precise to at least 4 significant digits and MQA leads to a solution precise to at least 6 significant digits. Comparison of the optimal beam (a variable-section beam) with a reference beam (a constant-section beam) shows that the weight reduction depends strongly on the frequency parameter β .

78-1779

Some Qualitative Considerations on the Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Mangiavacchi and A. Miele
Aero-Astronautics Group, Rice Univ., Houston, TX,
Rept. No. AAM-WP-2, AFOSR-TR-78-0724, 17 pp
(1977)
AD-A053 726/6GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated analytically. The range of values of the frequency parameter having technical interest is determined.

78-1780

Traveling Loads on the Timoshenko Beam

P.J. Torvik
Air Force Inst. of Tech., Wright-Patterson AFB, OH,
Rept. No. AFIT-TR-78-2, 42 pp (Apr 1978)
AD-A054 628/3GA

Key Words: Beams, Timoshenko theory, Moving loads, Critical speeds

A transverse force traveling along an infinite string or a beam at critical values of constant velocity generates unbounded amplitudes, in the absence of dissipation. This resonance is analogous to the unbounded amplitudes generated by a stationary force oscillating at one of the natural frequencies. The response of a finite elementary beam to a moving force of constant amplitude can be determined in terms of the eigenfunctions of the beam. Modification of elementary beam theory to take into account the effects of rotatory inertia and shear leads to the Timoshenko beam theory, from which a new set of eigenvalues and eigenfunctions can be determined. These eigenfunctions can be shown to have an orthogonality relationship which, although unusual, permits the solution of initial value and non-homogeneous problems. The procedure for solving such problems is given, and applied to the problem of a traveling load on a finite Timoshenko beam with arbitrary end conditions. Results are obtained for the case of pinned ends, and compared with those from elementary theory.

78-1781

Vibration of an Elastic Beam Subjected to Discrete Moving Loads

M. Kurihara and T. Shimogo
Faculty of Engrg., Keio Univ., Yokohama, Japan,
J. Mech. Des., Trans. ASME, 100 (3), pp 514-519
(July 1978) 6 figs, 6 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Time-dependent excitation, Spectral energy distribution techniques

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads is neglected,

the time history, the power spectral density, and the various moments of the response are examined and the effects of the speed of moving loads upon the beam are made clear.

78-1782

Stability of a Simply-Supported Beam Subjected to Randomly Spaced Moving Loads

M. Kurihara and T. Shimogo

Faculty of Engrg., Keio Univ., Yokohama, Japan,
J. Mech. Des., Trans. ASME, 100 (3), pp 507-513
(July 1978) 7 figs, 7 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Inertial forces, Coriolis forces

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads is taken into account, the stability problem relating to the speed and the mass of loads is dealt with, considering the inertia force, the centrifugal force, and the Coriolis force of the moving loads. As an analytical result a stability chart of the mean-squared deflection was obtained for the moving speed and the moving masses.

78-1783

The Vibration Characteristics of a Beam with an Axial Force

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

Dept. of Mech. Engrg., Univ. College London, London WC1E 7JE, UK, J. Sound Vib., 59 (2), pp 237-244 (July 22, 1978) 2 figs, 4 refs

Key Words: Beams, Equations of motion, Timoshenko theory

Equations of motion are found for a non-uniform damped Timoshenko beam with a distributed axial force. Principal modes may be extracted by numerical means when the boundary conditions are specified, and the appropriate orthogonality conditions are given. The theory of linear forced vibration can thus be derived. It is an implicit requirement that all axial forces are conservative.

78-1784

Vibrations of Continuous Timoshenko Beams on Winkler-Pasternak Foundations

T.M. Wang and L.W. Gagnon

Dept. of Civil Engrg., Univ. of New Hampshire,

Durham, NH 03824, J. Sound Vib., 59 (2), pp 211-220 (July 22, 1978) 7 figs, 7 refs

Key Words: Beams, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects

The dynamic analysis of continuous Timoshenko beams on Winkler-Pasternak foundations by means of the general dynamic slope-deflection equations is presented. A three-span continuous beam on a Winkler-Pasternak foundation subjected to free and forced vibrations is used to illustrate the application of the proposed method and to show the effects of rotary inertia, transverse-shear deformation and foundation constants on the beam.

78-1785

Parametric Study of Free Vibration of Sagged Cables

M.L. Gambhir and B. deV. Batchelor

Queen's Univ. at Kingston, Ontario, Canada, Computers Struc., 8 (5), pp 641-648 (May 1978) 8 figs, 10 refs

Key Words: Cables (ropes), Natural frequencies, Mode shapes, Finite element technique, Parametric excitation

The finite element method is applied to the study of natural frequencies and modes of vibration of sagged cables. Extensional characteristics of the element are fully considered. The method is applied to a numerical example taken from the literature and which has previously been analyzed by classical and other methods. The results obtained by the use of a straight element are compared with those obtained by the use of curved elements. Finally, a parametric study is conducted to determine the influence of various parameters on the spectrum of natural frequencies of a sagged cable and appropriate nondimensional curves are presented. These non-dimensional curves give an insight into the general characteristics of the sagged cable, and can be used to predict in-plane natural frequencies over a wide range of sag/span ratio.

BEARINGS

(Also see Nos. 1751, 1767)

78-1786

Elastomeric Bearings Don't Slide or Roll

J.R. Potter

Lord Kinematics, Lord Corp., Erie, PA, Power Transm. Des., 20 (7), pp 38-40 (July 1978) 11 figs

Key Words: Elastomeric bearings

Elastomeric bearings serve well in oscillatory or reciprocating motion applications. They require no lubrication and the functions of several bearing types can often be combined in one bearing, thus simplifying a design. This article presents the various types of elastomeric bearings and their operating principles.

78-1787

Single-Row Sphericals: Less Bearing, Longer Life

J. Rader

Bearing Div., McGill Mfg. Co., Valparaiso, IN, Power Transm. Des., 20 (7), pp 35-37 (July 1978) 6 figs

Key Words: Roller bearings

Specialists in bearing technology have long recognized the performance advantages of single-row spherical roller bearings, which accommodate large shaft deflection and misalignment to $\pm 3^\circ$. The article discusses an application of single-row sphericals and two applications where one row was better than two.

BLADES

(Also see No. 1895)

78-1788

Vibration Characteristics of Hollow Symmetrical Blades Based on Thin Shell Theory

A.M. Al Jumaily and L.L. Faulkner

Dept. of Mech. Engrg., Ohio State Univ., Columbus, OH, J. Mech. Des., Trans. ASME, 100 (1), pp 183-187 (Jan 1978) 5 figs, 4 tables, 9 refs

Key Words: Turbomachinery blades, Blades, Shells, Natural frequencies

This paper presents the results of investigating the vibrational characteristics of a hollow symmetrical blade based on thin shell theory which allows closed function representation of vibrational characteristics which are inaccessible using beam theory. A modified shell theory is presented and used for the analysis. This technique is used to express the results in a continuous function analytical formation. The method presented is clearly for long hollow blades and does not require the computer storage of numerical methods. Comparison is made between the present technique, the beam theory, and experimental data for two laboratory models. The formulation can be extended to most types of blades and still retain the functional representation.

78-1789

Comparison of Some Optimal Control Methods for the Design of Turbine Blades

B.M.E. de Silva and G.N.C. Grant

Aircraft Aerodynamics Branch, Aerodynamics Div., Ames Res. Center, NASA, Moffett Field, CA, J. Mech. Des., Trans. ASME, 100 (1), pp 173-182 (Jan 1978) 2 figs, 3 tables, 48 refs

Key Words: Turbine blades, Structural synthesis, Optimization, Numerical methods, Timoshenko theory

This paper attempts a comparative study of some numerical methods for the optimal control design of turbine blades whose vibration characteristics are approximated by Timoshenko beam idealizations with shear and incorporating simple boundary conditions. The blade was synthesized using the following methods: conjugate gradient minimization of the system Hamiltonian in function space incorporating penalty function transformations, projection operator methods in a function space which includes the frequencies of vibration and the control function, ϵ -technique penalty function transformation resulting in a highly nonlinear programming problem, finite difference discretization of the state equations again resulting in a nonlinear program, second variation methods with complex state differential equations to include damping effects resulting in systems of inhomogeneous matrix Riccati equations some of which are stiff, and quasi-linear methods based on iterative linearization of the state and adjoint equation. The paper includes a discussion of some substantial computational difficulties encountered in the implementation of these techniques together with a resume of work presently in progress using a differential dynamic programming approach.

78-1790

Experimental Study on Blade Bending Vibration

T. Matsuura

Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/A-Turbo/TR-88; ISSN-0309-6521, 32 pp (1977)

N78-23090

Key Words: Compressor blades, Flexural vibration, Vibration prediction, Experimental data

Experiments were performed on the forced vibration of cascade blades due to the upstream periodic wakes. The resonance vibration amplitude and phase of the 1st bending mode were measured in a compressor rotor with the h/t ratio of 0.4. Smith's unsteady lift coefficients were used, and the mechanical damping of the blade was introduced to predict the resonance amplitude and phase. Reasonable agreement was seen between the measured results and the prediction.

78-1791

Aerodynamic Phenomena in an Oscillating Transonic MCA Airfoil Cascade Including Loading Effects

S. Fleeter and R.E. Riffel

Detroit Diesel Allison, Indianapolis, IN, In: AGARD Unsteady Aerodyn., 16 pp (Feb 1978)

N78-22066

Key Words: Fan blades, Aerodynamic response

The steady, quasi-steady, and unsteady aerodynamics were determined for a multiple circular arc (MCA) airfoil cascade which modeled the tip section of an advanced design fan blade. The steady airfoil surface aerodynamic performance of the cascade was measured at two levels of aerodynamic loading and correlated with the predictions from a time-marching, steady, transonic flow analysis. The chord-wise distribution of the quasi-static unsteady pressure coefficient for a 0 deg interblade phase angle was determined and correlated with two appropriate predictions: one based on the steady transonic analysis and the other on steady inviscid supersonic flat plate theory. Finally, the MCA cascade was harmonically oscillated in the torsional mode at a reduced frequency value of 0.14. The fundamental unsteady aerodynamic data was obtained at a Mach number equal to 1.55 over a range of interblade phase angles for two values of the cascade static pressure ratio. Results were correlated with the predictions from state-of-the-art unsteady flat plate cascade analyses.

78-1792

Dynamic Analysis of an Assembly of Shrouded Blades Using Component Modes

A.V. Srinivasan, S.R. Lionberger, and K.W. Brown
Commercial Products Div., Pratt & Whitney Aircraft,
United Technologies Corp., East Hartford, CT, J.
Mech. Des., Trans. ASME, 100 (3), pp 520-527
(July 1978) 11 figs, 3 tables, 9 refs

Key Words: Shrouds, Fan blades, Component mode synthesis, Vibration response

The problem of vibratory behavior of an assembly of shrouded fan blades is examined. The point of view that forms the basis for the analysis is that the vibration characteristics of an assembly of blades can be predicted from a knowledge of vibration characteristics of its components. Clearly, linear behavior is assumed. A viscous type of damping mechanism is included to account for any energy dissipation due to vibratory rubbing action at shroud interfaces. As the component modes are computed with a single blade and shroud modeled with plate elements, the extent of chord-wise motion in different modes is examined. Numerical results of an application of the analysis to a typical fan design are included.

78-1793

Synthesis of Blade Flutter Vibratory Patterns Using Stationary Transducers

A. Kurkov and J. Dicus

Lewis Res. Center, NASA, Cleveland, OH, ASME Paper No. 78-GT-160

Key Words: Blades, Flutter

Flutter frequency was determined and rotor vibratory amplitude and phase distributions during flutter were reconstructed from stationary aerodynamic type measurements. A previously reported optical method for measuring blade-tip displacements during flutter was extended by means of digital analysis. Displacement amplitudes and phase angles were determined based on this method. For selected blades, spectral results were also obtained from strain gage measurements. The results from these three types of measurement were compared and critically evaluated.

78-1794

Vibrations of Cambered Helicoidal Fan Blades

K.P. Walker

Pratt & Whitney Aircraft, East Hartford, CT 06108,
J. Sound Vib., 59 (1), pp 35-57 (July 8, 1978)
9 figs, 12 tables, 30 refs

Key Words: Fans, Blades, Shells, Natural frequencies, Mode shapes, Transverse shear deformation effects, Rotatory inertia effects

A conforming finite shell element suitable for the analysis of curved twisted fan blades is developed and applied to a number of fan blade models. The element is assumed to be a doubly curved right helicoidal shell, in which the curvature is shallow with respect to the twisted base plane defining the helicoid. Element stiffness and mass formulations are based on Mindlin's theory and include the effects of transverse shear and rotary inertia. The thick shell element has 64 generalized co-ordinates, and by deleting transverse shear effects, a thin shell version of the element having 40 generalized co-ordinates is obtained. The thin shell element is used to predict the natural frequencies and mode shapes of a number of fabricated fan blade structures and the results are correlated with experiment.

CONTROLS

78-1795

An Analysis of the Three-Way Underlapped Hydraulic Spool Servovalve

C.K. Taft and J.P. Twill

Dept. of Mech. Engrg., Univ. of New Hampshire, Durham, NH, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 117-123 (June 1978) 11 figs, 11 refs

Key Words: Hydraulic servomechanisms, Valves, Fluid-induced excitation, Mathematical models

A flow model of a three-way underlapped hydraulic servo-valve is presented and used to derive a mathematical description of the flow momentum forces acting on the valve spool. The effect of these forces on valve performance is investigated by examining both the linearized system differential equations and digital computer solutions of the system nonlinear differential equations, and by experimental measurements. A three-dimensional phase space is used to display computer simulation results. Because of the oscillatory nature of system response, projections on a plane illustrate system dynamic response forms. The effects of system parameters on system stability are discussed.

CYLINDERS

78-1796

Dynamic Response of a Geometrically Nonlinear Elastic/Viscoelastic Cylinder

A.J.K. Neighbors

Ph.D. Thesis, The Univ. of Alabama, 173 pp (1977)
UM 7809870

Key Words: Cylinders, Composite structures, Viscoelastic-core containing media, Impact response

This work is concerned with the dynamic analysis of an infinitely long circular composite cylinder with a viscoelastic core and a thin elastic case. The thin elastic case serves as the principal load carrying structure while the viscoelastic core contributes mass and damping effects to the dynamic behavior. The cylinder is subjected to a uniform internal static pressure and an externally distributed impulse load.

78-1797

Shock Induced Structural Response

J.G. Gallo

Naval Postgraduate School, Monterey, CA, 58 pp (Mar 1978)
AD-A053 877/7GA

Key Words: Cylinders, Submerged structures, Interaction: structure-fluid, Shock response

An infinitely long, ring-stiffened, submerged, elastic cylinder having uniformly spaced elastic bulkheads is considered. Loading is applied by a plane acoustic shock wave with front parallel to the cylinder axis. Dynamic pressure in the fluid is resolved into a free-field incident part and a scattered part. Structural response and scattered pressure in the surrounding fluid are found using finite element modeling of structure and fluid. Introduction of Fourier series makes the fluid region mathematically two-dimensional. A radiation, or nonreflecting, condition at the outer boundary of the fluid region is shown to give good results. A parametric study is made of effects of shock pulse rise time and duration on structural response. Results are presented as combinations of shock pressure and submergence pressure just sufficient to induce structural failure.

DUCTS

(Also see Nos. 1735, 1767)

78-1798

High Frequency Sound Attenuation in Short Flow Ducts

J.W. Posey

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-78708, 25 pp (May 1978)
N78-23876

Key Words: Ducts, Sound attenuation, High frequencies, Acoustic linings

A geometrical acoustics approach is proposed as a practical design tool for absorbent liners in such short flow ducts as may be found in turbofan engine nacelles. As an example, a detailed methodology is presented for three different types of sources in a parallel plate duct containing uniform ambient flow. A plane wave whose wavefronts are not normal to the duct walls, an arbitrarily located point source, and a spatially harmonic line source are each considered. Optimal wall admittance distributions are found, and it is shown how to estimate the insertion loss for any admittance distribution.

FRAMES, ARCHES

78-1799

Computer-Aided Optimum Seismic Design of Ductile Reinforced Concrete Moment-Resisting Frames

S.W. Zagajeski and V.V. Bertero

Earthquake Engrg. Res. Center, California Univ., Richmond, CA, Rept. No. UCB/EERC-77/16, 146 pp (Dec 1977)
PB-280 137/1GA

Key Words: Seismic design, Computer-aided techniques, Framed structures, Multistory buildings, Concrete

A computer-aided design procedure based on limit state design concepts is proposed for multistory reinforced concrete frames of buildings which are expected to experience severe earthquake ground shaking during their service life. In this procedure a structure is designed to meet various serviceability criteria under service loading conditions, damage limitations for abnormal environmental conditions, and safety requirements for extreme earthquake excitations. The design procedure, which makes use of computer optimization methods as well as static and dynamic elastic and nonlinear analysis procedures, consists in five basic steps which are grouped into a preliminary design phase and a final design phase.

78-1800

Spatial Symmetrical Vibrations and Stability of Circular Arches with Flexibly Supported Ends

Y. Wasserman

Dept. of Mech. Engrg., Ben Gurion Univ. of the Negev, Beersheva, Israel, *J. Sound Vib.*, **59** (2), pp 181-194 (July 22, 1978) 7 figs, 3 tables, 10 refs

Key Words: Arches, Fundamental frequencies

In this work, exact formulae have been obtained for determining the lowest natural frequencies and critical loads of elastic circular arches with flexibly supported ends for symmetrical vibration in the direction perpendicular to the initial curvature of the arch. This investigation is concerned with three cases of load behavior during the process of deformation. The values of the frequencies and critical loads are shown to be dependent on the opening angle of the arch, on the stiffness of the flexibly supported ends and on the ratio of the flexural rigidity to the torsional rigidity of the arch cross-section.

GEARS

78-1801

Simulation of Resonances and Instability Conditions in Pinion-Gear Systems

M. Benton and A. Seireg

Dept. of Mech. Engrg., Univ. of Wisconsin, Madison, WI, *J. Mech. Des.*, *Trans. ASME*, **100** (1), pp 26-32 (Jan 1978) 9 figs, 16 refs

Key Words: Gears, Periodic excitation, Periodic response, Stiffness, Computerized simulation

This paper describes a computer simulation procedure based on the phase-plane method for predicting the steady-state response, resonances and instabilities of pinion-gear systems subjected to sinusoidal excitation. An experimental technique is also presented which is capable of checking the accuracy of the simulation under different operating conditions. The experimental set-up which utilizes a shaker for producing variations of mesh stiffness without complete rotation of the gear pair provides a relatively simple and convenient means for investigating this class of problems.

78-1802

Stress Condition, Vibrational Exciting Force, and Contact Pattern of Helical Gears with Manufacturing and Alignment Error

A. Kubo

Kyoto Inst. of Tech., Matsugasaki, Kyoto, Japan, *J. Mech. Des.*, *Trans. ASME*, **100** (1), pp 77-84 (Jan 1978) 9 figs, 12 refs

Key Words: Helical gears, Spur gears, Gears, Geometric imperfection effects

The general method for calculation of load sharing to every tooth pair in meshing, load distribution, and contact pattern on tooth flank of helical gears with manufacturing and alignment error is shown, for which some parts of tooth flanks on the geometrical line of contact can separate from each other due to the errors. For such gears, stiffness of meshing tooth pair, exciting force of gear vibration, and total composite error (single flank) under loaded condition is derived. Using this calculating method, tooth stiffness, vibration excitation, tooth fillet stress, and contact pattern are calculated for some helical and spur gears, and they are compared with measured results.

78-1803

Dynamic Tooth Loads and Stressing for High Contact Ratio Spur Gears

R.W. Cornell and W.W. Westervelt

Hamilton Standard, Div. of United Technologies Corp., Windsor Locks, CT, *J. Mech. Des.*, *Trans. ASME*, **100** (1), pp 69-76 (Jan 1978) 13 figs, 2 tables, 10 refs

Key Words: Spur gears, Mathematical models, Computer programs

A time history, closed form solution is presented for a dynamic model of spur gear systems for all practical contact ratios. The analysis determines the dynamic response of the gear system and the associated tooth loads and stressing. The dynamic model is based on work done by Richardson

and Howland and assumes the two gears act as a rigid inertia and the teeth act as a variable spring of a dynamic system excited by the meshing action of the teeth. Included in the analysis are the effects of the nonlinearity of the tooth pair stiffness during mesh, the tooth errors, and the tooth profile modifications. Besides reviewing the features, solution, and program of this analysis, preliminary results from applying the analysis are presented, which show that tooth profile modification, system inertia and damping, and system critical speeds can affect the dynamic gear tooth loads and stressing significantly.

78-1804

Design Synthesis of a Multi-Speed Machine Tool Gear Transmission Using Multiparameter Optimization

M.O.M. Osman, S. Sankar, and R.V. Dukkipati
Concordia Univ., Montreal, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 303-310 (Apr 1978) 12 figs, 2 tables, 6 refs

Key Words: Power transmission systems, Gear drives, Machine tools, Structural synthesis, Optimization

This paper presents a novel method for the design synthesis of a multi-speed machine tool gear drive using a multiparameter optimization technique. The method eliminates any complex and tedious algebraic analysis normally required in gear train designs. It requires only the formulation of mesh and speed ratio equations from the geometrical arrangement of the gear drive and the selection of a suitable optimization criterion and constraints.

LINKAGES

78-1805

An Experimental and Analytical Study of Impact Forces in Elastic Mechanical Systems with Clearances

S. Dubowsky and M.F. Moening
Univ. of California, Los Angeles, CA 90024, Mech. Mach. Theory, 13 (4), pp 451-465 (1978) 14 figs, 1 table, 25 refs

Key Words: Joints (junctions), Impact response

Important performance limitations in mechanical systems result from correction clearances which cause rapid wear, and increased noise and vibration. Relatively little experimental investigation has been performed in this area, although a number of analytical studies have been carried out. Recent studies of the latter kind show the effect of clearances is

to amplify, greatly, connection forces, and that the introduction of link flexibility tends to reduce these impact forces significantly. This study shows experimentally the validity of the analytical studies and the mitigating effects of link flexibility on impact forces.

78-1806

Dynamics of High-Speed Linkages with Elastic Members

A. Midha
Ph.D. Thesis, Univ. of Minnesota, 167 pp (1977)
UM 7809704

Key Words: Linkages, Periodic response, Transient response

A great deal of attention has been given to the areas of analysis and synthesis of linkages with elastic members within the past fifteen years. Recently, kinematicians have turned to the use of structural dynamics analysis techniques for ease in handling complex linkage systems on computers. With a very few exceptions, little attention has been given to the economy of the computational methods. In this dissertation, after developing the equations of motion for a representative four-bar crank-rocker linkage, two computationally efficient numerical methods are generated. One method computes directly the periodic response, while the other is adaptable to the transient response analysis of the high-speed linkage.

MECHANICAL

78-1807

Sensitivity Analysis and Optimal Design of a Mechanical System with Intermittent Motion

R.C. Huang, E.J. Haug, Jr., and J.G. Andrews
Div. of Materials Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (3), pp 492-499 (July 1978) 6 figs, 1 table, 11 refs

Key Words: Intermittent motion, Weapons systems, Optimization, Steepest descent method

In this paper, a specific weapon recoil mechanism is treated in order to illustrate the problem class, to allow for development of a method of solution, and to provide a practical test of the method. A steepest descent optimization method, developed for mechanical design applications is employed to solve illustrative optimal design problems. Generalizations of the method will be treated in a future paper.

78-1808

Evaluation of Mutual Radiation Impedances Between Circular Pistons by Impulse Response and Asymptotic Methods

P.R. Stepanishen

Dept. of Ocean Engrg., Univ. of Rhode Island, Kingston, RI 02881, J. Sound Vib., 59 (2), pp 221-235 (July 22, 1978) 7 figs, 1 table, 14 refs

Key Words: Pistons, Impact response (mechanical)

A general approach is presented to evaluate the mutual radiation impedance between circular pistons of arbitrary size and spacing in an infinite rigid planar baffle. The impedance is expressed as a Fourier transform of a generalized impulse response which is defined by an integral relationship. Although the integral must, in general, be numerically evaluated, several special cases of interest can readily be evaluated by using asymptotic techniques. Several asymptotic expressions for the mutual radiation impedance are developed and their limitations are noted. Numerical results are then presented for the generalized impulse response and mutual radiation impedance corresponding to pistons of equal size and arbitrary spacing.

PIPES AND TUBES

78-1809

Forced Vibration of Continuous System with Nonlinear Boundary Conditions

T. Watanabe

Faculty of Education, Yamanashi Univ., Kofu, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 487-491 (July 1978) 6 figs, 13 refs

Key Words: Piping, Nuclear reactor components, Forced vibration, Continuous beams

This paper deals with the nonlinear vibration problem concerning mechanical equipment-piping systems in nuclear power plants and others. An analytical method by approximate solutions is introduced for these systems as a continuous system with nonlinear boundary conditions, and some numerical examples are shown. Finally some numerical results obtained as a continuous system are compared with those of a single-degree-of-freedom system.

78-1810

Cross-Flow Induced Vibrations in a Tube Bank - Vortex Shedding

L.K. Grover and D.S. Weaver

Dept. of Mech. Engrg., Rochester Inst. of Tech., Rochester, NY, J. Sound Vib., 59 (2), pp 263-276 (July 22, 1978) 9 figs, 1 table, 16 refs

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

An experimental wind-tunnel facility which was developed specifically to study cross-flow induced vibrations in heat exchanger tube banks is described. Nineteen tubes in the center of the closely packed array were flexibly mounted in order that their response and interaction with the flow could be studied. The surrounding 116 tubes were fixed and could be easily removed to study the effect of tube bundle size on flow phenomena and tube response. Results are presented in this paper for vortex shedding.

78-1811

Cross-Flow Induced Vibrations in a Tube Bank -- Turbulent Buffeting and Fluid Elastic Instability

D.S. Weaver and L.K. Grover

Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 59 (2), pp 277-294 (July 22, 1978) 14 figs, 21 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Turbulence

Experimental results are reported for a wind tunnel study of cross-flow induced vibrations in a tube bank. The rotated triangular array had a pitch ratio of 1.375 and consisted of 19 flexibly mounted tubes surrounded by 116 rigid, removable tubes. The natural frequency and damping of the flexibly mounted tubes could be carefully controlled. Details of the experimental facility and the vortex shedding behavior of the tube bank were reported in the first of these two companion papers. The turbulent buffeting and fluid elastic response are treated in this second paper. The effects on the fluid elastic threshold of the motion of surrounding tubes, damping and number of upstream rows of tubes are discussed.

78-1812

Dispersive Effects in Wave Propagation in Thin-Walled Elastic Tubes

T.B. Moodie and J.B. Haddow

Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada T6G 2E1, J. Acoust. Soc. Amer., 64 (2), pp 522-528 (Aug 1978) 12 figs, 5 refs

Key Words: Elastic waves, Wave propagation, Tubes, Elastomers, Fluid-induced excitation

A simple procedure, based on Love's approximate theory [The Mathematical Theory of Elasticity (Cambridge U.P., Cambridge, England, 1927), 4th ed.] for wave propagation in a bar, is proposed in order to consider dispersive effects in wave propagation in a thin-walled, fluid-filled, elastomer tube. It is assumed that the perturbation from steady flow in the tube is small enough that a linearized theory is valid, and that the elastic modulus of the tube is small compared with the bulk modulus of the fluid so that compressibility of the fluid can be neglected. The flexural rigidity of the tube wall, the inertia of the tube wall, and the radial inertia of the fluid are taken into account, and an approximate expression for the dispersion relation for the fundamental mode is obtained.

78-1813

Experiments on Fluidelastic Vibration of Cantilevered Tube Bundles

S.S. Chen and J.A. Jendrzejczyk

Components Tech. Div., Argonne National Lab., Argonne, IL, J. Mech. Des., Trans. ASME, 100 (3), pp 540-548 (July 1978) 9 figs, 6 tables, 3 refs

Key Words: Tubes, Fluid-induced excitation, Interaction: structure-fluid, Coupled response, Periodic response, Natural frequencies, Mode shapes

This paper presents the results of three series of experiments on coupled tube/fluid vibration. Natural frequencies and mode shapes of coupled modes as well as steady-state responses are measured for each tube bundle. An analysis is also made for each test. Experimental data and analytical predictions are found to be in good agreement.

78-1814

Torsional Oscillations of an Infinite Cylindrical Elastic Tube Under Large Internal and External Pressure

H. Engin and E.S. Suhubi

Tech. Univ. of Istanbul, Turkey, Intl. J. Engr. Sci., 16 (6), pp 387-396 (1978) 1 fig, 2 tables, 10 refs

Key Words: Tubes, Elastomers, Torsional vibration

This study is concerned with the small amplitude torsional oscillations of a hyperelastic infinite circular cylindrical thick tube made of a rubber-like material subjected to a large static internal and external pressure. The material is represented by a Mooney-type strain energy relation. The governing differential equation is first solved by the Frobenius method, then a variational approach, which is more suitable for numerical calculations, is developed. Several values for the natural frequencies are obtained.

78-1815

Cure Exchanger Acoustic Vibration

E.A. Barrington

Shell Oil Co., Houston, TX, Hydrocarbon Processing, 57 (7), pp 193-200 (July 1978) 10 figs, 2 tables, 9 refs

Key Words: Heat exchangers, Tubes, Acoustic resonance

Shell side acoustic vibrations can occur in tubular exchangers. Flow phenomena can generate unacceptably loud noise and potentially destructive pressure fluctuations due to the acoustic characteristics of the tubular heat exchanger. Such effects have been particularly noted in exchangers with natural gas, hydrogen-rich vapor, nitrogen gas or flue gas on the shell side. Trends in current design towards larger diameter tubulars and higher fluid velocities increase the likelihood of severe problems due to acoustic resonance. The occurrence of acoustic resonance is predicted and it is shown how to avoid the problem by proper design features.

PLATES AND SHELLS

(Also see Nos. 1707, 1731, 1788)

78-1816

Non-Linear Resonances in the Forced Responses of Plates. Part II: Asymmetric Responses of Circular Plates

S. Sridhar, D.T. Mook, and A.H. Nayfeh

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 59 (2), pp 159-170 (July 22, 1978) 9 refs

Key Words: Circular plates, Harmonic excitation, Nonlinear response, Perturbation theory

The dynamic analogue of the von Karman equations is used to study the forced response, including asymmetric vibrations and traveling waves, of a clamped circular plate subjected to harmonic excitations when the frequency of excitation is near one of the natural frequencies. The method of multiple scales, a perturbation technique, is used to solve the non-linear governing equations. The approach presented provides a great deal of insight into the nature of the non-linear forced resonant response.

78-1817

Vibration of Circular Double-Plate Systems

A.S.J. Swamidas and V.X. Kunukkasseril

Dept. of Appl. Mechanics, Indian Inst. of Tech.,

Madras 600 036, India, J. Acoust. Soc. Amer., 63 (6), pp 1832-1840 (June 1978) 12 figs, 7 refs

Key Words: Circular plates, Composite structures, Vibration response

Vibrational characteristics of circular double-plate systems connected together by concentric, intermediate, elastic ring supports have been considered in this work. The analysis is based on the assumption that both of the plates are thin, elastic, and isotropic. Also, the plates are subjected to initial in-plane loads. The solutions are shown to be in terms of Bessel functions for the case of complete and annular (with equal in-plane loads) circular isotropic plate systems. The vibrational characteristics of the systems are illustrated by presenting numerical results for isotropic plate systems with one intermediate connection. When both the plates are identical with identical edge forces and boundary conditions, in-phase and out-of-phase vibration modes are observed.

78-1818

Acoustic Reflection from a Thick Plate with One Reinforcing Rib. Exact Integral Evaluation is Proved Superior to Integral Approximation in Analysis of Acoustic Reflections from a Timoshenko-Mindlin Plate Reinforced with One Rib

B.L. Woolley

Naval Ocean Systems Center, San Diego, CA, Rept. No. NOSC/TR-176, 198 pp (Dec 1977)
AD-A054 610/1GA

Key Words: Plates, Acoustic reflection, Timoshenko theory, Mindlin theory, Computer programs

The reflection of a plane sound wave from a thick, i.e., Timoshenko-Mindlin, fluid-loaded elastic plate reinforced with a stiffness member is investigated. The case is first solved without using integral approximation techniques. This solution gives relatively lower returns than those given by integral approximation techniques. The solution is also found by an integral approximation technique and then by an integral approximation technique taking into account leaky wave poles. The results of numerical calculations are presented and reviewed. Computer programs are given to carry out the calculations.

78-1819

Vibration Statistics of Thin Plates with Complex Form

A. Waberski

Silesian Technical Univ., Gliwice, Poland, AIAA J., 16 (8), pp 788-794 (Aug 1978) 10 figs, 20 refs

Key Words: Probability theory, Plates

A new mathematical method of calculation of the probabilistic characteristics of mechanical systems with complex geometry is presented. This method has been demonstrated on the example of random vibrating plates. This method is based on the application of certain special functions called R functions. In order to demonstrate this method, numerical calculations are presented of probabilistic characteristics for plates with complex geometry which have been clamped on the edge.

78-1820

A General Model for the Calculation of Thick Plates (And Rods)

G. Kumbetlian

Marine Institute, Constanta, Rumania, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (2), pp 249-262 (Mar/Apr 1978) 4 refs

Key Words: Plates, Rods, Harmonic excitation

This paper presents a general theoretical model for the calculation of thick plates (and rods) under biharmonic loads, which satisfies the large majority of loads occurring in practice.

78-1821

Design of Clamped Composite-Material Plates to Maximize Fundamental Frequency

C.W. Bert

School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK, J. Mech. Des., Trans. ASME, 100 (2), pp 274-278 (Apr 1978) 1 fig, 6 tables, 23 refs

Key Words: Rectangular plates, Composite materials, Fundamental frequency, Optimum design, Optimization

Methodology and equations are developed for maximizing the fundamental frequency (ω_f) of small-amplitude, free flexural vibration of a clamped, rectangular plate consisting of multiple, equal-thickness layers of the same unidirectional filamentary composite material. The synthesis is based on a concise, explicit equation for ω_f in terms of plate dimensions, density, and the anisotropic flexural and torsional rigidities. The equation is developed in the paper and shown to be quite accurate.

78-1822

Buckling and Vibration of In-Plane Loaded Plates

Treated by a Unified Ritz Approach

S.F. Bassily

Teledyne Systems Co., Northridge, CA., J. Sound Vib., 59 (1), pp 1-14 (July 8, 1978) 7 figs, 2 tables, 6 refs

Key Words: Rectangular plates, Flexural vibration, Buckling, Ritz method

The problem of the buckling and lateral vibration of rectangular plates subject to in-plane loads is treated by using a Ritz approach for both the determination of the middle surface stresses caused by the in-plane loading and the analysis of the consequent out-of-plane buckling and vibrational characteristics of the plates. Since the stress function formulation of the middle surface stress problem is formally analogous to the plate bending problem, the same type of admissible functions -- ordinary and degenerated beam vibration mode shapes -- are employed in the Ritz series for both parts of the problem. The approach permits the accurate treatment of plates subject to real in-plane loads, where the middle surface stresses may not be realistically representable by simple polynomials as has been assumed in earlier studies. Several numerical examples are presented, illustrating the applicability of the approach and giving an indication of the order of errors that may result in the determination of the out-of-plane characteristics of plates when using simplifying assumptions for the in-plane stress field.

78-1823

Vibration of the Elastic Cylindrical Shells (Zur Schwingung des elastischen Hohlzylinders)

U. Gerner

I. Institut f. Mechanik der Technischen Universität Wien, Vienna, Austria, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (1), pp 53-60 (Jan/Feb 1978) 2 tables, 15 refs
(In German)

Key Words: Tubes, Cylindrical shells, Vibration response, Amplitude

The cylindrically symmetric vibration of an incompressible elastic tube is investigated. A phase curve is derived by means of the law of conservation of energy. Potential energy is calculated for two types of materials: the Mooney material and the modified Mooney material. A phase diagram is presented for a vibration of Mooney material. Then the dependence of vibration duration on the amplitude is investigated.

78-1824

Torsional Vibrations of Pretwisted Cantilever Plates

K. Gupta and J.S. Rao

Indian Inst. of Tech., New Delhi, India, J. Mech. Des., Trans. ASME, 100 (3), pp 528-534 (July 1978) 7 figs, 6 tables, 12 refs

Key Words: Shells, Plates, Cantilever plates, Torsional vibration

A pretwisted cantilever plate is treated as a thin shallow shell. Its potential and kinetic energies in torsional vibration are determined by assuming an appropriate displacement field. Applying Hamilton's principle, the problem is reduced to a fourth-order ordinary differential equation with constant coefficients, which is solved to obtain the first four torsional frequencies of vibration. Plates of aspect ratios varying from 1.0 to 8.0 are analyzed with pretwist angles varying from 0 to 90 deg. Results of the present analysis are compared with existing theoretical and experimental results.

78-1825

Dynamics of Shells of Revolution Under Axisymmetric Load Involving Shear Deformation

Y. Tene and I. Sheinman

Faculty of Civil Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Computers Struct., 8 (5), pp 563-568 (May 1978) 11 figs, 7 refs

Key Words: Shells of revolution, Transverse shear deformation effects, Rotatory inertia effects, Finite difference theory

A general solution procedure, based on the linear theory, is presented for arbitrary shells of revolution subjected to arbitrary axisymmetric dynamic loads. The equations of motion admit shear deformation and rotational inertia. The numerical solution is obtained by Houbolt's method and by finite differences.

78-1826

Vibration and Buckling of Fluid-Filled Cylindrical Shells Under Torsion

J. Tani and H. Doki

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, Nucl. Engr. Des., 48 (2/3), pp 359-365 (Aug 1978) 5 figs, 12 refs

Key Words: Cylindrical shells, Fluid-filled containers, Torsional excitation, Free vibration

On the basis of the Donnell-type equations modified with the transverse inertia force, the free vibration and the buckling of fluid-filled circular cylindrical shells under torsion are theoretically analyzed by using Galerkin's method. The fluid is assumed to be incompressible, irrotational and

inviscid. Calculations are carried out for a simply-supported typical shell. It is found that the natural frequency of the shell under torsion decreases rapidly with the internal fluid, but the buckling load of the fluid-filled shell agrees precisely with that of the empty one.

78-1827

Studies on the Failure of Stiffened Cylindrical Shells Subjected to Dynamic Loads

C.A. Ross, R.L. Sierakowski, I.K. Ebcioğlu, C.C. Schauble, and C.F. Yen

Graduate Engrg. Center., Florida Univ., Eglin AFB, FL, Rept. No. AFOSR-TR-78-0697, 249 pp (Dec 31, 1977)

AD-A053 954/4GA

Key Words: Cylindrical shells, Stiffened shells, Blast effects, Energy methods

The major objective of this study was to investigate the effects of axial stiffening of cylindrical shells subject to transverse blast loadings. Two existing methods for predicting dynamic response of cylindrical shells were modified to include axial stiffening. A semi-analytical energy method was chosen as a first cut design predictor and tables of normalized deflection versus external energy imparted to the structure are presented. In addition a more detailed analytical energy method was modified to include axial stiffening. In both cases the stiffeners were introduced by simply adding terms to the kinetic and potential energy terms of the basic shell equations rather than introducing membrane-bending coupling by use of more complicated anisotropic constitutive relations.

STRUCTURAL

78-1828

Travelling-Wave-Induced Instability of Structures

M. Farshad and I. Tadjbakhsh

School of Engrg., Pahlavi Univ., Shiraz, Iran, J. Franklin Inst., 305 (6), pp 343-350 (1978) 2 figs, 11 refs

Key Words: Seismic excitation, Ground motion, Structural members, Dynamic stability

The effect of transmission time of propagating disturbances on the dynamic instability of structures is discussed in this paper. Through a parametric study it is shown that for certain values of transmission time and wave frequency parameters, the structure may become dynamically unstable. An example is worked out, and graphical results depicting

the regions of instability are presented.

78-1829

Transient Response of Continuous Viscoelastic Structural Members

W.D. Pilkey and J.S. Strenkowski

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525303/MAE-78/102, 33 pp (Mar 1978)

AD-A054 255/5GA

Key Words: Structural members, Viscoelastic media, Modal analysis, Beams, Plates

A comprehensive theory for the dynamic response of linear continuous viscoelastic structural members is formulated with a modal analysis. The constitutive relation is in the form of a hereditary integral. A general set of formulas is derived that may be used for both non-self-adjoint and self-adjoint systems of governing equations of motion. Applications include a Voigt-Kelvin beam and a viscoelastic circular plate.

78-1830

Transient Analysis of Structural Members by the CSDT Riccati Transfer Matrix Method

W.D. Pilkey and F.H. Chu

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525-303/MAE78/103, 38 pp (Mar 1978)

AD-A054 256/3GA

Key Words: Structural members, Numerical analysis, Transient response, Transfer matrix method, Bars, Beams

A method for direct integration of the dynamic governing partial differential equations of motion for structural members is presented. This technique is called the continuous space discrete time (CSDT) Riccati transfer matrix method. Numerical results for bar and beam example problems indicate that the method is numerically stable and accurate for calculating the dynamic response of linear structural members.

78-1831

Optimum Design of Bridge Girders for Electric Overhead Traveling Cranes

S.S. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kanpur-16, India., J. Engr. Indus., Trans. ASME, 100 (3),

pp 375-382 (Aug 1978) 4 figs, 5 tables, 18 refs

Key Words: Girders, Overhead cranes, Shock absorption, Design techniques

The problem of the design of box-type bridge girders for electric overhead traveling cranes is formulated as a minimum weight design problem with inequality constraints. The restrictions placed on the design problem include limitations on the maximum allowable deflections and stresses as well as on the shock absorbing capacity during accidental collision. The overall stability and rigidity considerations are also taken into account. Several load conditions, as per the code specifications, are considered in the design problem. The resulting nonlinear programming problem is solved by using an interior penalty function method. Numerical examples are given to illustrate the effectiveness of the approach. The resulting computer program is used to make a sensitivity analysis of the problem.

78-1832

How to Design Walls for Desired STC Ratings

R.E. Jones

Forest Products Lab., Forest Service, U.S. Dept. of Agriculture, S/V, Sound Vib., 12 (8), pp 14-17 (Aug 1978) 4 figs, 1 table, 2 refs

Key Words: Walls, Noise barriers, Sound transmission loss

Sound Transmission Class STC values typical of several common wall systems are presented to illustrate a range of STC performance from about 35 to 65. The effectiveness of single-panel and double-panel designs is contrasted and a technique for calculating the transmission loss below the coincidence frequency is summarized.

78-1833

Effect of Sound-Absorptive Facings on Partition Airborne-Sound Transmission Loss

S.M. Brown, J. Niedzielski, and G.R. Spalding
Res. and Dev. Center, Armstrong Cork Co., Lancaster, PA 17604, J. Acoust. Soc. Amer., 63 (6), pp 1851-1856 (June 1978) 5 figs, 2 tables, 12 refs

Key Words: Sound transmission loss, Walls, Coatings

Laboratory measurements of the improvement of partition airborne-sound transmission loss in the presence of sound-absorptive partition facings are presented. For a double-leaf partition of 1/2-in.-thick gypsum board on 2 X 4-in. studs, the application of such facings has led to improve-

ments in transmission loss in excess of 10 dB in the 1/3-octave bands above 1 kHz. Corresponding, but smaller, improvements have been measured at lower frequencies.

78-1834

The Riccati Transfer Matrix Method

G.C. Horner and W.D. Pilkey

Mechanical Technology Inc., Latham, NY, J. Mech. Des., Trans. ASME, 100 (2), pp 297-302 (Apr 1978) 1 fig, 4 tables, 18 refs

Key Words: Transfer matrix method, Structural members, Shafts, Rotors

The Riccati transfer matrix method is a new technique for analyzing structural members. This new technique makes use of an existing large catalog of transfer matrices for various structural members such as rotating shafts. The numerical instability encountered when calculating high resonant frequencies, static response of a flexible member on a stiff foundation, or the response of a long member by the transfer matrix method is eliminated by the Riccati transfer matrix method. The computational time and storage requirements of the Riccati transfer matrix method are about half the values for the transfer matrix method. A rotating shaft analysis demonstrates the numerical accuracy of the method.

TIRES

78-1835

Improved Tire/Wheel Concept

P.M. Harper, Sr.

Langley Res. Center, NASA, Langley Station, VA., Rept. No. N78-22374/0, NASA-CASE-LAR-11695-1, 12 pp (Apr 6, 1978)

Sponsored by NASA

PAT-APPL-SN-893 865/GA

Key Words: Aircraft tires, Vehicle wheels, Wheels

A tire and wheel assembly is described in which a low profile pneumatic tire has sidewalls which deflect inwardly under load and a wheel has a rim featuring a narrow central channel and extended rim flanges from the combination. The extended rim flanges support the tire sidewalls under static and dynamic loading conditions to produce a combination particularly suited to aircraft applications.

SYSTEMS

ABSORBER

78-1836

Alternative Tuned Absorbers for Steady State Vibration Control of Tall Structures

R.L. Jenniges and D.A. Frohrib

Dept. of Mech. Engrg., The Design Center, Univ. of Minnesota, Minneapolis, MN, J. Mech. Des., Trans. ASME, 100 (2), pp 279-285 (Apr 1978) 13 figs, 6 refs

Key Words: Tuned dampers, Vibration absorbers (equipment), Multistory buildings, Periodic response, Flexural vibration, Torsional vibration

Two forms of damped vibration absorbers are evaluated to describe their value in reducing steady state vibration of tall buildings. The first model contains a set of two identical one-degree-of-freedom elements symmetrically mounted in a horizontal plane on either side of the building's long axis. An alternate model has independent translational and torsional elements mounted at the building's center. Damping parameters are included for building fundamental bending and torsion modes to evaluate those effects on response. The sensitivity of absorber performance to absorber-building mass ratio μ is of interest to minimize the size of the absorber. Performance of the absorber models was compared based on maximum transmissibility and a quality integral, which is an integrated transmissibility over a frequency spectrum based on amplification at a point on the building top.

78-1837

Response Spectra Design Methods for Tuned Equipment-Structure Systems

J.M. Kelly and J.L. Sackman

Dept. of Civil Engrg., Univ. of California, Berkeley, CA 94720, J. Sound Vib., 59 (2), pp 171-179 (July 22, 1978) 2 figs, 8 refs

Sponsored by the Defense Nuclear Agency

Key Words: Equipment response, Equipment mounts, Tuned damping, Response spectra, Design techniques

A description is given of a design method that allows response spectra to be used to estimate maximum displace-

ments and accelerations in equipment-structure systems. The type of system considered involves light equipment tuned to a natural frequency of the structure. The solution is developed by using transform methods, residue theory and asymptotic analysis. A very simple result is obtained which should be of value to designers of equipment, equipment mountings and non-structural components in structures subject to dynamic loading. The simple nature of the result is explained by a direct physical interpretation of the response.

78-1838

The Steady State Response of Systems with Hardening Hysteresis

R.K. Miller

Dept. of Mech. and Environmental Engrg., Univ. of California, Santa Barbara, CA., J. Mech. Des., Trans. ASME, 100 (1), pp 193-198 (Jan 1978) 6 figs, 9 refs

Key Words: Periodic response, Hysteretic damping, Viscous damping, Single degree of freedom systems, Multi degree of freedom systems

A physical model for hardening hysteresis is presented. An approximate analytical technique is used to determine the steady-state response of a single-degree-of-freedom system and a multi-degree-of-freedom system incorporating this model. Certain critical model parameters which determine the general nature of the responses are identified.

78-1839

Analysis of Performance of Pneumatic Impact Absorbers

M.S. Hundal

Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT, J. Mech. Des., Trans. ASME, 100 (2), pp 236-241 (Apr 1978) 4 figs, 7 tables, 5 refs

Key Words: Absorbers, Pneumatic dampers

Performance of impact absorbers employing a pneumatic damper and a linear spring in parallel is analyzed. The governing nonlinear differential equations are derived and converted to nondimensional form. For the case of a damper with fixed area orifice the equations are numerically integrated. Performance charts are presented in terms of three dimensionless parameters: mass, spring stiffness and orifice area ratio. Then, a second case is considered in which the damper orifice area is made to vary in two stages.

NOISE REDUCTION

(Also see Nos. 1862, 1869, 1872)

78-1840

Noise Control for Fan and Vent Shafts in Subways

P.Y.N. Lee

Wilson, Ihrig & Associates, Inc., 5605 Ocean View Dr., Oakland, CA 94618, Noise Control Engr., 10 (3), pp 102-107 (May/June 1978) 8 figs, 3 tables, 4 refs

Key Words: Fans, Subway cars, Noise control

Subway fan and vent shafts can be prominent sources of noise impact to both the adjacent community and to patrons in the subway stations. The author discusses the available methods for reduction of fan and train noise propagated out of vent shafts and fan noise propagated into stations. In addition, the results of fan noise measurements in station platforms and outside the fan shafts at existing rapid transit facilities are presented.

78-1841

Low Noise Propulsion System for General Aviation

B. Berdrow

Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen, West Germany, Rept. No. BMFT-FB-W-77-23, 384 pp (Dec 1977)

(In German)

N78-22108

Key Words: Propulsion systems, Noise reduction, Aircraft noise

The program described is aimed at the development of low noise propulsion systems of up to 200 HP for general aviation. The study is broken down into three stages (definition, production and testing). The objective of the program is a noise reduction of 10 dB(A) in comparison to the 1975 LBA noise economy, derived from standard passenger car engines. A comprehensive noise study on possible propellers (including shrouded propellers) forms the basis for the propeller rpm's required for low noise propulsion systems. The conversion of the high rpm's normal for passenger car engines to the low propeller rpm's required is via gearboxes, which are a fundamental problem dealt with. The solution to the problem is given in the definition stage. Studies on the installation of propulsion systems in existing airframes does not show particular problems.

78-1842

The Nine Tools of Noise Control

W. Fearon

Peabody Noise Control Inc., Dublin, OH, Des. News, 34 (2), pp 26-35 (June 19, 1978) 9 figs

Key Words: Noise reduction, Design techniques, Materials

The nine avenues open to the designer to make a product quiet, grouped into two major categories - designed-in solutions and added-on solutions, are discussed. Selection of materials for barriers, absorbers, dampers and vibration isolators is discussed.

78-1843

Diffraction of Arbitrarily Oriented Directional Sources by Rigid Planar Screens

G.W. Johnston

Inst. of Aerospace Studies, Univ. of Toronto, Downsview, Ontario, Canada M3H 5T6, J. Acoust. Soc. Amer., 64 (2), pp 665-676 (Aug 1978) 11 figs, 7 refs

Key Words: Noise barriers, Guardrails

An analysis has been carried out to determine the diffracted fields due to directional sources located near rigid planar screens with application to the suppression of noise by acoustic barriers, especially highway barriers. Firstly, the diffracted field due to an arbitrarily oriented point dipole source is obtained by source position differentiation using the classical exact results due to McDonald. The dipole results are then combined with the monopole results to obtain the diffracted fields due to a series of combined sources having arbitrary directivity and orientation with respect to the plane of the screen. It is noted that while the diffraction problem with simple sources and planar screens exhibits reciprocity, diffraction results obtained in the present problem do not exhibit reciprocity with respect to source and observer locations. Typical computed insertion loss results are shown indicating the trends associated with source directionality, source orientation, and source location.

AIRCRAFT

(Also see Nos. 1725, 1726)

78-1844

Modal Investigation of Lightweight Aircraft Structures Using Digital Techniques

R.W. Gordon, H.F. Wolfe, and R.D. Talmadge
Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-124, 66 pp (Dec 1977)

AD-A053 782/9GA

Key Words: Aircraft, Testing techniques, Natural frequencies, Mode shapes, Modal damping, Honeycomb structures

Digital impact response test techniques were used to measure the dynamic properties of lightweight aircraft structures to include natural frequencies, mode shapes and modal damping. Two different types of structures were tested, honeycomb and skin-stiffened panels. The digital impact response method used consisted of applying a transient force pulse to the structure, measuring the structure's response at various points, digitizing, calculating the transfer functions using fast Fourier transforms, and determining the dynamic properties from these data. A second method was used on these same structures for direct comparison purposes. This method was an analog technique using sine sweep tests and accelerometer mapping.

78-1845

Effects of Cavity Resonances on Sound Transmission into a Thin Cylindrical Shell

L.R. Koval

Dept. of Mech. and Aerospace Engrg., Univ. of Missouri-Rolla, Rolla, MO 65401, J. Sound Vib., 59 (1), pp 23-33 (July 8, 1978) 4 figs, 7 refs
Sponsored by NASA

Key Words: Aircraft noise, Internal noise, Noise reduction, Cylindrical shells, Cavity resonance, Mathematical models

In the context of the transmission of airborne noise into an aircraft fuselage, a mathematical model is presented for the effects of internal cavity resonances on sound transmission into a thin cylindrical shell. The "noise reduction" of the cylinder is defined and computed, with and without including the effects of internal cavity resonances. As would be expected, the noise reduction in the absence of cavity resonances follows the same qualitative pattern as does transmission loss.

78-1846

An Acoustic Range for the Measurement of the Noise Signature of Aircraft During Flyby Operations

D.A. Hilton and H.R. Henderson

Langley Res. Center, NASA, Hampton, VA 23665, Noise Control Engr., 10 (3), pp 120-126 (May/June 1978) 15 figs, 6 refs

Key Words: Aircraft noise, Acoustic signatures, Measurement techniques

The authors present a detailed description of the Remotely Operated Multiple Array Acoustic Range currently operated by NASA. Also given are examples of actual measurements that demonstrate ROMAAR's application to ground noise footprint measurement for different types of aircraft.

78-1847

Noise Prediction Technology for CTOL Aircraft

J.P. Raney

Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TM-78700, L-12234, 16 pp (May 1978)

N78-23875

Key Words: Aircraft noise, Noise prediction, Propulsion systems

The application of a new aircraft noise prediction program to CTOL noise prediction is outlined. Noise prediction is based on semiempirical methods for each of the propulsive system noise sources, such as the fan, the combustor, the turbine, and jet mixing, with noise-critical parameter values derived from the thermodynamic cycle of the engine. Comparisons of measured and predicted noise levels for existing CTOL aircraft indicate an acceptable level of accuracy.

78-1848

Noise From Engine Thrust Reversal of Landing Aircraft

R.F. Higginson and A.J. Rennie

National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-83, 63 pp (Aug 1977)

N78-23098

Key Words: Aircraft noise, Engine noise, Noise measurement

Measurements were made of aircraft noise, with particular reference to the levels of engine thrust reversal noise of different aircraft types at and near to London Airport - Gatwick. The object was to determine the contribution of reverse thrust noise to the total noise exposure at points on the ground. The results show that generally this contribution is small in relation to that of the principal sources of noise, aircraft taking off and climbing out.

78-1849

Community Noise Exposure Resulting from Aircraft Operations. Volume 1. Acoustic Data on Military Aircraft

J.D. Speakman, R.G. Powell, and J.N. Cole

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-1, 51 pp (Nov 1977)

AD-A053 699/5GA

Key Words: Aircraft noise, Noise measurement

This report is one of a series describing the research program undertaken by the Aerospace Medical Research Laboratory to develop the procedures (NOISEMAP) and data base (NOISEFILE) for predicting community noise exposure resulting from military aircraft operations. It presents the results of field test measurements to define the single event noise produced on the ground by military fixed wing aircraft during controlled level flyovers and ground runups.

78-1850

Community Noise Exposure Resulting from Aircraft Operations. Volume 2. Acoustic Data on Military Aircraft: Air Force Bomber/Cargo Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee
Aerospace Medical Res. Lab., Wright-Patterson AFB, OH., Rept. No. AMRL-TR-73-110-VOL-2, 768 pp (Nov 1977)
AD-A053 700/1GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the single event noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 F temperature and 70% relative humidity. Noise data are presented in this Volume 2 for many military aircraft.

78-1851

Community Noise Exposure Resulting from Aircraft Operations. Volume 3. Acoustic Data on Military Aircraft: Air Force Attack/Fighter Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee
Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-3, 763 pp (Feb 1978)
AD-A053 701/9GA

Key Words: Aircraft noise, Noise measurement

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

standard acoustic reference conditions of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 3 for many military aircraft.

78-1852

Community Noise Exposure Resulting from Aircraft Operations. Volume 4. Acoustic Data on Air Force Trainer/Fighter Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee
Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-4, 644 pp (Feb 1978)
AD-A053 702/7GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 4 for many military aircraft.

78-1853

Long-Distance Focusing of Concorde Sonic Boom

L. Liszka
Kiruna Geophysical Inst., S-981 01 Kiruna 1, Sweden, J. Acoust. Soc. Amer., 64 (2), pp 631-635 (Aug 1978) 9 figs, 9 refs

Key Words: Aircraft noise, Sonic boom

Infra-acoustic signals from supersonic flights of Concorde are regularly recorded in northern Sweden at distances up to 5000 km from the aircraft. Relatively high signal amplitudes (up to 0.1 N/m^2) are explained by a kind of long-distance focusing effect. Principle and consequences of the focusing effect are discussed.

78-1854

Full Scale Crash Test Experimental Verification of a Method of Analysis for General Aviation Structural Crashworthiness

G. Wittlin, M.A. Gamon, and W.L. LaBarge
Lockheed-California Co., Burbank, CA., Rept. No.

LR-28306, FAA-RD-77-188, 424 pp (Feb 1978)
AD-A054 154/0GA

Key Words: Crash research (aircraft)

The results of the Task II effort to experimentally verify a method of analysis of the structural dynamics response of general aviation airplanes subjected to a crash environment are presented. Included in this report is a description of the preparation for the performance of four instrumented full-scale crash tests involving a single-engine, high wing type airplane. All crash testing was performed at the NASA Langley Impact Dynamics Research Facility (IDRF). The crash tests involved a wide range of impact attitudes and included one impact into a soil covered terrain.

78-1855

Tests of Crash-Resistant Fuel System for General Aviation Aircraft

W.M. Perrella, Jr.

Experimental Center, National Aviation Facilities,
Atlantic City, NJ, Rept. No. FAA-NA-77-48, FAA/
RD-78-28, 32 pp (Mar 1978)
AD-A054 141/7GA

Key Words: Crash research (aircraft), Fuel tanks

A significant percentage of general aviation aircraft accidents result in postcrash fires due to the ignition of fuel spillage, often contributing injury or death to the aircraft occupants. Testing was performed to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Included in these tests were three full-scale crash tests of a typical light twin aircraft.

BUILDING

(Also see Nos. 1717, 1744, 1745, 1746, 1747)

78-1856

Development of an Empirical Relationship for the Prediction of Damping in Steel-Framed Buildings

T.J. Rusnak

Army Military Personnel Center, Alexandria, VA,
219 pp (May 3, 1978)
AD-A054 438/7GA

Key Words: Buildings, Damping, Prediction techniques

Test data from the forced vibration and ambient experiments on actual structures are used as input to a regression analysis

routine to develop equations for the prediction of damping in steel-framed buildings. The data is categorized by building height and building width (the dimension in the direction parallel to the applied forces). The best resulting equation is used as the basis for a new design methodology to predict damping. This methodology consists of using the prediction equation in a situation where a set of conditions are satisfied. These conditions pertain to the particular characteristics of the structure and the approximate level of excitation which is expected. It is anticipated that this methodology will be especially useful in the early stages of design. Included also are two types of sensitivity analysis which indicate the amount of variation in displacement response that can be expected by using the developed prediction equation.

78-1857

Inelastic Response of Multistory Buildings to Tornadoes

M. Seniwongse

Ph.D. Thesis, Texas Tech Univ., 400 pp (1977)
UM 7810851

Key Words: Multistory buildings, Wind-induced excitation

The purpose of this research project is to perform a computer study of the response of multistory steel frame buildings to tornadic winds in order to determine if such structures can be economically designed to withstand tornadoes and, if so, what design provisions would be appropriate. A number of factors and their effects on the building response are investigated. These factors include various parameters describing the tornado windfield, the effects of dynamic as well as static response, and the influence of yielding, non-structural stiffness and strength, and $P - \Delta$ moments.

78-1858

Earthquake Simulation Tests of a Nine Story Steel Frame with Columns Allowed to Uplift

A.A. Huckelbridge

Ph.D. Thesis, Univ. of California, Berkeley, 177 pp
(1977)
UM 7812455

Key Words: Buildings, Seismic response, Computerized simulation, Experimental data

This thesis presents experimental and analytical response data for a model nine-story building frame under seismic excitation, both with and without supplementary anchorage of the columns provided. The experimental work was carried out on the shaking table of the U.C. Berkeley Earthquake Simulator Laboratory.

CONSTRUCTION

78-1859

Road Construction Noise Prediction and Measurement - A Case Study

D.M. Martin and A.V. Solaini

Transport and Road Res. Lab., Crowthorne, UK,
Rept. No. TRRL-LR-758, 28 pp (1977)

PB-280 508/3GA

Key Words: Noise prediction, Noise measurement, Construction equipment, Earth handling equipment

Noise predictions and measurements have been made during the earthworks phase of a road construction scheme in order to illustrate the roles that noise prediction and measurement can play in assessing noise control strategies in earthworks operations. Measurements were made over periods of six hours or more.

FOUNDATIONS AND EARTH

(See Nos. 1749, 1837)

HUMAN

78-1860

Measurement of the Energy Dissipated in the Hand and Arm Whilst Using Vibratory Tools

J.S. Anderson and R.A.C. Boughtflower

Dept. of Mech. Engrg., The City Univ., London
EC1V4PB, UK, Appl. Acoust., 11 (3), pp 219-224 (July 1978) 3 figs, 6 refs

Key Words: Tools, Vibratory tools, Human response

Acceleration levels during hand-held grinding have been measured. By controlling the input to a vibration shaker the same acceleration levels were introduced into a specially designed handle gripped by a human hand. From measurements of force, acceleration and phase the power dissipated in the hand was calculated in third-octave bands. Approximate agreement was achieved with power dissipation estimates obtained from the acceleration alone by assuming the hand-arm system to be a linear, single degree of freedom system. The power dissipated is proposed as an important parameter affecting vibration-induced white finger.

78-1861

Vibration Aspects of Ride Quality Modeling for the DOT PTACV - Theory and Experiment

R. Katz

Metrex Div., MITRE Corp., McLean, VA., Rept. No.
FRA/ORD-78/02, 59 pp (Dec 1977)

PB-279 846/0GA

Key Words: Ground effect machines, Ride dynamics, Human response

An important aspect of passenger ride comfort in a transportation vehicle is the acceleration level of the passenger cabin. In order to incorporate ride quality into the design process of such vehicles, it is necessary to have reasonably validated analytical models to predict the acceleration levels at frequencies which affect passenger ride comfort. The purpose of the report is to discuss the suitability of analytical models used to predict the heave acceleration in the passenger cabin of The Department of Transportation's Prototype Tracked Air Cushion Vehicle (PTACV). The basis of this evaluation is a comparison of theoretical predictions from an analytical model, typical of those in common usage today, with measured responses accumulated during testing of the PTACV on its test track.

ISOLATION

78-1862

One Stage and Two Stage Vibration Isolators as Applied to High Speed Textile Spindles to Achieve Noise Reduction

L.W. Foster

Lord Kinematics, Erie, PA, J. Mech. Des., Trans.
ASME 100 (1), pp 33-40 (Jan 1978) 11 figs, 7 refs

Key Words: Textile spindles, Vibration isolators, Noise reduction

This paper describes the use of two types of elastomeric vibration isolators located between the spindle bolster and the rail to achieve reductions of vibration and noise levels associated with the spindle-bobbin-rail subsystem of spinning frames. The two types of elastomeric isolators employed are: a single-stage isolator where a bonded elastomeric mounting of annular design is placed between the bolster and the rail, and a two-stage isolator which incorporates an annular intermediate mass element between two annular elastomeric sections that provide the interfaces to the spindle and to the rail.

78-1863

Optimization of Pneumatic Vibration Isolation System for Vehicle Suspension

E. Esmailzadeh

Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, 100 (3), pp 500-506 (July 1978) 13 figs, 12 refs

Key Words: Suspension systems (vehicles), Vibration isolators, Pneumatic springs, Optimization

An optimization technique is applied to evaluate the optimum values of many parameters involved for which the maximum transmitted motion to the body would be minimum over the broad frequency range. Theoretical expressions for the transmissibility of the body and the wheel, optimum values of mass ratio, stiffness ratio and damping ratio are presented. Design data are presented nondimensionally for parameter variations which are sufficiently broad to encompass a wide range of practical engineering problems.

78-1864

Optimizing Railroad Freight Car Truck Suspension Systems Having Coulomb Damping

R.L. Bullock and D.B. Cooley

Standard Car Truck Co., Chicago, IL, J. Engr. Indus., Trans. ASME, 100 (3), pp 311-317 (Aug 1978) 4 figs, 4 tables

Key Words: Suspension systems (vehicles), Freight cars, Railroad cars, Coulomb friction

This paper describes the design process followed in developing a 100 ton freight car truck suspension system having coulomb damping. Classical linear vibration analysis was used for the conceptual design phase. Within the constraints placed upon truck suspension systems, a constant damping parameter, i.e., the ratio of friction force to static force imparted by the base, for all load conditions was established as a design goal. Optimization of the actual design parameters and comparison to existing truck suspensions was accomplished using the latest vehicle model developed by the AAR/TTD.

MECHANICAL

78-1865

Analytical and Experimental Studies of a Dynamic System with a Gap

S.F. Masri

Dept. of Civil Engrg., Univ. of Southern California,

Los Angeles, CA., J. Mech. Des., Trans. ASME, 100 (3), pp 480-486 (July 1978) 6 figs, 4 refs

Key Words: Forced vibration, Periodic response, Harmonic excitation, Mechanical systems, Motion-limiting stop

An analytical and experimental study is made of the forced vibration of a dynamic system with a motion-limiting stop, which is encountered in many practical cases involving mechanical equipment. An exact closed-form analytical solution is derived for the steady-state motion of the system when it is subjected to harmonic excitation. Experimental measurements with a mechanical model verify the analytical findings. The effects of various system parameters on the response are determined. Some interesting features of the motion are observed and compared to the jump resonance phenomenon exhibited by the solution of Duffing's equation.

METAL WORKING AND FORMING

78-1866

Experimental and Analytical Investigation of Self-Excited Chatter Vibrations in Metal Cutting

N. Saravanja-Fabris and A.F. D'Souza

Bell Telephone Labs., Naperville, IL, J. Mech. Des., Trans. ASME, 100 (1), pp 92-99 (Jan 1978) 12 figs, 22 refs

Key Words: Metal working, Chatter, Self-excited vibrations

Chatter in metal cutting is a nonlinear self-excited vibration of the limit cycle type. This investigation is concerned with the analysis of chatter from the viewpoint of the describing function. Vibrations with different frequencies and amplitudes were superimposed on the steady feed motion of the tool in orthogonal cutting in order to simulate chatter. The relationships between the oscillating cutting and thrust forces and tool vibrations are discussed from the point of view of energy transfer and describing functions. Experimentally obtained describing functions of the dynamically varying cutting process are given. The stability of a typical machine tool structure under primary chatter conditions with dynamical cutting process represented by its describing function is discussed.

78-1867

Investigation of the Cutting Process Dynamics in Turning Operations

K. Srinivasan and C.L. Nachtigal

Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 323-331 (Aug 1978) 9 figs, 7 tables, 13 refs

Key Words: Cutting, Chatter, Machine tools, Parameter identification technique

This paper describes the application of a sequential equation error minimization technique to determine empirically the optimum parameter values in a predetermined set of force component models from dynamic cutting data. The identification technique was verified on an analog computer simulation of the dynamic behavior of a machine tool system. The identified parameter values were compared with the actual simulated values.

78-1868

Identification of Machining System Dynamics by Equation Error Minimization

K. Srinivasan and C.L. Nachtigal

Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 332-339 (Aug 1978) 6 figs, 4 tables, 1 ref

Key Words: Parameter identification technique, Machine tools, Chatter, Self-excited vibration

The application of a sequential equation error minimization method to the identification of the dynamics of machining systems is described here. The development of the identification method was motivated by the need for models of machining system dynamics for the design of active chatter controllers. The dynamic cutting force parameters as well as the machine structure transfer function parameters are required for this task.

OFF-ROAD VEHICLES

78-1869

Off-Highway Hydraulic Noise

Auto. Engr., 86 (9), pp 34-40 (Sept 1978) 7 figs, 4 refs

Key Words: Off-highway vehicles, Agricultural machinery, Noise control

Sources of hydraulic noise and ways to minimize it are examined. Two specific examples of noise control are offered: one for a harvesting machine, the other for a rough-terrain forklift truck used by the military.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1766, 1794)

78-1870

Nonlinear Resonance as the Cause of Multiple Pure Tones

P.G. Vaidya and K.S. Wang

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 15 (8), pp 526-533 (1978) 4 figs, 14 refs

Key Words: Fans, Ducts, Noise generation, Resonant response, Noise reduction

When the fans of aeroengine ducts go supersonic, they often produce radiation at the subharmonics of blade-passage frequency, known as multiple pure tones (MPT). It has been shown that the conventional explanation, that these MPT's are created by the shock waves, is inadequate. An alternative mechanism based on the concept of a "strong interaction" between the harmonics is proposed. Expression for the governing equation for such an interaction is derived. The results show an improved agreement with observed data. The analysis has also led to several practical suggestions for a suppression of the noise.

78-1871

Controlling Fan Noise In and Around Power Plants

J.G. Funk

Environmental Elements Corp., Power, 122 (9), pp 114-117 (Sept 1978) 8 figs

Key Words: Fans, Noise reduction

A procedure for reducing the inlet, exhaust, and casing noise from forced- and induced-draft and primary-air fans is described.

78-1872

Generation and Suppression of Fan-Compressor Noise

S.L. Sarin

Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-3-1823, 22 pp (1977) N78-22107

Key Words: Fans, Compressors, Aircraft noise, Noise reduction, Acoustic linings

The generation mechanism of fan-compressor noise during the landing phase of an aircraft is examined. Various techniques (reduction of interaction tones at the source, flow choking, use of acoustic liners) to suppress this component of total aircraft noise are described. It is concluded that the choice of an optimum liner for the maximum possible suppression demands a predictive capability with regard

to liner optimum impedance, and its translation into a real hardware, and liner performance.

RAIL

(Also see No. 1729)

78-1873

An Investigation of Techniques for Validation of Railcar Dynamic Analyses

W.J. Fallon, N.K. Cooperrider, and E.H. Law
Dept. of Mech. Engrg., Arizona State Univ., Tempe,
AZ, Rept. No. FRA/ORD-78/19, 123 pp (Mar
1978)
PB-279 996/3GA

Key Words: Railroad cars, Freight cars, Interaction: rail-wheel, Mathematical models, Spectral energy distribution techniques

A linear model of the vertical dynamics of a railcar was validated by the application of spectral techniques to experimental data. Track input spectra were computed from test track surface measurements gathered in the TDOP test program. Acceleration measurements of a freight car were used to compute vehicle acceleration spectra in response to the test track. The corresponding response of the linear model was computed from the analytical transfer functions and experimental track input spectra. Validation of the linear model was based upon a comparison of corresponding analytical and experimental vehicle acceleration spectra. The truck suspension was isolated and analyzed from experimental measurements of corresponding truck and car body accelerations. Spectral functions were employed to evaluate the assumptions of suspension linearity.

78-1874

Dynamics of a High-Speed Sliding Power Collector in Consideration of Sliding Friction

K. Yoshida and T. Shimogo
Faculty of Engrg., Keio Univ., Yokohama, Japan,
J. Mech. Des., Trans. ASME, 100 (2), pp 242-250
(Apr 1978) 18 figs, 1 table, 6 refs

Key Words: High speed transportation systems, Sliding power collector, Interaction: rail-wheel, Sliding friction, Mathematical models

Considering the sliding friction force produced between a

contactor and a rigid collecting rail with a randomly wavy surface, the paper deals with the dynamics of a sliding power collector for a very-high-speed railway. An analytical model is formulated, which has two contact points and takes into account the pitching of a contactor, the stiffness of the sliding direction in a contactor support system, and the non-linearity of the contact stiffness between a contactor and a rail. Mainly, the influences of the sliding friction and the contact stiffness on the dynamic characteristics, i.e., the contact force variation, the probability of contact break, etc., are investigated.

REACTORS

78-1875

Vibration Analysis of Heat Exchanger and Steam Generator Designs

M.J. Pettigrew, Y. Sylvestre, and A.O. Campagna
Chalk River Nuclear Labs., Atomic Energy of Canada,
Ltd., Chalk River, Ontario K0J 1J0, Canada, Nucl.
Engr. Des., 48 (1), pp 97-115 (June 1978) 20 figs,
2 tables, 25 refs

Key Words: Nuclear reactor components, Heat exchangers, Boilers, Fluid-induced excitation, Design techniques

A thorough flow-induced vibration analysis of nuclear components such as heat exchangers and steam generators is essential at the design stage to ensure good performance and reliability. This paper presents our approach and techniques in this respect.

78-1876

Engineering of Nuclear Power Facilities for Earthquake Loads

A.H. Hadjian
Los Angeles Power Div., Norwalk, Bechtel Power
Corp., P.O. Box 60860 - Terminal Annex, Los Angeles,
CA 90060, Nucl. Engr. Des., 48 (1), pp 21-47
(June 1978) 15 figs, 6 tables, 32 refs

Key Words: Nuclear power plants, Seismic design

The state-of-knowledge to engineer nuclear power facilities for earthquake loads is reviewed as it was collectively presented at the fourth SMiRT Conference. All aspects of the design process are critically examined starting with the definition of ground motion. Both past achievements in each of the several areas of endeavor, and the gaps in our knowledge that need further research and study are emphasized. Several alternatives to above ground facilities are reviewed, and issues are raised regarding easy solutions to very complex problems associated with these alternatives.

78-1877

Seismic Response of Gas-Cooled Fast Breeder Reactor Core Structural Assembly Via Modal Synthesis

T.H. Lee and A.S. Chuang

General Atomic Co., San Diego, CA 92138, Nucl. Engr. Des., 49 (3), pp 269-277 (Sept 1978) 8 figs, 17 refs

Key Words: Seismic response, Nuclear reactors, Modal synthesis

An investigation has been conducted to determine theoretically the dynamic response of the GCFR core support structural assembly when subjected to boundary excitation from seismic disturbances. The system analyzed consists of a thick grid plate to which many core elements are vertically attached. The dynamic problem was solved by synthesizing component modes of two substructures and treating them as continuous subsystems. Numerical system modal data and time-history response results are presented.

RECIPROCATING MACHINE

(Also see No. 1769)

78-1878

Influence of the Periodic Variations of the Mass Inertia on the Torsional Vibrations of a Four-Cylinder Engine (Einfluss der periodischen Schwankung des Massenträgheitsmomentes auf die Torsionsschwingungen des Vierzylinder-Motors)

H. Klier

Lustheide 95, D-5060 Bergisch Gladbach 3, Germany, MTZ Motortech. Z., 39 (7/8), pp 341-345 (July/Aug 1978) 3 figs, 3 tables, 4 refs
(In German)

Key Words: Engine vibration, Diesel engines, Torsional vibration, Damping

This paper describes the effect of periodic mass inertia variation of crank assembly. For this purpose, series of torsional vibration measurements were made by systematically changing the sizes of mass inertia moment at the flywheel and front end side of the crankshaft. The engine used is a small fast running four-cylinder diesel, designed for passenger cars.

78-1879

Current Alternatives in Exhaust System Acoustical Evaluation

L.J. Eriksson

Nelson Industries, Inc., Stoughton, WI, S/V, Sound Vib., 12 (8), pp 18-25 (Aug 1978) 17 figs, 1 table, 21 refs

Key Words: Engines, Exhaust noise

Various procedures for the evaluation of exhaust system performance are presented and discussed. Analytical as well as experimental techniques are considered. Comparisons are made with measurements on actual engine exhaust noise. The major approaches are ranked with respect to accuracy and cost.

ROAD

(Also see No. 1728)

78-1880

Important Data for Lateral Vehicle Dynamics (Wichtige Daten f. die Kurshaltung von Kraftfahrzeugen)

M. Mitschke

Institut f. Fahrzeugtechnik, Hans-Sommer-Strasse 4, 3300 Braunschweig, Automobiltech. Z., 80 (6), pp 263-270 (June 1978) 5 figs, 4 tables, 7 refs

Key Words: Automobiles, Steering effects, Lateral response

Four frequency responses concerning the driver-vehicle-system are examined herein. Input is the steering wheel angle, outputs are yaw velocity, sideslip angle, lateral acceleration and steering wheel torque. The velocity is kept constant.

78-1881

Research Safety Vehicle - Phase II. Volume II. Comprehensive Technical Results

N. DiNapoli, M. Fitzpatrick, C. Strother, D. Struble, and R. Tanner

Minicars, Inc., Goleta, CA., Rept. No. DOT-HS-803 250, 609 pp (Nov 1977)
PB-280 153/8GA

Key Words: Collision research (automotive)

Phase I identified trends leading to the desired national social goals of the mid-1980's in vehicle crashworthiness, crash avoidance, damageability, pedestrian safety, fuel economy, emissions and cost, and characterized an RSV to satisfy them. In Phase II an RSV prototype was designed, developed and tested to demonstrate the feasibility of meeting these goals simultaneously.

ROTORS

(Also see Nos. 1752, 1834)

78-1882

A Simple Stability Analysis for Flexible Rotors in Tilting Pad Bearings

E.A. Bulanowski

Solid Mechanics Res. and Advanced Product Dev., Delaval Turbine, Inc., Trenton, NJ., J. Mech. Des., Trans. ASME, 100 (1), pp 165-172 (Jan 1978) 10 figs, 1 table, 5 refs

Key Words: Rotor-bearing systems, Tilting pad bearings, Stability analysis

A simplified stability analysis for flexible rotors in tilting pad bearings is developed which provides a convenient and practical approach for the consideration of nonsynchronous vibrations during the design phase of rotor bearing systems. This paper demonstrates that the free vibrations, and hence the system damping factor, of a distributed mass flexible rotor in tilting pad bearings may be analyzed using a single mass, two tier spring-damper model. The relationship between the system damping factor and rotor stability is discussed. Nonsynchronous tilting pad bearing characteristics are incorporated into the expression for the damping factor, and nondimensional curves are presented which establish values of the damping factor as a function of operating speed, critical speed, bearing clearance and Sommerfeld number. The subject curves provide a quick method for establishing stability guidelines during rotor design and for comparing existing rotor bearing systems.

78-1883

The Stability of an Asymmetric Rotor in Damped Supports

A.J. Smalley, J.M. Tessarzik, and R.H. Badgley
Mechanical Technology, Inc., Latham, NY, ASME Paper No. 78-GT-172

Key Words: Rotor-bearing systems, Tilting-pad bearing

A general-purpose method of evaluating the stability of an asymmetric flexible rotor, mounted in symmetric damped bearings, is defined. This method evaluates the complex eigenvalues of the rotor system by solving the equations of motion in a rotating coordinate frame. The application of this method to a rotor mounted in tilting-pad bearings is demonstrated. The observed behavior of a number of different rotor configurations is compared with corresponding predictions of stability.

78-1884

The Dynamics of Multi-Rotor Systems Supported on Oil Film Bearings

A.G. Holmes, C.M.M. Ettles, and I.W. Mayes

Dept. of Mech. Engrg., Imperial College, London, UK, J. Mech. Des., Trans. ASME 100 (1), pp 156-164 (Jan 1978) 12 figs, 9 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Oil film bearings, Alignment, Self-excited vibrations

The self-excited transverse vibration of an elastic multirotor system due to vertical misalignment of the support bearings is investigated using initial value problem techniques. The equations of motion are expressed in terms of the free-free modes of the shaft and the modal coefficients propagated in time. The method was used to study a two-rotor four-bearing system subjected to misalignment.

78-1885

Some Experiments on Instability of Rotors Supported in Fluid-Film Bearings

J. Tonnesen and J.W. Lund

Dept. of Machine Elements, The Technical Univ. of Denmark, 2800 Lyngby, Denmark, J. Mech. Des., Trans. ASME, 100 (1), pp 147-155 (Jan 1978) 20 figs, 11 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Experimental data, Whirling, Unbalanced mass response

Experiments are conducted on two rotors supported in cylindrical bearings with two axial grooves. The journal position in the bearing is measured by built-in capacitance displacement probes, and the dynamic behavior is monitored by pressure probes. The self-excited whirl at the threshold speed of instability, as well as the influence of unbalance on the whirl frequency, is investigated in detail. By adding damping at the supports, the heavier rotor is stabilized and operated up to 330 Hz. Correlation with theoretical predictions is presented.

78-1886

Finite Element Analysis of Rotor-Bearing Systems with Matrix Reduction

K.E. Rouch

Ph.D. Thesis, Marquette Univ., 263 pp (1977)
UM 7810293

Key Words: Rotor-bearing systems, Finite element technique, Computer programs

This dissertation investigates the application of the finite element technique to dynamic analysis of rotor-bearing systems. In addition, the use of reduced stiffness, mass, and damping matrices to represent the shaft, in place of the complete global stiffness matrices, is explored.

78-1887

Keep Rotor Vibration Under Control

M.L. Adams

Univ. of Akron, Akron, OH, *Power*, 122 (8), pp 28-29, 65 (Aug 1978) 3 figs, 5 refs

Key Words: Rotor-bearing systems, Subharmonic oscillations, Vibration damping

Rotor subharmonic resonance is a potentially catastrophic vibration phenomenon that could happen in units with fixed-arc journal bearings if a large rotor imbalance occurs, for example, as a result of a turbine blade loss. Properly designed pivoted-pad bearings, unlike fixed-arc bearings, do not lose their damping ability in the subsynchronous frequency range, thus provide effective damping of subharmonic vibration.

78-1888

Critical Speeds, Stability and Response of a Geared Train of Rotors

J.W. Lund

Dept. of Machine Elements, The Technical Univ. of Denmark, Lyngby, Denmark, *J. Mech. Des.*, *Trans. ASME*, 100 (3), pp 539-535 (July 1978) 9 refs

Key Words: Rotors, Torsional vibration, Lateral vibration, Forced vibration, Free vibration

A method is described for calculating the coupled torsional-lateral vibrations in a geared system of rotors. It considers both forced vibrations, caused by mesh errors or by mass unbalance, and free, damped vibrations whose complex eigenfrequencies define the damped critical speeds and the stability of the rotor system. The rotors, supported in fluid-film bearings, are calculated independently, using the Holzer method for torsional vibrations and the Myklestad-Prohl method for lateral vibrations, after which they are coupled through impedance matching at the gear meshes. The resulting equations are solved for the unknown mesh contact forces, and the roots of the coefficient matrix determinant give the eigenvalues of the system. The method is efficient and readily programmed.

78-1889

Transient Response of a Rotor in Damped Bearings

W.D. Pilkey, J.S. Strenkowski, and P.Y. Chang
Univ. of Virginia, Charlottesville, VA., *J. Mech. Des.*, *Trans. ASME*, 100 (2), pp 257-265 (Apr 1978) 7 figs, 10 refs

Key Words: Rotors, Transient response, Mathematical models, Modal analysis

In this paper, the transient response of a rotor subjected to a general forcing function is presented. The rotor model permits any number of in-span bearings, which include stiffness, damping, and mass properties. The excitation forces may include distributed loadings along the rotor as well as transient bearing base motion. The response is found by use of a modal analysis that incorporates the damped mode shapes. An illustrative example is presented of a rotor subjected to an initial displacement and a saw-tooth bearing base displacement.

78-1890

Residual-Flexibility Corrections for Transient Modal Rotordynamic Models

D.W. Childs and J.B. Bates, III

Speed Scientific School, Univ. of Louisville, Louisville, KY, *J. Mech. Des.*, *Trans. ASME*, 100 (2), pp 251-256 (Apr 1978) 8 figs, 10 refs

Key Words: Rotors, Modal analysis, Mathematical models

An extension is presented to a modal formulation for the dynamics of flexible rotors. To date, rotordynamic modal formulations have retained for integration those modes of vibration whose natural frequencies are within or slightly above the operating speed range of the rotor, with higher-order modes simply discarded. In this study, the residual-flexibility technique is employed to account for the "static" contribution of these higher-frequency modes without requiring their integration. The residual-flexibility technique accounts directly for the static contribution of higher frequency modes due to imbalance and external transient loading, and has been adapted to account for reaction forces which are not accounted for by the nominal rotor/bearing stiffness matrix, e.g., bearing damping forces or speed-dependent bearing stiffnesses. The High-Pressure-Oxygen Turbo-pump of the Space Shuttle Main Engine (SSME) is analyzed.

78-1891

Steady-State Unbalance Response of a Three-Disk Flexible Rotor on Flexible, Damped Supports

R.E. Cunningham

Lewis Res. Center, NASA, Cleveland, OH, *J. Mech.*

Des. Trans. ASME, 100 (3), pp 563-573 (July 1978)
15 figs, 15 refs

Key Words: Unbalanced mass response, Rotors (machine elements), Squeeze-film dampers

Experimental data are presented for the unbalance response of a flexible, ball bearing supported rotor to speeds above the third lateral bending critical. Values of squeeze film damping coefficients obtained from measured data are compared to theoretical values obtained from short bearing approximation over a frequency range from 5000 to 31,000 cycles/min. Experimental response for an undamped rotor is compared to that of one having oil squeeze film dampers at the bearings.

78-1892

Torsional Frequencies of Multi-Stepped Shafts with Rotors

D.K. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India., Intl. J. Mech. Sci., 20 (7), pp 415-422 (1978) 4 figs, 2 tables, 12 refs

Key Words: Crankshafts, Shafts, Rotors, Inertia effects, Torsional response, Natural frequencies

An exact frequency determinant for natural frequencies of a multi-stepped shaft-rotor system, which includes the effect of shaft inertia, is developed. Frequency equations and modes of a heavy homogeneous engine, and those with one or two additional rotors, are derived using this result. Numerical results indicate that the effect of shaft inertia reduces with an increase in the mode number.

78-1893

Buckling and Vibration of a Rotating Spoke

W.D. Lakin, R. Mathon, and A. Nachman

Dept. of Mathematics, Univ. of Toronto, Toronto, Canada, J. Engr. Math., 12 (3), pp 193-206 (July 1978) 4 figs, 9 refs

Key Words: Wheels, High speed rotors, Eigenvalue problems

The buckling and vibration of the spoke of a rotating wheel is examined. Since the axial load is a function of position closed form solutions for the eigenmodes are prescribed and recourse is made to regular and singular perturbation expansions in terms of several dimensionless parameters appearing in the governing equations. Some numerical results are also included in the interest of completeness.

SELF-EXCITED

(See No. 1867)

SPACECRAFT

(See Nos. 1774, 1775)

TRANSMISSIONS

(Also see No. 1804)

78-1894

Load Distribution in Timing Belts

G. Gerbert, H. Jonsson, U. Persson, and G. Stensson
Machine Elements Div., Lund Tech. Univ., Lund, Sweden, J. Mech. Des., Trans. ASME, 100 (2), pp 208-215 (Apr 1978) 24 figs, 6 refs

Key Words: Belt drives, Mechanical drives

A theory is presented for determining the distribution of the belt tension and the tooth load in timing belts. It appears that the distribution of both loads is of exponential character and one important parameter is the ratio between the spring constant of the tooth and the spring constant of the cord (a nondimensional number). Friction between the belt and the top of the pulley is also considered.

TURBOMACHINERY

78-1895

An Analytic Study of the Energy Dissipation of Turbomachinery Bladed-Disk Assemblies Due to Inter-Shroud Segment Rubbing

R.L. Bielawa

Rotary Wing Technology Group, United Technologies Research Center, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (2), pp 222-228 (Apr 1978) 9 figs, 3 refs

Key Words: Turbomachinery blades, Shrouds, Energy dissipation, Coulomb friction

A novel computational method is presented for analytically studying the energy dissipative characteristics of turbomachinery bladed-disk assemblies due to inter-shroud segment rubbing. Coulomb friction, as the dissipative mechanism, is utilized in this method with broader generality than that in other similar studies heretofore. The immediate objectives of this study were to obtain an understanding of the

general slippage characteristics of the shroud segment interfaces in the presence of both steady normal (to the shroud segment interfaces) lock-up stresses and stresses due to modal vibration, and to incorporate these characteristics in a calculation of the minimum modal deflection required for incipient slipping as well as an estimation of the energy dissipation (damping) due to subsequent rubbing.

78-1896

Unsteady Flows in Turbomachines: A Review of Current Developments

M.F. Platzer

Naval Postgraduate School, Monterey, CA., In:
AGARD Unsteady Aerodyn., 28 pp (Feb 1978)
N78-22065

Key Words: Turbomachinery, Aerodynamic response, Prediction techniques

The state-of-the-art of turbomachinery unsteady aerodynamics is reviewed with emphasis on theoretical prediction techniques.

ANNUAL AUTHOR INDEX

A

Abbas, B.A.H. 829
 Abbas, S.F. 998
 Abbott, J.M. 349, 517
 Abdel-Ghaffar, A.M. 1019
 Abdulkarim, O.I. 688
 Abe, E. 1085
 Abedi-Hayati, S. 1419
 Abel, I. 1256
 Abel, L.W. 630
 Abraham, B. 1015
 Abrahamson, A.L. 94
 Abrahamson, G.R. 933
 Abrams, C.F., Jr. 1343
 Achenbach, J.D. 712
 Adams, G.H. 205, 206
 Adams, M.L. 1887
 Adams, T.P. 188
 Adamson, A.P. 826
 Adeli, H. 830
 Adler, A. 1592
 Agarwal, G.C. 1018
 Agbabian, M.S. 60
 Ahlbeck, D.R. 472, 1034
 Ahlers, E.B. 467
 Ahmade, G. 1141
 Aida, T. 1607, 1608
 Ainsworth, O.R. 913
 Aishton, T.H. 1006
 Akay, A. 932
 Akkas, N. 107, 792
 Alem, N.M. 234
 Alexander, A.M. 533
 Alexandridis, A.A. 67
 Alfaro-Bou, E. 793
 Alfredson, R.J. 680, 751
 Al-Hassani, S.T.S. 980
 Aliche, G. 1151
 Al-Jumaily, A.M. 80, 1788
 Al-Khattat, I.M. 583
 Allaire, P.E. 892, 1129,
 1193, 1512

Allemang, R.J. 1074
 Allen, D.S. 1271
 Allen, H.C. 192
 Almroth, B.O. 706
 Alspaugh, D.W. 1253
 Altman, W. 851
 Altus, E. 953
 Alwar, R.S. 311
 Amari, M. 1443
 Ambardar, A. 1172
 Amdursky, V. 501
 Andersen, C.M. 301
 Anderson, D.L. 1619
 Anderson, G.L. 1290
 Anderson, J.C. 665
 Anderson, J.S. 1860
 Anderson, R.J. 478
 Anderson, R.L. 795, 796, 797
 Anderson, W.J. 396, 397
 Anderson, W.W. 870
 Andersson, G.O. 493
 Ando, Y. 132
 Andrej, G. 1190
 Andresen, J.A. 1187
 Andress, E.A. 1421
 Andrew, L.V. 762
 Andrews, D.W. 1011
 Andrews, J.G. 1807
 Antonides, G. 973
 Aravamudan, K.S. 1429
 Arbabi, F. 155
 Ardayfio, D. 1297
 Arndt, R.E.A. 1477
 Arnemann, J. 1727
 Arnquist, J.L. 374
 Arora, J.S. 1705
 Artobolevskii, I.I. 1660
 Asano, K. 1148
 Ash, J.E. 1671
 Ashley, H. 1326, 1522
 Ashworth, R.P. 1695
 Astley, R.J. 1299
 Asztely, J. 494
 Atalik, T.S. 789

Atkočiūnas, J. 850
 Attenborough, K. 1541
 Auret, F.D. 1060
 Aurich, H. 600
 Auslander, D. 1419
 Au-Yang, M.K. 111, 1310
 Avinor, M. 1430
 Ayre, R.S. 88
 Azuma, T. 1394

B

Babuska, I. 1059
 Bachschmid, N. 622
 Badgley, R.H. 1883
 Baig, M.I. 897
 Bailey, C.D. 1292
 Bailie, J.A. 706
 Bainum, P.M. 1774, 1775
 Baitis, A.E. 1406
 Baker, E.W. 63
 Baker W.E. 17, 43
 Balachandra, M.B. 74
 Baladi, G.Y. 614
 Balanis, G.N. 1553, 1573
 Balasubramanya, H.M. 1029
 Ballard, R.F., Jr. 1057
 Banerian, G. 823
 Banerjee, D. 590
 Banerjee, M.M. 1613
 Banerjee, S. 419
 Bansal, P.N. 1752, 1753
 Bapu Rao, M.N. 1312
 Baranski, B.R. 1505
 Barber, T.J. 811
 Barboni, R. 1691
 Barcion, V. 1776
 Barlett, F.R. 1431, 1434
 Bar Itzhack, I.Y. 1061
 Barman, A. 474
 Barna, P.S. 421
 Baron, M.L. 236
 Barr, A.D.S. 510, 774, 1287, 1695

Barrett, L.E.	892, 1129, 1196	Berardino, J.J.	683	Bollinger, J.G.	1275
Barrington, E.A.	1815	Berdrow, B.	1841	Boni, L.	1688
Bassily, S.F.	1822	Berg, J.v.d.	130	Bonn, M.R.	336
Basu, P.K.	1550	Berger, B.S.	108, 109, 1145	Bonnett, M.	1270
Bartel, C.	220	Berglund, J.W.	782	Boore, D.M.	1742
Barth, E.W.	903	Bergmann, E.P.	466, 467	Bore, C.L.	447
Barton, C.K.	1012	Berkovits, A.	1596	Borgese, D.	825
Baruch, M.	1061	Berman, A.	24, 375	Bort, R.L.	1245
Baschiere, R.J.	988	Bernard, J.E.	317, 1224	Boshenko, M.	1205
Baseheart, T.M.	693	Bernard, M.C.	1563	Bossler, R.B., Jr.	375
Basu, P.K.	580	Berry, W.	1689	Böswirth, L.	99
Bates, J.B., III.	1890	Bert, C.W.	119, 1458, 1821	Botkin, M.E.	836
Batra, R.C.	1625	Bertero, V.V.	390, 461, 675, 788, 1799	Botman, M.	805, 1751
Batsinov, T.	1457	Berthelot, M.	30	Boughtflower, R.A.C.	1860
Baublys, P.	835	Bertram, A.	894	Bouwkamp, J.G.	735
Baumeister, K.J.	280	Bervig, D.	828	Bowes, M.A.	375
Baxa, D.E.	257	Besieris, I.M.	1390	Bowser, F.J.	1493
Bar-Yoseph, P.	367	Bettess, P.	1580	Bowsher, J.M.	549
Baz, A.	531	Betzhold, C.	327, 1633	Boxwell, D.A.	343, 422
Bazley, E.N.	406	Bezler, P.	101, 1104	Boyd, M.A.	48
Beaman, J.J.	611	Bickel, H.J.	248, 468	Boyd, W.N.	1482
Bean, S.P.	1049	Bielak, J.	868	Bozich, J.	1414
Beards, C.F.	1723	Bielawa, R.L.	1895	Bradbury, J.N.	1035
Bechert, D.W.	35, 784	Bien, F.	90	Bradley, J.S.	519
Beck, S.A.	542	Bies, D.A.	1302	Brass, J.	27
Becker, H.	408	Biggs, J.M.	394	Bravin, O.	825
Becker, J.	457	Bigret, R.	540, 825	Breitbach, E.	1327, 1479
Beckmann, H.-D.	889	Bishop, D.E.	218, 219	Brill, D.W.	382
Beddoes, T.S.	1683	Bishop, R.E.D.	189, 758, 1362 1783	Brock, J.E.	6
Bedi, A.	661	Bisimis, E.	18, 889	Broersen, P.M.T.	168
Bedore, R.L.	1036	Bismarck-Nasr, M.N.	851	Broichhausen, K.D.	352
Bekofske, K.L.	338	Bjorkenstam, U.	226	Broner, N.	1653
Belanger, P.R.	877	Bjurvald, M.	145	Bronstad, M.E.	356, 357
Beliveau, J.G.	1581	Blanchard, U.J.	497	Brooks, J.E.	503
Belkune, R.W.	849	Błaszczuk, J.	731	Brown, A.G.	684
Bell, H.H.	64	Blech, J.J.	367	Brown, D.	1118
Bell, W.A.	1740	Bleich, H.H.	236, 807	Brown, D.L.	71, 380
Belsheim, R.O.	506	Bloch, H.P.	253, 669	Brown, D.L.	513, 514
Beltzer, A.	1572	Blomquist, D.S.	1715	Brown, K.W.	1792
Belytschko, T.B.	1669	Bloomer, H.E.	330, 606	Brown, S.M.	1833
Benedetto, G.	36	Bodlund, K.	651	Brown, T.J.	37
Benepe, D.B., Sr.	450	Bodner, S.R.	979	Brownfield, H.A.	1098
Bennett, J.G.	881	Bodsworth, B.	1007	Bruce, J.R.	933
Bennett, R.O.	398	Bogdanoff, J.L.	897, 960	Bruce, N.E.	567
Bennett, S.C.	1301	Boghani, A.B.	348	Bruchmüller, H.G.	69
Bensema, W.D.	545, 546	Bohannan, W.R.	607	Brueck, D.M.	321
Bensinger, C.T.	859	Bohn, D.	352	Bruton, D.	191
Benson, J.B.	234, 1654	Bojadziev, G.N.	1178, 1210	Bryant, R.W.	1095
Benton, M.	1801			Bucco, D.	1309
Beranek, L.L.	822			Bucher, K.M.	1408

Budcharoentong, D.	1442	Cavin, R.K.	1687	Chonan, S.	578, 1440, 1614
Budzynski, G.	1126	Cawthorn, J.E.	70	Chopra, A.K.	229, 390, 791, 1585
Bulanowski, E.A.	1882	Cawthorn, J.M.	217, 1484, 1558	Choudhary, S.	1134
Bull, M.K.	102	Caywood, W.C.	740	Chow, J.H.	1523
Bullen, R.	387	Cendral, J.L.	1689, 1690	Choy, K.C.	1193, 1512
Bullock, R.L.	1864	Ceranoglu, A.N.	1150	Christiano, P.P.	739
Bullough, W.A.	1252	Cermak, G.W.	1078	Chrostowski, J.D.	747, 1710
Buono, D.F.	1753	Cermak, J.E.	676	Chu, F.H.	1830
Burkhardt, T.H.	1008	Chae, Y.S.	1021	Chuang, A.S.	1877
Burros, R.H.	1368	Chakrabarti, S.	739	Chuang, S.	370
Burroughs, C.B.	1462	Chamis, C.C.	647	Chung, J.Y.	436
Burrows, C.R.	184, 188	Chanaud, R.C.	1559	Chwieroth, F.S.	382
Bush, H.G.	1202	Chandiramani, K.L.	1142, 1369	Chyu, W.J.	1687
Bushnell, D.	926	Chandra, J.	576	Clapis, A.	537
Butler, T.A.	1693	Chandrasekaran, K.	429	Clapper, W.S.	68, 823
Byham, G.H.	1683	Chang, C.	1374	Clark, A.V., Jr.	1255
Byrne, R.	1187	Chang, C.H.	1304	Clark, B.J.	1013

C

Cadoff, M.A.	262, 1716	Chang, D.C.	630	Clark, D.R.	142
Cadou, P.B.	1493	Chang, H.	1560	Clark, J.A.	1280
Cagley, J.R.	1627	Chang, K.Y.	609	Clark, R.	866
Calcote, L.R.	356, 357	Chang, P.Y.	1889	Clarke, R.M.	1562, 1715
Camac, M.	90	Chang, S.H.	1685	Clayton, R.	383
Camp, R.T.	462	Chang, Y.W.	1672	Close, W.H.	1396
Campagna, A.O.	1875	Chao, K.-L.	1464	Clough, D.P.	391, 700, 1149
Canevet, G.	1634	Charnley, T.	1555	Clough, R.W.	675, 1149, 1645
Cannarozzi, A.A.	304	Chawla, D.R.	534	Coates, G.D.	217, 798
Caprihan, A.	407	Cheeseman, I.C.	256	Cochran, J.E.	190
Carbon, G.	1118	Chen, F.H.K.	1140	Cockayne, J.E.	935
Carden, H.D.	779	Chen, J.C.	4, 895	Cocking, B.J.	524
Cardou, A.	900	Chen, M.	1332	Coffey, C.G.	965, 1281
Carey, W.W.	1714	Chen, P.	1387	Cohen, M.J.	271, 272
Carlsoeoe, S.	145	Chen, P.J.	241	Coke, C.F.	453
Carlson, R.L.	409	Chen, S.S.	200, 201, 296, 945, 976, 1456, 1813	Cole, J.N.	1849
Carlton, D.	661	Chen, T.L.C.	1458	Collins, J.A.	59
Carne, T.G.	1140	Chen, Y.	757	Collins, J.D.	49
Carpenter, J.E.	434	Chen, Y.N.	1146	Collins, K.M.	1276
Carrier, R.	1361	Chenault, D.M.	28	Collins, R.G.	390
Carta, F.O.	810	Chenoweth, H.B.	1480	Collmann, K.D.	733
Caruso, H.	1432	Chenoweth, J.M.	947	Colpin, J.	1664
Casirati, M.	1043	Cherchas, D.B.	22	Colsher, R.	559
Castellani, A.	1411	Chesta, L.	456	Colton, D.	1385
Castoldi, A.	1043	Chester, C.V.	1565	Commings, D.E.	385
Catherines, J.J.	1635, 1636	Cheung, Y.K.	1644	Connelly, W.H.	111
Cattaneo, L.E.	1221	Chi, M.	1728	Connor, W.K.	1079
Caughey, T.K.	632, 1525	Childs, D.W.	874, 1890	Cooke, R.F.	573
		Chirby, A.E.	192	Cooley, D.B.	1864
		Chiu, H.	1528	Cooperrider, N.K.	473, 1729, 1873
		Cho, A.C.	192	Corbin, B.	973
		Chon, C.T.	1566	Cornell, R.W.	1803

Cost, T.L.	153, 1620, 1623, 1708	Davies, H.G.	1734	Distefano, N.	1528
Costantino, C.J.	697	Davies, M.	411, 1521	Dittmar, J.H.	617, 1010, 1666
Costello, G.A.	1626	Davis, A.M.J.	1386	Dittrich, G.	1661
Coull, A.	1643	Davis, J.	1766	Dix, R.C.	511
Coulter, G.	238	Davis, L.K.	45	Dobeck, G.J.	1383
Coupry, G.	1639	Davis, W.R., Jr.	71	Dodd, V.R.	539, 1109
Craggs, A.	131	Dawson, B.	411, 1521	Doggett, R.V., Jr.	1481
Craig, R.R., Jr.	199	Dawson, T.H.	1569	Dokainish, M.A.	150
Cramer, P.L.	795	Dayman, B., Jr.	1188	Dokhac, M.	1578
Cramer, P.L.	796, 797	De, S.	1225, 1543, 1544, 1722	Doki, H.	1826
Crandall, S.H.	1762	de Alba, P.	1403	Dokumaci, E.	1600
Crews, S.T.	615	De Barcellos, C.S.	1215	Dollyhigh, S.M.	449
Crighton, D.G.	256, 302, 961	deBarranger, A.	1692	Done, G.T.S.	911
Crimi, P.	1101	DeChoudhury, P.	903	Donnelly, H.L.	740
Crist, R.A.	1221	Decker, E.	1727	Doran, A.L.	875
Crocker, M.J.	441, 718, 1081	Deel, J.C.	379	Dorey, A.D.	173
Cronin, D.L.	765	Degener, M.	772, 894, 1200	Dornfeld, D.A.	1503, 1504
Cross, J.L.	140	Delany, M.E.	406, 1276	Dornfeld, W.H.	1258
Cross, R.	209	Delauzun, F.R.	464	Dove, R.C.	881
Crostack, H.A.	650	DeLoach, R.	863, 1484, 1558	Dowell, E.H.	760
Crowson, R.D.	61	Delph, T.J.	1574	Dowling, A.	1306
Culver, C.	1747	Demiray, H.	662	Dowling, P.J.	845
Cummings, A.	1303	Dempsey, T.K.	217, 798	Downs, B.	963
Cumpsty, N.A.	154	Dennison, E.E.	1042	Doyle, G.R., Jr.	879
Cunningham, A.M., Jr.	450	Densmore, J.E.	728	Doyle, V.L.	223
Cunningham, R.E.	754, 1051, 1891	Dent, E.J.	1685	Dozier, L.B.	1706
Cupp, R.E.	1771	Denver, R.E.	643	Dragonette, L.R.	1077
Cupps, F.J.	294	Deo, R.B.	127	Drake, M.L.	860, 1047
Curami, A.	540	De Pater, A.D.	158	Drenick, R.F.	392, 1545
Curreri, J.R.	40, 101, 1104	DerHagopian, J.	569	Dresig, H.	512
D		Derham, C.J.	1404	Drevet, P.	29
Dagen, J.D.	153	De Rouvray, A.L.	1584	Drosjack, M.J.	838
Dahlberg, T.	465, 1658	Deruntz, J.A.	944	D'Souza, A.F.	1866
Dalal, J.S.	1399, 1400	DeSilva, B.M.E.	420, 1789	Dubey, R.N.	1070
Dalibert, A.	224	Destuynder, R.	724	Dublin, M.	1686
Daniels, B.E.	291	Deurden, C.	1537	Dubois, J.J.	1584
Darlow, M.S.	1152, 1568, 1755	deV. Batchelor, B.	1785	Dubowsky, S.	1, 1805
Das, B.M.	1681	DeVries, W.R.	1503	Duchild, R.H.	715
Das, S.C.	1122	Dey, S.S.	768	Duda, J.	405
Dasgupta, G.	1585	Dhar, M.	1377	Duffek, W.	23
Dash, P.K.	1519	Dharmarajan, S.	120	Duggin, B.W.	56
Dastoli, B.J.	604	Diana, G.	825, 862	Duke, G.A.	834
Datta, P.K.	1524	Dicus, J.	1296, 1793	Dukkipati, R.V.	1804
Dau, K.	457	Dietrich, D.A.	349, 745	Dumont, R.S.	572
Davidson, I.	1035	Diez, L.	308	Dunderdale, T.C.	218
		DiMaggio, F.L.	236, 807, 999, 1000, 1542, 1624	Dungar, R.	1579
		Dimaragonas, A.D.	474	Dunn, S.E.	753
		DiNapoli, N.	1881	Duponchel, J.P.	29
		Di Pasquantonio, F.	622	Durenberger, D.W.	721, 1011
				Durgunoglu, H.T.	1746

Dutt, D.N. 1446
 Dyer, D. 1767
 Dykstra, R.A. 257
 Dym, C.L. 1764
 Dzygadlo, Z. 730, 731

E

Eastepe, F.E. 1316
 Ebcioglu, I.K. 1827
 Eberhard, J.P. 1547
 Eberhardt, W.I. 285
 Eckerle, W.A. 1020
 Edgar, L.J. 1322
 Edwards, J.W. 857
 Edwards, W.T. 1357
 Eghbali, B. 815
 Egolf, D.P. 261
 Ehlers, F.E. 459
 Eichler, J. 1328, 1711
 Eidinger, J.M. 1404
 Elber, W. 571
 Eldred, P.J.L. 1579
 Elishakoff, I. 992
 Elkins, J.A. 160
 Ellen, C.H. 96, 1308
 Elliott, S.J. 549
 Ellis, J.R. 179
 Elmadany, M.M. 150
 El Menoufy, M. 1346
 Elsabee, F. 1763
 El-Sharkawy, A.I. 1136
 Elwany, M.H.S. 1287
 Emery, A.F. 294
 Engel, Z. 1154
 Engels, R.C. 1228, 1397, 1531
 Engin, H. 1814
 Engler, G. 1112
 Engquist, B. 383
 Engstrom, S.P. 1086
 Enochson, L. 813
 Enserink, B. 1097
 Erickson, L.L. 1687
 Ericsson, L.E. 763, 1593
 Eriksson, L.J. 1879
 Eringen, A.C. 662
 Eshleman, R.L. 538
 Esmailzadeh, E. 1863

Eswaran, K. 417
 Ettles, C.M.M. 1356, 1884
 Evans, F.J. 1530
 Evans, G.D. 404
 Evensen, D.A. 747, 1710
 Eversman, W. 1299, 1300
 Ewins, D. 569

F

Fafian, M. 1677
 Fahy, F.J. 819, 1279, 1486, 1736
 Falco, M. 862
 Falk, S. 1366
 Fallon, W.J. 1873
 Fancher, P.S., Jr. 178
 Fandrich, R.T. 72
 Farassat, F. 37
 Farshad, M. 1612, 1828
 Fasanella, E.L. 861
 Faulkner, L.L. 80, 855, 1006, 1788
 Fave, J. 1578
 Fawcett, J.N. 814, 1515, 1516
 Fawzy, I. 758
 Fearon, W. 1842
 Feiler, C.E. 605, 606
 Fein, J.A. 371
 Felix, M.P. 1020
 Felsen, L.B. 1134
 Felske, A. 359, 1117
 Felszeghy, S.F. 293
 Feng, T.-T. 908, 1705
 Ferrara, P.L. 608
 Ferris, C.D. 1172
 Ferritto, J.M. 529
 Ficcadenti, G. 1314
 Fien, A. 133
 Filho, F.V. 1721
 Filipich, C. 582, 1144
 Filippi, P.J.T. 214, 1230, 1231
 Finck, H.D. 446
 Fine, D.S. 1678
 Fink, H.I. 697
 Fink, M.R. 727, 1676
 Finley, T.D. 863
 Finney, R.H. 126
 Fiorato, A.E. 434

Firbank, T.C. 901
 Firth, R.D. 1619
 Fischer, E.G. 916
 Fischer, K.E. 1046
 Fischer, U. 504
 Fish, R. 162, 1182
 Fisher, D.K. 64, 65, 258
 Fisher, E.A. 625
 Fisher, W.E. 594
 Fistedis, S.H. 1672
 Fitzpatrick, M. 1881
 Fix, G.J. 907
 Flax, L. 1077
 Fleeter, S. 1791
 Fleming, D.P. 620
 Flink, J. 1272
 Flis, W.J. 86
 Florence, A.L. 703, 1748
 Flower, W. 1156
 Floyd, J.K. 1352
 Flynn, L. 207
 Foersching, H. 1464
 Foley, F. 16
 Foss, R.N. 221, 325
 Foster, A.W. 1157
 Foster, C.R. 1388
 Foster, L.W. 1862
 Foughner, J.T., Jr. 859
 Foutch, D.A. 1334, 1646
 Fowler, J.R. 625
 Fox, G.L. 147
 Foxon, M.B. 1252
 Fradellos, G. 1530
 Frain, W.E. 66
 Franz, L. 516
 Frazier, B.D. 1547
 Fredberg, J.J. 1171
 Freund, L.B. 830
 Freymann, R. 894
 Friedman, M. 500
 Friedrich, H. 1242
 Frieze, P.A. 845
 Frigeri, C. 540
 Frohrib, D.A. 1836
 Fryer, B.A. 21
 Frye, J.L. 1420
 Fu, H. 439
 Fuca, T. 386
 Fuchs, H.V. 1389, 1477
 Fujii, K. 1761

Fujii, Y.	1607, 1608	Gear, G.W.	1701	Gran, C.S.	960
Fujimoto, H.	1289, 1337	Gebhardt, W.	151	Grant, D.A.	1291
Fujisawa, F.	1665	Geers, T.L.	944	Grant, G.N.C.	420, 1789
Fujiwara, K.	132	Geissler, W.	1640	Greenfield, L.P.	1494
Fukano, T.	1347	Geller, R.J.	1338	Gregory, D.L.	62
Fukazawa, K.	556	Genin, J.	276, 1311	Greif, R.	557
Fukuoka, H.	402	George, J.	382	Griffin, M.J.	144, 1341, 1342, 1491, 1652
Fuller, C.R.	1302	George, O.D.	942, 943	Griffin, O.M.	263, 277, 1412
Fullman, D.G.	135	George, P.T.	1768	Griffiths, I.D.	464
Funahashi, A.	1099	Gerardi, T.G.	138	Groeneweg, J.F.	605, 752
Fung, Y.C.	287	Gerbert, G.	1894	Groesbeck, D.	523
Funk, J.G.	1871	Gergely, P.	658	Groom, N.J.	870
Funnell, W.R.	884	Ghai, R.C.	270	Grover, G.K.	995
Funnell, W.R.J.	1461	Gianetti, C.E.	308, 1144	Grover, L.K.	1810, 1811
Furuhashi, T.	1305	Giansante, N.	24, 375	Grubb, R.L.	1041
Furukawa, Y.	596	Gillespie, T.D.	177	Grundmann, H.	664
Fyfe, I.M.	1218	Glacel, R.A.	1632	Grzedzinski, J.	809, 1197

G

Gagnon, L.W.	1784	Glaser, F.W.	604	Gunter, E.J.	892, 1129, 1193, 1195, 1196, 1512
Gahlau, H.	327, 1633	Glassford, E.J.	1175	Gunter, R.R.	1185
Gahn, B.M.	692	Glenn, P.K.	1239	Gunzburger, M.D.	907
Galatsis, A.G.	612	Glynn, C.C.	78	Gupta, B.P.	126
Gallo, J.G.	1797	Gmelin, B.	1488	Gupta, K.	1824
Galloway, W.J.	385, 463, 640	Go, J.C.	28	Gupta, N.K.	1712
Gallus, H.E.	352	Godden, W.G.	339	Gupta, R.S.	1282
Gambhir, M.L.	1785	Goel, B.S.	1319	Gupta, U.S.	1616
Gamer, U.	1823	Goff, R.J.	1410	Guruswamy, P.	1312
Gamon, M.A.	1725, 1854	Goglia, G.L.	274, 644	Guthrie, K.M.	526
Ganapathi, K.	417	Gokhale, P.S.	1001	Gutierrez, J.A.	791
Garba, J.A.	634, 895	Gold, B.	938	Gutierrez, R.H.	430, 707
Garg, D.P.	880	Goldsmith, W.	293	Gutowski, T.G.	1487, 1764
Garg, V.K.	878	Good, M.C.	173, 480	Guyader, J.L.	1391, 1466
Garinther, G.R.	612	Goodall, R.E.	1153	Guyenne, T.D.	1690
Garner, H.C.	458	Goodling, E.C.	906		
Garnier, J.L.	1254	Gordon, D.F.	526		
Garrott, W.R.	114	Gordon, J.T., Jr.	1016		
Gartenbaum, E.	735	Gordon, R.W.	137, 1844		
Gasch, R.	165, 186, 365	Gorman, D.J.	993, 1317		
Gasper, R.	1113	Gosele, K.	245		
Gasparetto, M.	862	Gösele, R.	347		
Gasparini, D.A.	393	Gosele, U.	245		
Gatchel, S.G.	1601	Gossmann, E.	1548		
Gates, R.M.	373, 374	Gostling, R.J.	160		
Gaul, L.	738	Goto, N.	1582		
Gazanhes, C.	1254	Gottlieb, C.L.	1018		
Gazzillo, V.	386	Gouda, Z.M.	372		
		Gould, P.L.	1550		
		Goyder, H.G.D.	196		
		Grabitz, G.	282		
		Graham, L.J.	1108		
		Graham, R.A.	1115		

H

Habault, D.	1230, 1231
Habercorn, G.E., Jr.	204
Habermann, H.	968, 1604
Hablani, H.B.	924
Hackett, O.F.	143
Hackney, J.R.	1097
Haddad, S.D.	613

Hadden, J.A.	473	Hatano, M.M.	1675	Higginson, G.R.	1489
Haddow, J.B.	1246, 1812	Hatano, S.	686	Higginson, R.F.	1848
Hadjian, A.H.	1876	Haug, A.J.	1232	Hight, T.K.	1490
Hafen, B.E.	966	Haug, E.J., Jr.	908, 1705, 1807	Hilber, H.M.	767
Hafez, M.M.	377, 1703	Haupt, U.	1295	Hildebrandt, C.	322
Hagg, A.C.	12	Hauschild, W.	165	Hill, J.T.	891
Hahn, E.J.	368, 369, 1194	Hawkings, D.L.	124	Hill, R.E.	192
Hales, F.D.	918	Hayama, S.	103	Hillquist, R.K.	639
Hall, W.E., Jr.	337	Hayashi, T.	402	Hilton, D.A.	191, 1846
Hall, W.J.	1333	Hayden, R.E.	744	Himelblau, H.	192
Halle, H.	975	Hayes, G.G.	481	Hinchey, M.J.	746
Haller, M.N.	1724	Hayon, R.	1575	Hinckley, D.	16
Halliwell, D.G.	470	Hays, W.W.	1749	Hipkin, E.L.	1415
Halloran, J.D.	552, 553, 554, 1497, 1591	Healey, A.J.	885, 1340	Hiromitsu, S.	1216
Halvorsen, W.G.	380, 1758	Heard, J.M.	1708	Hirose, A.	121
Hamdan, S.M.	1370	Heard, W.L., Jr.	1202	Ho, C.-H.	342
Hamel, P.	1488	Hearn, N.D.	1048	Ho, W.F.	1395
Hamilton, J.F.	855	Hearn, T.C.	194	Hobbs, R.E.	845
Hammann, J.	237	Hedaya, M.T.	667	Hoch, R.G.	30
Hananel, A.S.	1685	Hedrick, J.K.	163, 611	Hodges, D.H.	616
Hancock, R.N.	20	Heggie, A.S.	1536	Hodgson, T.H.	932
Hanff, E.S.	678	Heidmann, M.F.	349, 745, 1013	Hoenlinger, H.	725
Hansbo, S.	1765	Heimann, A.	1415	Hoesly, R.L.	646
Hansson, J.E.	145	Heimann, B.	1220	Hofmann, L.G.	364
Happe, A.	359	Heimbigner, G.	1589	Hofmeister, L.D.	1704
Harada, H.	1507	Heimbold, G.K.	1055	Holder, B.W.	81
Harari, A.	295	Hein, W.	1204	Holliday, B.G.	863, 1484, 1558
Harder, T.	143	Heinrich, H.G.	794	Holmer, C.I.	1009
Hardtke, H.J.	1219	Heissing, B.	955	Holmes, A.G.	1356, 1884
Hare, R.B.	612	Heller, R.	1659, 1729	Holmes, H.K.	863, 1484, 1558
Harnik, E.	677	Helms, H.	166	Holmes, P.J.	378, 499, 1105
Harp, J.A.	1510	Hemmig, F.G.	1316	Holmes, R.	1028
Harper, P.M., Sr.	1835	Henderson, F.M.	210	Holoyen, S.	1449
Harr, M.E.	886	Henderson, H.R.	1846	Holzweissig, F.	1219
Harris, A.S.	1223	Henderson, T.D.	673	Homans, B.	1637
Harris, C.J.	1054	Henneke, E.G., II	1770	Honda, A.	246
Harris, W.L.	344, 1429	Hennig, K.	1242	Hong, C.	1248
Harrison, E.	858	Hensing, P.C.	734	Hongo, S.	1379
Harrison, H.D.	1034	Herbage, B.S.	558	Hood, W.C.	332
Hart, G.C.	636, 642, 781, 864, 865	Herrara, R.A.	788	Hoover, J.W.	1453
Hart, J.'t	360	Herrmann, G.	266, 830, 1574	Hopkin, A.S.	649
Hartnett, E.B.	496	Hersh, A.S.	547, 1234	Hoppe, G.	1117
Hartung, C.	593	Herting, D.N.	646	Horner, G.C.	1834
Hartwig, H.	1557	Hertz, E.V.	1660	Horonjeff, R.D.	218, 219
Hashmi, M.S.J.	980	Herzog, W.	1165	Horvath, A.J.T.	1032
Haslinger, K.H.	882	Hesselmann, N.	1005	Horvath, K.	10
Hassall, J.	1270	Heyman, J.S.	1264	Horvay, G.	938
Hasselmann, T.K.	1710	Hibner, D.H.	1752	Houghton, J.R.	13, 1588
		Hibner, D.H.	1753	Houser, D.R.	838
		Hidaka, T.	694	Housner, G.W.	1019, 1222

Howell, L.J. 67, 1161
 Howells, R.W. . . . 898, 1363, 1529,
 1696
 Howes, H.E. 275
 Hsieh, B.J. 1617
 Hsu, D. 1217
 Hsu, T.-I. 1563, 1744
 Hu, A.S. 1049
 Huang, B.K. 1680
 Huang, C.C. 48
 Huang, C.L.D. 583
 Huang, R.C. 1807
 Hübner, R. 433
 Huckelbridge, A.A., Jr. 1645,
 1647, 1858
 Hudson, D.E. 682
 Hughes, A. 250
 Hughes, T.J.R. . . . 767, 1525, 1526,
 1527
 Hullender, D. 1351
 Humar, J.L. 780
 Hundal, M.S. 1839
 Hung, S.J. 936
 Hunt, B.I. 146
 Hurst, N.J. 50
 Husak, A.D. 739
 Hussain, F.A. 1455
 Huston, R.L. 1656
 Hutter, K. 984
 Hwang, C. 453
 Hwang, Y.F. 1435

I

Ibrahim, R.A. 510, 774, 920,
 1072, 1226
 Ibrahim, S.R. 14, 208, 644
 Ikeda, K. 1003
 Illingworth, R. 169
 Imaichi, K. 121, 122, 123
 Imam, M.H. 1321
 Inasaki, I. 743, 1179
 Inoue, T. 187
 Ioi, T. 1003
 Irie, T. 310
 Isada, N. 164
 Isenberg, J. 981
 Ishida, K. 883

Ishii, N. 121, 122, 123
 Ishiyama, H. 1445
 Ito, H. 1289, 1337
 Ito, T. 246
 Ito, Y. 1249
 Iwahashi, Y. 87
 Iwan, W.D. 786, 1091
 Iwata, Y. 595
 Iwatsubo, T. 623
 Iyengar, K.T.S.R. 116
 Iyengar, R.N. 1519
 Iyengar, S.K.R. 915

J

Jackson, C. 957, 1416
 Jackson, J.E. 153
 Jacobson, I.D. 134
 Jacobson, M.J. 27
 Jacques, J.R. 29
 Jain, D.L. 1233
 Jain, V.K. 1383
 James, A. 1682
 James, P.K. 1775
 Jan, C. 1044
 Janetzke, D.C. 353
 Jarchow, F. 969
 Jayaram, V.D. 969
 Jayawant, B.V. 172
 Jeanpierre, F. 1459
 Jedryszek, J. 1052
 Jendrzeczyk, J.A. 990, 991,
 1813
 Jennings, D.E. 1630
 Jennings, P.C. 1222, 1334
 Jenniges, R.L. 1836
 Jha, S.K. 1635, 1636
 Jhaveri, D.P. 660
 Jillesma, P.J. 130
 Johal, L.S. 434
 Johannes, J.D. 152
 Johnson, G. 1657
 Johnson, M.R. 1186
 Johnson, W. 141, 1650, 1712
 Johnston, D.E. 364, 482
 Johnston, G.W. 1843
 Johnston, J.P. 1392
 Joiner, J. 1393

Jones, C.J. 129
 Jones, D.I.G. 974
 Jones, N. 1124
 Jones, R. 1027
 Jones, R.E. 1832
 Jones, W.L. 752
 Jonsson, H. 1894
 Joppa, P.D. 1218
 Joshi, S.G. 1213, 1367
 Joubert, P.N. 173
 Jovicic, J.O. 215, 216
 Junger, M.C. 1378
 Jury, E.I. 1720

K

Kaczenski, E.S. 938
 Kadala, P.S. 1659
 Kakad, Y.P. 871
 Kaliski, S. 934
 Kalnins, A. 699
 Kamal, M.M. 1073
 Kamal, W. 971
 Kamash, K.M.A. . . . 181, 182, 1354
 Kamat, M.P. 51, 705
 Kamel, H.A. 1198
 Kamil, H. 937
 Kamperman, G.W. . . . 816
 Kan, C.L. 229
 Kan, W. 1454
 Kanabis, W.G. 648
 Kanai, A. 595
 Kanai, K. 1227
 Kanarachos, A. 273
 Kanaya, O. 1002
 Kanber, H. 1699
 Kane, T.R. 815
 Kantola, R.A. 354
 Kanwal, R.P. 1233
 Kao, G.C. 609
 Kao, R. 1324
 Kapur, A.D. 534
 Karbassioun, A. 1318
 Kargaudas, V. 846
 Karkauskas, R. 850
 Karmakar, B.M. 117
 Karrholm, G. 1765
 Karsick, R. 1087

Kasbekar, P.V.	878	Kingery, C.	238	Koyanagi, S.	161
Kascak, A.F.	769	Kingsbury, H.B.	1102	Kraft, R.E.	692
Kasemset, C.	1644	Kingsland, R.B.	896	Krag, B.	334
Kato, Y.	1289	Kinnear, P.W.	192	Krajcinovic, D.	98
Katra, T.	1277	Kirk, J.A.	587, 713	Kramer, E.	621
Katsaitis, S.	1468	Kirk, R.G.	1191	Kreitlow, W.	824
Katto, Y.	288, 289	Kirk, W.P.	1496	Krenz, G.	454
Katz, R.	1861	Kishan, H.	460	Kress, R.	1385
Kauffmann, W.M.	139, 1339	Kitching, R.	1120	Krettek, O.	159
Kaul, M.K.	764	Kiyono, S.	1607, 1608	Krieg, R.	1668
Kaul, R.K.	1574	Kizirnis, S.W.	543	Krings, W.	1066, 1548
Kausel, E.	1763	Klahs, J.W.	575, 1116	Krishna, M.B.	1351
Kawahara, K.	623	Klammert, A.	1111	Krishna Murty, A.V.	1622
Kawai, R.	623	Klier, H.	1878	Krishnamoorthy, G.	342
Kawai, T.	1743	Knoell, A.C.	588	Kropp, P.K.	592
Kawamo, K.	187	Knofel, L.	1242	Krouse, J.K.	251
Kawashima, K.	1443	Knothe, K.	165	Krutinis, A.	835
Kayanickupurathu, J.T.	40	Ko, N.W.M.	384, 1395, 1733	Krutzik, N.	937
Kaza, K.R.V.	690	Kobayashi, S.	685	Ku, A.B.	267
Kearny, C.H.	1565	Koch, J.E.	806	Kubo, A.	1802
Keil, A.	562	Koch, M.	1655	Kugler, B.A.	385
Kellenberger, W.	684	Koch, W.	423	Kuist, C.H.	1398
Keller, A.C.	1274	Kodaira, M.	570	Kukreti, A.R.	629
Kelley, J.	996	Kodama, Y.	1347	Kulak, R.F.	1673
Kelley, J.M.	657	Koelbel, J.G.	917	Kulisiewicz, M.	633
Kellogg, R.B.	502	Koff, B.L.	1674	Kulkarni, P.A.	487
Kelly, J.M.	1244, 1404, 1837	Kogure, K.	485	Kulowski, A.	1126
Kampner, J.	1146	Kohler, W.E.	1390	Kumar, A.	416
Kennedy, J.M.	1669	Kohn, J.S.	691	Kumar, R.	576
Kennett, E.W.	1547	Kojima, H.	76	Kumar, S.	475
Kenton, E.	1546, 1719	Kolodziej, R.M.	552, 553, 554, 1497, 1591	Kumar, V.	843
Kerwin, J.E.	1684	Komori, S.	1460	Kumar, V.K.	1775
Kessler, F.M.	1559	Komura, Y.	1344	Kumbetlian, G.	1820
Khetan, R.P.	712	Koopman, G.H.	1511	Kundert, W.R.	817, 1269
Khurasia, H.B.	1465	Koopmann, G.H.	277	Kunicki, R.G.	1238
Kienappel, K.	1513	Koplik, B.	39	Kunieda, T.	1163
Kiessling, F.	1376	Kordes, E.E.	1686	Kunihiro, M.	1443
Kiger, S.A.	46, 61	Körner, K.	603	Kunukkasseril, V.X.	307, 1817
Kik, W.	165	Korner, W.	1648	Kurihara, M.	1781, 1782
Kikuchi, K.	685	Kortum, W.	23	Kurkov, A.	1296, 1793
Kilmer, R.D.	1715	Koshut, R.J.	1772	Kuroda, M.	686
Kim, K.H.	1680	Kost, G.	937	Kurtz, E.F., Jr.	478
Kim, Y.K.	1102	Koster, M.P.	983	Kvaternik, R.G.	690, 691
Kimball, B.S.	397	Kot, C.A.	698	Kwak, Y.K.	1176
Kimball, C.E.	356, 357	Kotowski, S.	424		
Kimsey, K.D.	1549	Kottapalli, S.B.R.	536		
Kimura, A.	1085	Koutsy, L.J.	1492		
Kimzey, W.F.	602	Koval, L.R.	1845		
King, K.W.	1749	Koyanagi, R.S.	671		
King, W.F., III	222, 521, 610				

L

Laan, J.N. 281

LaBarge, W.L.	1725, 1854	Leonard, R.G.	261, 1709	Lugner, P.	174
Lake, R.T.	1257	Leppington, F.G.	1386, 1556	Luhrs, R.A.	748
Lakin, W.D.	958, 1893	Lesser, M.	1407	Luisoni, L.E.	582, 872, 1144, 1314
Lakshminarayana, B.	689	Lester, G.M.	1423	Lujan, R.A.	28
Lal, S.	995	Lesueur, C.	1391, 1466	Luke, R.R.	625
Lal, R.	1616	Leung, Y.T.	563	Lukkunaprasit, P.	996
Lalanne, M.	569	LeVert, F.E.	954	Lund, J.W.	1130, 1885, 1888
Lambert, R.G.	58	Levine, H.S.	981	Lundberg, B.	1407
Lancey, T.W.	1236	Levinson, M.	1346	Lundholm, G.	972
Landgrebe, A.J.	142	Lewis, C.H.	1341, 1342	Luttrell, N.W.	1181
Lane, K.R.	530	Lewis, F.M.	1684	Luttwak, G.E.	1103
Lang, H.H.	440	Lewis, P.T.	1682	Lybas, J.M.	341, 709, 710, 1323
Langenberg, H.	493	Lewis, R.B.	863, 1484, 1558	Lynch, J.W.	863
Langer, H.J.	1488	Lewis, W.G.	143	Lyon, R.H.	775
Langland, R.	143	Liao, S.	1741	Lysmer, J.	1183
Lapini, G.	537	Liard, G.	968, 1604		
Lapins, M.	134	Libai, A.	702		
Large, J.B.	1080	Lin, Y.J.	1615		
Laszlo, C.A.	1461	Lin, Y.K.	243, 452, 1105		
Laudiero, F.	304	Lindberg, H.E.	933, 1619		
Laura, P.A.A.	308, 430, 582, 707, 872, 1144, 1314	Lindner, R.	785		
Laurenson, R.M.	628	Lingener, A.	551		
Law, E.H.	473, 1659, 1873	Linscott, B.S.	1122		
Law, R.	1069	Lionberger, S.R.	1792	McCarty, A.M.	1207
Lawdermilt, L.J.	1383	Lippmann, S.A.	316	McCharen, J.	782
Lawrence, A.	1007	Lisewski, W.	599	McConnell, K.G.	941
Lawrence, W.P.	975	Lisnitzer, M.	630	McCormick, R.B.	893
Lay, S.E.	1004	Liszka, L.	1853	McDaniel, D.M.	152
Leach, P.G.L.	1364	Little, L.M.	1410, 1637	McDonald, W.B.	1735
Leasure, W.A., Jr.	586	Liu, C.K.	913	McDonough, J.F.	693
Leatherwood, J.D.	798	Liu, D.	1198	McFarland, D.B.	513, 514
Lebel, D.	1360	Liu, H.-H.	581	McGarvey, J.H.	1027
Lee, A.	25, 34, 344, 1429, 1650, 1651	Liu, L.K.	1455	McGaughey, J.W.	1042
Lee, J.M.	941	Liu, W.K.	1525, 1526, 1527	McGehee, D.Y.	1340
Lee, L.C.	60	Livolant, M.	1459	McGehee, J.R.	779, 861
Lee, L.H.N.	2	Lloyd, A.J.P.	26	McGivern, J.G.	314
Lee, P.C.Y.	1384	Lo, H.	959	McGregor, R.M.	543
Lee, P.Y.N.	1840	Lodge, C.G.	455, 726	McGuckin, W.J.	249
Lee, R.A.	1850, 1851, 1852	Lofgren, E.V.	935	McIntosh, S.C., Jr.	1522
Lee, T.H.	1877	Longhouse, R.E.	1663	McIvor, I.K.	396, 397, 398
Lee, T.W.	899	Longinotti, D.B.	541	McKindra, C.D.	1502
Legendre, R.	831	Lopatowa, H.	1154	McKinzie, D.J., Jr.	1168
Leipholtz, H.H.E.	9, 912, 1365	Lottero, R.E.	1549	McLarty, T.E.	331
Leis, B.N.	1759	Lou, Y.K.	1463	McLarty, T.T.	212
Leissa, A.W.	203, 1209	Loukakis, T.A.	1199	McLaughlin, P.W.	1046
Leland, T.J.W.	348	Love, R.A.	1229, 1382	McLean, D.	335
Lemnios, A.Z.	275	Lu, D.Y.	887	McLean, L.A.	1494
Lena, A.L.	1427	Lu, Y.P.	110	McLean, L.J.	1194
		Lubin, B.T.	841	McNiven, H.D.	1532, 1533
		Luco, J.E.	737	McTasney, R.	1769

Mc

M

MacBain, J.C.	303	Manuelyan, R.	1044	Meindl, H.G.	220
Macchi, A.	540	Marble, F.E.	154	Meirovitch, L.	1228, 1531
Macey, D.	1476	Marce, J.L.	626, 1578, 1690	Meissner, E.	104
Macinante, J.A.	867	Marchand, M.	1017	Melbourne, W.H.	400
Maciulevičius, D.	787	Marcus, M.S.	1611	Mellander, H.	1655
Mackay, J.F.W.	1240	Margolis, D.L.	635	Meller, T.	1159
Mackinnon, M.J.	1666	Marino, D.	840, 949	Mellor, M.	741
MacLaughlin, T.F.	1097	Mark, W.D.	1452	Melosh, R.J.	51
Madaramé, H.	1359	Markert, R.	365	Meltzer, G.	518
Maday, C.J.	1119	Marmol, R.A.	1754	Melvin, J.W.	234, 235, 1654
Madrox, V.	252	Maroney, G.E.	254	Melzig-Thiel, R.	518
Madsen, N.F.	1609	Marriner, J.E.	513, 514	Menichello, J.M.	643
Maekawa, S.	452	Marsh, A.H.	1638	Mente, L.J.	112
Maekawa, Z.	132	Marshall, K.Z.	319	Merchant, D.H.	374
Maezawa, S.	663	Martin, D.M.	1859	Merchant, H.C.	1016
Magee, C.L.	1473	Martin, G.C.	878	Merritt, J.L.	936
Magnus, R.	442	März, G.	237	Merritt, P.H.	17
Magnuson, A.H.	1361	Maslix, A.K.	695	Merritt, R.G.	340
Magrab, E.B.	1462	Mason, R.	1087	Merson, J.L.	881
Mahalingam, S.	1437	Masri, S.F.	79, 1865	Mertz, D.W.	765
Mahig, J.	871	Massoud, M.	1071	Mes, M.J.	1107
Mahin, S.A.	390, 788	Masuko, M.	1249	Messale, R.F.	484
Mahmoud, M.S.	7	Mathews, F.H.	56	Mettler, E.	1520
Mahrenholtz, O.	593	Mathews, R.E.	1037	Meyer, J.	1508
Maidanik, G.	503	Mathon, R.	1893	Meyer, R.J.	1590
Maier, R.E.	1042	Matkowsky, B.J.	3	Meyer, T.R.	193
Mains, R.M.	128	Matsuda, T.	883	Meyer, W.L.	1740
Mair, R.I.	471	Matsui, N.	148	Meyers, G.J.	1618
Majumdar, B.C.	486	Matsukura, Y.	187	Miao, W.	1357
Makarewicz, R.	1082, 1084	Matsumoto, H.	570, 1247, 1298	Michalak, C.H.	887
Makdisi, F.I.	1401, 1403	Matsumoto, K.	1139	Michalke, A.	522
Malik, L.R.	461	Matsuoka, Y.	1247	Michalopoulos, C.D.	81
Mallik, A.K.	100, 125, 555	Matsuura, M.	1305	Michel, U.	784, 1477
Malsch, H.	1441	Matsuura, T.	1790	Mickle, M.H.	7
Malthan, J.A.	74	Matsuzaki, Y.	287	Midha, A.	1806
Malvern, L.E.	59	Matta, R.K.	223	Miele, A.	1777, 1778, 1779
Mamode, A.	626	Matthai, H.	1117	Miksch, H.	955
Mancuso, J.R.	902	Matthiesen, R.B.	679	Mikulas, M.M., Jr.	1202
Mandadi, R.	1365	Mattu, R.K.	1037	Mikulcik, E.C.	14
Mangiavacchi, A.	1778, 1779	Matzen, V.C.	1532, 1533	Miller, C.A.	697
Mani, R.	823	Mayes, I.W.	1356, 1884	Miller, D.R.	320
Mann, F.I.	778	Mayes, W.H.	863, 1484, 1558	Miller, H.M.	714
Mann, R.A.	913	Maymon, G.	702	Miller, N.A.	672
Manor, H.	1284	Mayo, R.A.	619	Miller, R.K.	786, 1838
Manos, P.	647	Mazumdar, J.	194, 1309	Miller, S.R.	1409
Mantegazza, C.C.-P.	808	Mead, D.J.	125	Miller, W.T.	1558
		Meerbeck, K.	5	Mills, J.F.	218
		Meggitt, D.J.	966	Milton, J.E.	112
		Mehta, R.K.	1755	Minagawa, S.	803
		Mei, C.	95, 708	Mindlin, R.D.	268

Mingori, D.L.	875	Morrow, C.T.	44	Nakra, B.C.	534
Mioduchowski, A.	1246	Mors, H.	1160	Nalecz, A.	1189
Mirandy, L.	820	Mortell, M.P.	804	Nappi, A.	1411
Mirizzi, N.	840, 949	Mortland, K.	163	Narita, Y.	310
Misra, A.K.	812	Moseley, P.	15, 16	Narkis, Y.	271
Misra, J.C.	593, 1329	Moss, G.F.	448	Nash, P.T.	47
Mitchell, E.E.	858	Mote, C.D., Jr.	584, 1449, 1540	Nashif, A.D.	1758
Mitchell, G.C.	783	Motsinger, R.E.	692	Nassar, E.M.	1345
Mitschke, M.	1880	Mozo, B.T.	462	Nath, Y.	31
Mittal, A.K.	1518	Mruk, G.K.	552, 553, 554, 1497, 1591	Natham, E.	885
Mittendorf, S.C.	557	Muir, R.S.	376, 574	Nau, J.M.	790
Miura, H.	909	Muirhead, V.U.	673, 674, 721	Nayfeh, A.H.	705, 1136, 1450, 1816
Miwa, S.	951	Mukherjee, A.	415	Neal, E.	1728
Mixson, J.S.	1012	Mukherjee, P.R.	1643	Nefske, D.J.	1161
Miyashita, M.	595, 1050	Mukherjee, S.	1648	Neighbors, A.J.K.	1796
Mizoguchi, K.	1460	Müller, D.	1355	Nelson, F.C.	852
Mizushima, Y.	1114	Müller, J.	1111	Nelson, I.	985
Mizutani, K.	1599	Munaswamy, K.	1642	Nelson, P.M.	1732
MLakar, P.F.	276	Murata, S.	300	Nelson, R.L.	1439
Mochizuki, M.	742	Murman, E.M.	377, 1703	Nemat-Nasser, S.	803
Modi, V.J.	812, 1283	Murphy, G.	509	Neubert, V.H.	1601
Moe, G.	1762	Murphy, H.L.	1567	Neumann, R.	564
Moening, M.F.	1805	Murphy, J.A.	1418	Newbrough, D.E.	192
Moffitt, R.C.	142	Murray, L.O.	371, 483, 484	Newman, M.	778
Mohanty, A.K.	1029	Murthy, S.S.	490	Newmark, N.M.	1026
Mohanty, B.P.	1778	Murthy, V.R.	274, 421	Newsom, D.E.	656
Mohr, R.L.	337	Murty, A.V.K.	490	Ng-A-Qui, N.T.	886
Mohri, Y.	103	Myers, T.T.	364	Ni, C.	940, 1678
Moiseev, N.	689	Mykytow, W.J.	444	Nicholas, J.C.	970, 1196
Mojaddidy, Z.	1469			Nichols, R.S.	42
Molnar, A.J.	12			Nicholson, D.W.	1570, 1571, 1700
Montgomery, C.J.	1333, 1335			Nicol, S.W.	814, 1515, 1516
Montgomery, L.D.	1175			Niedzielski, J.	1833
Montgomery, S.T.	241			Nielsen, J.P.	1014
Moodie, T.B.	1812			Nigam, S.P.	995
Mook, D.T.	1816			Nikolakopoulou, G.	1624
Moore, E.F.	1106			Nilsson, A.C.	495
Moore, M.	816			Nishiwaki, N.	1249
Morado, J.Y.	1702			Nissim, E.	591, 1256
Moran, B.	197			Nix, H.D.	498
Moran, D.D.	483, 484			Nobile, M.A.	853
Moran, M.J.	1006			Noda, K.	89
Morand, H.	1575, 1577			Nogami, T.	950
Morfey, C.L.	32, 1737, 1738, 1739			Nogis, R.	787
Mori, E.	930			Nogis, R.	847
Morita, N.	1305			Nohara, M.	694
Morosow, G.	550, 1686			Nolle, H.	240
Morr, H.	1596			Nonaka, M.	1417
Morrav, J.P.	1763			Nonami, K.	1050

Noonan, C. 973
 Noor, A.K. 301
 Nordby, K.S. 1164
 Nordlin, E.F. 716
 Norgan, R. 1428
 Norling, R.L. 1534
 Norman, C.D. 866
 Norris, D.M. 197
 Norris, T.R. 612
 Nunn, R. 342

O

Obal, M.W. 75
 Oblizajek, K.L. 316
 O'Brien, J. 1040
 Oesterle, R.G. 434
 Ogawa, K. 1139
 Ogawa, T. 596
 Ogg, J.S. 687
 Oh, K.P. 1131
 O'Hearne, C.S. 193
 Ohga, J. 1114
 Ohmata, K. 284
 Ohta, M. 1216
 Ohta, Y. 1582
 Ohya, A. 1761
 Oie, S. 989
 Okamoto, T. 233
 Okayama, T. 1002
 O'Keefe, E. 1773
 O'Keefe, J.M. 1162
 Okrent, D. 1717
 Okumura, I. 1249
 Oladunni, J.O. 428
 Olas, A. 424
 Oleson, M.W. 506
 Olsen, N.L. 761
 Olsson, U. 1147
 Olunloyo, V.O.S. 984
 Orlandea, N. 1380
 Orlik-Ruckemann, K.J. 678
 Ormsbee, A.I. 492
 Osborn, J.E. 1059
 Oshita, J. 694
 Osman, M.O.M. 1804
 Ostiguy, G.L. 431
 Ota, H. 1599

Otsuki, Y. 1761
 Oved, Y. 1103, 1430
 Overway, N. 713

P

Paas, J.E. 692
 Pacejka, H.B. 130
 Packer, M.B. 1169
 Packman, P.F. 13, 1588
 Padovan, J. 106, 844
 Page, V.R. 350
 Paidoussis, M.P. 93, 561
 Pakstys, M.P. 52
 Pallett, D.S. 262, 1716
 Palmer, M.E. 109
 Pampreen, R.C. 890
 Pampura, D.P. 695
 Pan, M. 1133
 Pao, Y. 1150
 Pandit, S.M. 11, 773
 Pang, S.H. 981
 Pappas, M. 1702
 Pappas, M.S. 861
 Parashes, P.T. 1535
 Pardee, W.J. 1108
 Parekh, V.N. 409
 Parikh, P.D. 437
 Park, R.B. 1749
 Parker, A.T. 1768
 Parker, L.V. 1619
 Parker, R. 1307
 Parker, W.H. 345
 Parks, D.M. 716
 Parrott, T.L. 1076
 Parsons, K.C. 1491
 Partom, Y. 269
 Partridge, J.R. 566
 Passerello, C.E. 1656
 Pastorel, H. 1071
 Patel, M.H. 1641
 Patten, J. 164
 Patterson, J.H., Jr. 462
 Pavithran, S. 1312
 Pearson, R. 238
 Pearson, A.J. 443
 Pecelli, G. 777
 Pelz, W. 319

Penterson, C.A. 946
 Penzes, L.E. 106, 1036
 Penzien, J. 1332
 Pepitone, T.R. 1056
 Perera, W.G. 842
 Perkins, J. 1166
 Perl, E. 532
 Ferreira, N.D. 388
 Perrella, W.M., Jr. 1855
 Perrin, R. 1555
 Perrone, N. 1324
 Persson, U. 1894
 Perumalswami, P.R. 1399, 1400
 Peschier, T.D. 674, 721
 Peterka, F. 756
 Peterson, D. 627
 Petre, A. 1326
 Petrovski, J. 735
 Pettigrew, M.J. 1875
 Petyt, M. 265
 Petzold, L. 1701
 Pfaffinger, D.D. 1707
 Pfizenmaier, E. 35, 784
 Pfützner, H. 365
 Phelps, R.L. 319
 Philippin, G.A. 9
 Phillips, E.H. 1685
 Phillips, R.G. 1697
 Pick, R.J. 290
 Pickert, J. 597
 Pickett, G.F. 1229, 1382, 1506
 Piegert, R. 597
 Pierce, D. 448
 Piersol, A.G. 225, 759, 1237
 Pierson, W.D. 1628, 1629
 Pies, D. 220
 Pietrucha, J. 1170
 Pilkey, W.D. 1192, 1586, 1829,
 1830, 1834, 1889
 Piltner, R. 1554
 Piner, R.J. 1732
 Pinkham, C.W. 781, 864, 865
 Piotrowski, E. 730
 Pisarski, J.J. 1505
 Pish, R.H. 1381
 Piskorz, Z. 1123
 Piszczek, K. 1092
 Pittroff, H. 1498
 Pixton, T.A.H. 1158
 Pizzigoni, B. 622

Platin, B.E.	611	Radziszewski, B.	1062	Reismann, H.	581, 1618
Platzer, M.F.	1896	Rajamani, A.	305, 306	Remington, P.J.	749
Plimmer, R.N.A.	1605	Rajpaul, V.K.	26	Renfro, E.M.	736
Plotkin, K.J.	1238, 1239	Ramachandran, S.V.	1143	Renger, A.	1093
Pollard, J.D.	671	Ramaiah, G.K.	1315	Rennie, A.J.	1276, 1848
Pollard, M.G.	157	Ramakrishna, B.S.	1446	Rennison, D.C.	102
Pollin, I.	55	Ramakrishnan, R.	307	Rentz, P.E.	225, 759
Pollman, E.	1350	Raman, P.V.	116	Repa, B.S.	67
Pollock, A.	668	Ramberg, S.E.	263	Reynolds, W.R.	403
Pombo, J.L.	707	Ramboz, J.D.	671	Ribner, H.S.	1241
Poon, D.T.	1283	Ramesh, C.K.	849	Ricci, J.J.	484
Popov, E.P.	1023	Ramkumar, R.L.	705	Rice, E.J.	525, 606, 1135
Popplewell, N.	1240, 1243	Rammerstorfer, F.G.	704	Richards, T.H.	563
Posehn, M.R.	64, 65	Ramsden, J.N.	1509	Richards, T.R.	353
Posey, J.W.	1798	Ramsey, K.	1118	Richardson, H.H.	162, 1182
Post, M.J.	1771	Ramsey, M.	455	Richardson, J.D.	1318
Postlethwaite, B.C.	333	Raney, J.P.	1847	Richardson, M.H.	1214
Postnikow, O.K.	1110	Ranlet, D.	236, 999	Richardson, R.S.H.	240
Potter, J.R.	1786	Rao, B.V.A.	487	Rickley, E.J.	869
Pottinger, M.G.	319	Rao, D.K.	82, 1892	Riddle, D.W.	453
Powell, G.H.	213, 1610	Rao, G.V.	309	Rieger, N.F.	489, 1132
Powell, R.G.	1849, 1850, 1851, 1852	Rao, J.S.	91, 415, 418, 419, 1824	Riessberger, K.	167
Powers, W.R.	1102	Rao, M.V.	1312	Riffel, R.E.	1791
Prabhakaran, R.	305, 306	Rao, N.S.	1127	Riganti, R.	1089, 1756
Prasad, B.	266	Rao, S.S.	873, 1282, 1501, 1831	Riley, C.M.E.	978
Prathap, G.	413, 1313, 1444, 1467	Rao, U.N.	555	Rimrott, U.A.	1498
Pratt, H.K.	192	Rasmussen, G.	818	Ringo, B.C.	693
Pratt, R.L.	549	Rautenberg, M.	1295	Rio, R.A.	1766, 1769
Prause, R.H.	198	Ravenhall, R.	826	Ripianu, A.	1436
Price, G.V.	964, 965, 1281	Rawtarti, S.	1465	Rita, A.D.	1027
Price, M.H.	670	Ray, D.	660	Rivin, E.I.	1495
Price, W.G.	189, 1362, 1783	Razzacki, S.T.	476, 477	Rizk, M.H.	377, 1703
Pursel, H.D.	1095	Rebel, J.	720	Robbins, D.H.	398
Pustejovsky, M.	561	Rebiere, J.P.	1125	Robbins, F.F., Jr.	1008
Putter, S.	1284	Rebora, B.	77	Roberson, R.E.	479
R		Recklies, S.	598	Roberts, J.B.	1090, 1211
		Redd, L.T.	451	Roberts, J.W.	1226
		Reding, J.P.	1593	Robinson, D.W.	1713
		Reddingius, N.H.	211, 1075	Robinson, J.H., Jr.	394
		Reddy, C.P.	873, 1501	Robson, J.D.	181, 182, 1354
		Reddy, J.N.	426, 848	Rodger, I.A.	624
		Reddy, K.H.	505	Roeder, C.W.	1023
		Reding, J.P.	763	Roger, K.L.	723
		Rees, D.	914	Rogers, D.O.	1098
		Reethof, G.	427	Rogers, J.D.	946
		Reich, M.	39	Rogers, J.L., Jr.	708
		Reif, Z.	1113	Rogers, P.H.	395
		Reilly, M.J.	1100	Rogers, R.J.	290, 1285
		Reimherr, G.W.	1718	Rohde, S.M.	1131
		Reinl, H.	498	Rojahn, C.	679
		Rabinowitz, M.D.	368, 369		
		Rabinowitz, P.H.	195, 631		
		Radcliffe, C.J.	584		
		Råde, L.	1564		
		Rader, J.	1787		
		Rades, M.	1088		
		Radford, R.W.	876		
		Radwan, H.R.	170, 1311		

Romander, C.M.	1748	Sanderson, N.	1120	Schwerdtfeger, H.	1350
Romo-Organista, M.P.	654	Sandler, B.	982	Schwiesow, R.L.	1771
Rönitz, R.	889	Sankar, S.	105, 1804	Sciarra, J.J.	1529
Rosenberg, Z.	1103, 1430	Santini, P.	1250, 1411, 1691	Sclavounos, P.D.	1199
Rosendahl, R.	1559	Saravanja-Fabris, N.	1866	Scott, R.A.	776, 919
Roskam, J.	673, 674, 721	Sarin, S.L.	1872	Scotto, F.L.	1043
Ross, C.A.	112, 507, 1453	Sarpkaya, T.	278	Seabase, P.P.	313
	1827	Sarrailhe, S.R.	1048	Sebastian, J.D.	459
Ross, W.	16	Sasaki, K.	1417	Seed, H.B.	1183, 1401, 1403
Rossettos, J.N.	532	Sass, D.E.	991	Seeman, D.R.	1014
Rossini, T.	537	Sato, K.	565, 1121	Seffell, B.F., Jr.	1041
Rotem, A.	953	Sato, T.	1417	Segawa, Y.	1665
Rothe, P.H.	1033	Sattaripour, A.	183	Segel, L.	317
Rouch, K.E.	1886	Satter, M.A.	1141	Seidman, H.	219
Rowan, W.H.	54	Saucier, K.L.	230	Seifert, K.D.	936
Roy, T.K.	438	Saurenman, H.J.	750	Seifert, P.	1557
Rubin, M.	1717	Savell, C.T.	33	Seiffert, H.	237
Rubinstein, N.	740	Saxena, S.K.	1649	Seiffert, U.W.	322, 1409
Rudnick, I.	1699	Scavuzzo, R.J.	577	Seiler, J.P.	1266
Runstadler, P.W., Jr.	1033	Schaefer, J.W.	330, 606	Seireg, A.	1801
Rus, L.	156	Schapiro, S.M.	910	Sekimoto, M.	1298
Rusnak, T.J.	1856	Scharton, T.D.	225, 856	Seleglim, P.	905
Russell, H.G.	434	Schauble, C.C.	1827	Sellappan, R.	1774
Russell, R.H.	379	Schauer, R.	973	Selman, A.A.	1158
		Scheel, J.W.	1095	Senda, Y.	1289, 1337
		Scheible, D.	237	Seniwongse, M.	1857
		Schetky, L.M.	1166	Sensburg, O.	733
		Schibli, U.	771	Sentek, J.	1235
		Schiehlen, W.O.	149	Serravalli, W.	825
		Schiff, A.J.	656	Sessarego, J.P.	1254
		Schippers, P.	443	Sethna, P.R.	910
		Schmid, G.	948	Settles, W.T.	401
		Schmid, W.	1679	Sevy, R.W.	1724
		Schmidt, K.-J.	824	Seymour, B.R.	804
		Schmidt, W.E.	1392	Shackelford, J.F.	1008
		Schmit, L.A.	909	Shah, P.C.	1067, 1174
		Schmitz, F.H.	343, 422	Shahabadi, A.	1331
		Schoeller, K.	1206	Shahady, P.A.	543
		Scholl, H.E.	863	Shahin, R.M.	1044
		Schomer, P.D.	1410, 1559, 1637	Shapiro, W.	559
		Schomer, R.D.	462	Shapton, W.R.	1074
		Schönfeld, S.	516	Sharma, C.B.	1288
		Schoultz, M.B.	140	Sharma, D.K.	1022, 1174
		Schramm, G.	249	Sharma, R.K.	805, 1751
		Schreyer, H.L.	41, 782, 1670	Sharp, B.H.	1239
		Schriever, H.	1151	Sharp, J.D.	860, 1047
		Schubert, D.M.	589	Sharp, R.S.	129, 667
		Schuerman, J.A.	1046	Sharpe, E.L.	571
		Schuetz, P.H.	192	Sharpe, R.	937
		Schuss, Z.	3	Shastri, B.P.	309

S

Saalfeld, M.	1160
Saari, D.P.	794
Sachs, G.	446
Sachs, H.K.	176
Sachse, W.	1741
Sackman, J.L.	293, 1244, 1837
Sadek, M.M.	1471
Saffell, B.F., Jr.	1037
Safford, F.B.	1425, 1514
Sahraoui, S.	1125
Saini, S.S.	1580
Saito, H.	962
Sajiki, A.	289
Sakai, H.	1002
Salamone, D.J.	1195
St. Hilaire, A.O.	810
Sakaguchi, K.	346
Sakata, T.	113
Salem, E.	971
Salemme, C.T.	826

Shaw, E.A.G.	528	Singh, R.	1277, 1278	Speakman, J.D. . 1849, 1850, 1851,	
Shaw, L.	83, 84, 85	Singh, S.P.	92	1852	
Shaw, L.L.	136	Sinha, S.K.	1320, 1626	Spencer, A.J.M.	83, 84, 85
Shaw, L.M.	604	Sinhasan, R.	270, 416	Spencer, R.H.	1180
Shawa, O.M.	711	Sisto, F.	833	Spera, D.A.	320, 353
Shawki, G.S.A.	1760	Sjoflot, L.	145	Sperling, A.	269
Shayo, L.K.	1308	Slabinski, V.J.	1576	Spiro, H.	220
Shearer, G.R.	315	Slibar, A.	180	Sridhar, K.	1113
Sheer, R.E.	338	Skrikerud, P.E.	1408	Sridhar, S.	1450, 1816
Sheikh, R.M.	1433	Slone, R.M., Jr.	1239	Srinath, H.	417
Sheinman, I.	1825	Smalley, A.J. . . 1152, 1472, 1568,		Srinivasan, A.V.	1792
Shen, C.N.	1606	1587, 1755, 1883		Srinivasan, K. . . . 1499, 1867, 1868	
Shende, R.W.	488	Smallwood, D.O.	62, 1422	Srinivasan, M.G.	98
Shepherd, R.	1745	Smigielski, P.	544	Srinivasan, P.	1213, 1367
Sherrer, V.C.	927	Smilowitz, R.	1026, 1336	Srinivasan, R.S.	1143, 1642
Shiau, L.C.	959	Smith, C.C.	885, 1176, 1340	Stahle, C.V.	681
Shiba, F.	233	Smith, C.D.	1076	Stalnaker, R.L.	235
Shibata, H.	1039	Smith, H.W.	673, 674, 721	Stanley, G.M.	706
Shimada, K.	951	Smith, J.H.	47	Stanley, R.A.	607
Shimizu, T.	1179	Smith, J.S.	1470	Stansfeld, J.T.	884
Shimogo, T. . . . 1781, 1782, 1874		Smith, N.	175	Stanway, R.	184
Shimojima, H.	1139	Smith, Z.P.	967	Starr, E.A.	822
Shin, Y.S.	990, 991	Smullin, J.I.	652	States, J.D.	1409
Shiozaki, S.	596	Sneddon, M.D.	856	Steele, J.M.	1267
Shirakawa, K.	1148	Snow, R.	1069	Stein, S.	1338
Shirk, I.A.	314	Snowdon, J.C.	853	Steinberg, D.S. . . . 297, 707, 872,	
Shirley, E.C.	1675	Snyder, W.J.	140	1063	
Shivakumar, K.N.	1622	Snyman, J.A.	1060	Steinborn, H.	165
Shivamoggi, B.K.	115	Soderman, P.R.	350	Stella, R.	840, 949
Shladover, S.E.	162, 1182	Soedel, W.	1278, 1377, 1475	Stengel, R.F.	1208
Shrivastava, S.K.	924	Sofrin, T.G.	1506	Stensson, G.	1894
Shu, T.	721	Sofronie, R.	1173	Stepanishen, P.R. . 381, 931, 1808	
Shunmugavel, P.	170	Sohre, J.S.	766	Stephen, R.M.	735
Sierakowski, R.L. . 59, 507, 1453,		Solaini, A.V.	1859	Stephens, D.G. . . . 638, 863, 1484,	
1827		Solomon, S.G.	1232	1558	
Sigelmann, R.A.	407	Solomon, K.A.	1717	Sternberg, R.L.	527
Simmons, H.	867	Sommer, J.	1661	Stevens, C.L.	192
Simmons, P.E.	641	Soni, S.R.	232	Stevens, R.A.	192
Simonian, S.	636	Sonnenburg, P.N.	594	Stevenson, R.	1207
Simons, D.H.	1427	Sonoda, N.	686	Stewart, E.C.	451
Simpson, A. 8, 279, 403, 911		Sonoda, S.	300	Stewart, E.C.	1481
Simpson, I.C.	1583	Soper, W.G.	259	Stewart, R.M.	1767
Sinacori, J.B.	821	Sorgatz, U.	363	Stiffler, A.K.	1128
Sinclair, J.H.	647	Sosa, F.	63	Stoker, J.R.	716,, 1509
Sindelar, F.L.	64	Sozen, M.A.	709	Stokey, W.J.	577
Singh, A.K.	843	Sozen, M.A.	710	Stolberg, A.L.	1265
Singh, D.V.	270, 416	Spagnolo, R.	36	Stone, J.R.	1083
Singh, K.	100	Spalding, G.R.	1833	Stott, S.J.	1212
Singh, M.	176	Spanos, P.-T.	1091	Stoughton, R.L.	716
Singh, M.P.	655	Sparkes, C.	1080	Stravinskias, S.	839

Strenkowski, J.S.	925, 1829, 1889	Szostak, H.T.	364	Thomas, D.L.	1439
Strickland, W.S.	112, 507	Szymani, R.	1540	Thomas, E.S.	777
Striem, H.L.	389			Thomas, J.	829
Stringas, E.J.	33, 68, 823			Thomet, M.A.	879
Strong, B.R., Jr.	988			Thompson, D.E.	689
Strother, C.	1881			Thompson, G.D.	361, 1595
Strothman, W.	166			Thompson, W.C.	348
Struble, D.	1881	Tabba, M.M.	264	Thompson, W.E.	185
Stryczek, S.	1031	Tabor, F.H.	1594	Thomsen, K.K.	1130
Stühler, W.	1204	Tadjbakhsh, I.	1828	Thomson, B.	209
Su, T.C.	1463	Taft, C.K.	1795	Thormann, J.	186
Suematsu, Y.	246	Tagart, S.W., Jr.	1094	Thornton, E.A.	97
Suggs, C.W.	1343	Tagata, G.	1447	Thornton, P.H.	1473
Suhubi, E.S.	1814	Tagg, R.W.	1478	Threlfall, D.C.	1730
Sullivan, D.F.	852	Tait, J.N.	38, 242	Tijdeman, N.	443
Sullivan, J.W.	520, 1081	Takagi, S.	246	Tillou, F.M.	1424
Sullivan, P.A.	746	Takahashi, H.	742	Ting, L.	1451
Sullivan, T.L.	320	Takahashi, S.	410, 556, 1445	Tobe, T.	565
Sun, C.T.	118	Takamatsu, Y.	1347	Todd, E.S.	729
Sung, S.H.	696	Takano, E.	89	Tokel, H.	833
Sunnersjo, C.S.	1603	Takano, K.	288	Tominari, N.	742
Suss, S.	93, 561	Takatsu, N.	565	Tomlinson, G.R.	1349
Sutherland, G.H.	1448	Takeda, S.	76	Tonnesen, J.	1885
Sutherland, L.C.	220	Takemoto, S.	123	Tonou, K.	743
Sutton, L.R.	1551	Takeuchi, R.	989	Topper, T.H.	9
Sutton, T.	828	Talmadge, R.D.	1844	Tordion, G.V.	900
Suzuki, K.	410, 556, 1445	Tam, P.K.Y.	189	Torvik, P.J.	1780
Suzuki, N.	595	Tamura, A.	485	Townley, G.E.	1116
Suzuki, S.	312, 1507	Tanaka, H.	1294	Townsend, M.A.	13, 1588
Suzuki, S.-I.	412, 1286	Tanaka, K.	87	Townsend, W.H.	665
Svalbonas, V.	699	Tanaka, N.	595	Toyoda, M.	1251
Swaim, R.L.	135	Tanaka, T.	402	Traill-Nash, R.W.	460
Swamidas, A.S.J.	1817	Tani, J.	1826	Tree, D.R.	717, 1325
Swaminadham, M.	832	Tani, M.	1099	Trella, T.	1087
Swaminathan, M.	418	Tanimoto, N.	402	Trigg, N.E.	1260
Swanger, H.J.	1742	Tanner, R.	1881	Trippett, R.J.	1131
Swansson, N.S.	834	Tappert, F.D.	1706	Trn, R.M.	628
Sweet, A.L.	276	Taylor, H.R.	1500	Troger, H.	180
Swick, D.A.	227	Taylor, P.W.	286	Troha, W.A.	1769
Swift, M.R.	1360, 1361	Taylor, R.	1167	Troxell, D.E.	739
Syed, A.A.	1301	Taylor, R.E.	1694	True, D.G.	372
Sylvestre, Y.	1875	Tene, Y.	1825	True, H.C.	869
Symonds, P.S.	979, 1566, 1750	Teplitzky, A.M.	1561	Tsai, N.C.	666
Syring, R.P.	1628, 1629	Terauchi, Y.	694	Tsai, N.C.	1038
Szadkowski, A.	1062	Termuehlen, H.	1350	Tsay, C.-S.	426, 848
Szadkowski, J.	1058	Teshima, T.	1344	Tseng, W.S.	666, 1038
Szelag, D.	1170	Tessarzik, J.	1766	Tso, W.K.	1744
Szemplinska-Stupnicka, W.	1517	Tessarzik, J.M.	1883	Tsui, C.Y.	928
Szewczyk, V.M.	1737	Tessmann, R.K.	254	Tsujimoto, Y.	300
Szewczyk, V.M.	1738, 1739	Tester, B.J.	32	Tsztoo, D.F.	657
		Tezcan, S.S.	1746	Tu, K.	88

Tucker, A.I.	837	Varadhi, S.N.	1649	Ward, D.W.	1484, 1558
Tucker, J.R.	1728	Varma, P.K.	475	Ward, E.D.	321, 1709
Turhan, D.	939	Vaughan, V.L.	793	Washizu, K.	1761
Turkstra, C.J.	264	Vause, C.R.	343, 422	Wasserman, Y.	283, 1800
Turman, G.W.	887	Vavrick, D.J.	435	Watanabe, T.	103, 663, 1809
Turnbull, S.R.	814	Vendhan, C.P.	579	Watson, H., Jr.	1433
Turner, E.W.	732	Verdon, J.M.	298, 299	Watson, J.H.	1698
Turner, M.R.	726	Vered, M.	389	Weatherill, W.H.	459
Tustin, W.	73, 202, 1426	Verschoore, R.	318	Weaver, D.S.	1810, 1811
Tuten, J.M.	1659	Vey, E.	1649	Weber, O.	363
Twardosz, F.	997	Vijayakumar, K.	1315	Weeks, G.E.	1620
Tweed, L.W.	717, 1325	Vijayaraghavan, A.	632	Wegner, T.	997
Twerdochlib, M.	1496	Villalaz, P.A.	771	Wehage, R.	1380
Twill, J.P.	1795	Visnapuu, A.	1004	Weidenhamer, G.H.	785
Tzafestas, S.G.	1372	Vlk, F.	888	Weidlinger, P.	985, 986
		Vo, P.T.	1300	Weingold, H.D.	811
		Vogt, W.G.	7	Weir, D.H.	171
		Volin, R.H.	1413	Weissner, R.	1096
		von Buseck, C.R.	1078	Weitsman, Y.	57
		VonGlahn, U.	523	Welbourn, D.B.	568
		Voy, C.	1184	Welbourne, E.R.	1068
				Welch, C.R.	45
Überall, H.	382, 1232			Weller, W.H.	239
Uchiyamada, T.	1163			Wellford, L.C.	1703
Udwadia, F.	79			Wells, R.A.	1229, 1382
Udwadia, F.E.	1022, 1067, 1174			Wells, R.W.	1506
Uffer, F.	77			Wells, W.R.	19
Ugai, Y.	1507			Wen, Y.	655
Uginičius, P.	382			Wendler, B.H.	594
Ujihashi, S.	570			Wendroff, B.	53
Un, W.K.	1395			Wesler, J.	929
Upton, R.	1273			Westcott, M.E.	1486
				Westervelt, W.W.	1803
				Wetzel, D.	827
				Whaley, P.W.	75
				White, J.L.	729
				White, R.N.	658
				Whitham, E.M.	144, 1652
				Whitman, R.V.	1763
				Widnall, S.E.	344
				Wierwille, W.W.	67
				Wierum, H.	1371
				Wilby, J.F.	225, 652
				Wild, R.	1155
				Wild, R.E.	317
				Wiley, A.	828
				Wiley, J.C.	1380
				Wilgen, F.J.	491
				Wilken, I.D.	436
				Wilkerson, J.B.	515
				Williams, D.	339

ANNUAL SUBJECT INDEX

- A -												
Acoustic Measuring Instruments												
260 1264												
Acoustic Properties												
1773 1554												
Acoustic Radiation												
930												
Acoustic Reflection												
1392 1818												
Acoustic Resonance												
215 216 1307												
1815												
Acoustic Scattering												
1231 382 1734 1556 1387												
1741												
Acoustic Signatures												
1770 1074 1846 468 349												
1108												
1258												
Acoustic Techniques												
953 1057 1699												
1277												
Acoustic Tests												
1434 896 257 1168												
1426												
Acoustic Waves												
1385 1386												
Active Absorption												
1634												
Active Damping												
742 595												
Active Flutter Control												
1170 722 723 724 725 726 857 1488												
Active Isolation												
133 134 858 1169												
404												
Abstract												
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896												
Volume 10												
Issue: 1 2 3 4 5 6 7 8 9 10 11 12												

Ammunition					Artillery Fire									
683										55 56				
Amphibious Vehicles					Asymmetry									
483 484										1599				
Amplification					Automated Transportation Systems									
72 35					162									
					1182									
Amplitude Analysis					Automobile Bodies									
1823 1016					1140					396 397				
Amplitude Data										1116				
103														
Analog Simulation					Automobiles									
1184					1180 921 482 173 174 175 176 1188									
					1161 922 363 364 885									
Anechoic Chambers					1073									
1113 405 257 69					1353									
Angular Vibration					Automobile Seat Belts									
75										1096				
Anisotropic Properties					Automobile Tires									
use Anisotropy										437 438				
Anisotropy					Axial Excitation									
705					702 1443 1304									
Ankles					Axisymmetric Vibrations									
1018										997 1329				
Antennas														
1281 964 965 527														
Anthropomorphic Dummies					- B -									
234 1655 1049														
1654														
Approximate Methods					Balancing									
use Approximation Methods					use Balancing Techniques									
Approximation Methods					Balancing Techniques									
117					540 401 1416 1257 489									
1367					951 1586 1587 1769									
Arches					1766									
1800 981 283 47														
Articulated Vehicles					Ball Bearings									
180 1185 1156 179					1110 754 89 969									
					Barges									
					513 514									
					Bars									
					410 1121 402 1445 226 87 409									
					1830 1247									
Abstract														
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896														
Volume 10														
Issue: 1 2 3 4 5 6 7 8 9 10 11 12														

Beams											
80	81	82	83	84	85	86	47	268	79		
100	411	412	573	264	265	266	77	688	269		
420	471	872	853	284	435	516	267	908	829		
690	711	962	1123	534	555	686	507	1288	979		
830	961	1282	1323	1124	855	1286	557	1758	1359		
920	1291	1292	1343	1284	925	1336	977		1469		
1440	1321	1442	1443	1444	1215	1776	1287		1829		
1600	1441	1782	1783	1774	1285						
1780	1781			1784	1775						
1830											
Bearings											
1131	622	273			416	187	968				
	892	1413				537	1448				
	1472					1767					
	1602										
Bellows											
1510											
Bells											
				1555							
Belt Drives											
900	901		1894								
Bernoulli-Euler Method											
81	1442	853									
Bernoulli Theory											
						268					
Bibliographies											
21	922		204	205	206	207	1718	1719			
921					1546	1227					
Bioengineering											
1171	1172					1018	1329				
Biomechanics											
			194								
Blades											
810	21	832	353	574	275	376	417	298	299		
	91		603	834		826		1788	1449		
			1793	1794							
Blast Effects											
		1623				1827					
Blast Excitation											
60	112				46						
Blast Loads											
										27	
Blast Resistant Construction											
Blast Resistant Design											
Blast Resistant Structures											
1021									1565		
									1705		
Blast Response											
1620			964	965					47	529	
				1565					507	1549	
										1619	
Boilers											
	572								1875		
Bolotin Method											
									1315		
Bond Graphs											
Bond Graph Technique											
									635		
Bones											
	1172										
BOSOR (Computer Program)											
									926		
Boundary Condition Effects											
80									1445	308	
Boundary Layer Excitation											
										79	
Boundary Value Problems											
1700	1571		383						1356	108	
	1701		583								
Box Beams											
									264		
Brakes (Motion Arresters)											
									1224	1117	359
Braking Effects											
									482	364	178
Abstract											
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896											
Volume 10											
Issue: 1 2 3 4 5 6 7 8 9 10 11 12											

Bridges
460 1331 592
530 1332
1330 1642

Buckling
1822 276 408

Buildings
780 341 342 213 394 735 676 637 788 519
461 1022 243 1024 775 1026 1547 868 679
1021 393 1484 1025 1336 1717 1558 929
693 1744 1245 1486 1747 1858 1649
863 1335 1646
1023 1405 1746
1043 1485 1856
1333 1645
1643 1745

Bumpers
322 323 854 207
922

Buses
362 323

- C -

Cable Cars
1203 88

Cables (Ropes)
263 1785 966 88
1723

Calibration
use Calibrating

Cams
1110 982 983

Cantilever Beams
1290 1601 1282 413 964 515 616 687 418 1249
1482 963 1284 965 1777 1308 1779
1283 1125 1778

Cantilever Plates
1611 1312 114 97
1612 1824 687

Caps (Supports)
1324

Cargo Ships
493

Cavitation
1684 698

Cavities
1232

Cavity-Containing Media
1387 1218

Cavity Resonators
520 1232 1845

Center Line Deflections
1120

Ceramics
241

Chain Drives
1110 1111 883 1515 1516

Chains
814 1207

Chatter
1500 11 742 743 595 596 597 858 1179
1502 773 1866 1867 1868 1499

Chimneys
959

Circuit Boards
297

Circular Cylinders
1133 976

Circular Membranes
425

Circular Plates
80 311 583 584 705 1616 1817
703 704 1615 1816
1614

Circular Rings
852

Circular Shells
570

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Computer Programs (Continued)

780 781 562 373 274 625 926 747 398 649
 1020 1381 782 513 374 645 1726 887 488 699
 1380 1551 1052 643 514 1035 1886 927 498 779
 1550 1601 1332 693 644 1075 1017 648 1229
 1610 1611 1382 783 1224 1285 1657 778 1379
 1730 1671 1552 1383 1724 1485 1687 1188 1549
 1740 1731 1662 1623 1685 1727 1628 1629
 1693 1725 1678 1659
 1803 1708 1729
 1718 1739
 1728
 1818

Computer Simulation

396

Computerized Simulation

1 795 1656 197 1858 1659
 51 1775 397
 1801

Concrete Construction

60 61

Concretes

230 533 1694 45 356 357 1799
 1580 716 1697

Configuration Effects

use Geometric Effects

Conformal Mapping

430

Conical Shells

1622 1464 997 1619

Construction Equipment

1394 1505 1379
 1675 1859

Construction Industry

1487 1559

Containers

493

Containment

1672 529

Containment Structures

661 1624 1035 807 658

Continuous Beams

1809

Continuous Parameter Method

572
 1372

Continuum Mechanics

1531 2 688
 22
 1242

Control Equipment

1420 1421 1422 64 1297 1499
 1424

Control Systems

use Control Equipment

Conveyors

814 346

Cooling Fans

use Fans and Cooling Systems

Cooling Systems

834

Cooling Towers

580 1438 1439
 960

Coriolis Forces

1782

Cornering Effects

160 177 439
 .879

Correlation Techniques

1241 634

Coulomb Friction

240 242 1253 1864 1895 1659
 1730

Coupled Response

930 91 872 1813 1607 1608 419
 1250 629
 1369
 1469

Coupled Systems

913

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

[illegible]

Dams
1580 121 122 123
1401 1402 1403
739

Data Dependent Systems
11

Data Presentation
1186

Data Processing
62 1413
672

Data Reduction
use Data Processing

Design Techniques
480 351 492 493 1534 355 566 407 568 469
630 891 562 983 1674 405 906 1107 828 909
890 1831 1202 1293 1475 1696 1207 898
1842 1875 1837

Detection
1057

Diagnostic Instrumentation
250 1261 252 1263 407 1259
1262 537

Diagnostic Techniques
670 251 252 63 254 1415 1416 247 248 249
1110 401 952 253 554 957 538 379
1260 1071 1112 553 624 1417 668 539
1590 1111 1063 1414 1767 1108 669
1258 1109
1418 1589
1588 1769
1768

Diaphragm Couplings
902

Diesel Engines
1160 751 613 884 355 476 477 1878
1675 1087

Digital Simulation
1680 611 13 14 915 1046 138 479
1184 188

Digital Techniques
42 813 914 15 16 137
542 65
505

Discontinuity-Containing Media
942 943 295
1142

Discrete Fourier Transform
1214

Discs
use Disks

Disks
574 417 1318
584

Donnell Theory
570

Drillships
use Drills/Ships

Drop Tests (Impact Tests)
683

Ducts
280 21 282 53 94 525 376 1137 978 1299
1300 281 692 423 1134 1135 746 1307 1798
1450 1301 1302 1303 1634 1676
1870 1451 1392

Dynamic Analysis
891 772

Dynamic Antiresonant Vibration Isolators
284 1027

Dynamic Balancing
667

Dynamic Buckling
1324 115 699

Dynamic Excitation
820

Dynamic Loads
use Dynamic Excitation

Abstract											
Numbers:	1:194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699 1700-1896
Volume 10											
Issue:	1	2	3	4	5	6	7	8	9	10	11 12

Dynamic Plasticity
711 1124 996 98 979

1566

Dynamic Properties
372 633 914 1205 1046 1017 1139

Dynamic Relaxation
845

Dynamic Response
570 741 513 164 625 446 447 448 619
1200 1361 783 304 695 1286 1018 1029
1490 1671 1243 334 765 1319
1383 514
694
984

Dynamic Stability
730 911 972 1053 1524 135 1196 1617 1248 769
910 1612 575 1828

Dynamic Stiffness
1472 563 1585

Dynamic Structural Analysis
770 461 1673 4 1055 26 77 998
771 1064 1686 767 1198
917

Dynamic Structural Response
use Dynamic Response

Dynamic Synthesis
1160 899

Dynamic Systems
1710 1 632 3 7 378 1709

Dynamic Tests
770 771 682 1043 1035 1686 197 678
1472 1453 1048
1593

Dynamic Vibration Absorption (Equipment)
853 714 76
1003

Dynamometers
1595

- E -

Earth Handling Equipment
1492 1177 1859

Earth Models
1338

Earthquake Damage
390 391 342 1334 1746 1217 389
1227

Earthquake Prediction
1722

Earthquake Resistant Design
use Earthquake Resistant Structures

Earthquake Resistant Structures
230 341 392 393 394 735 986 637 659
340 781 1222 693 434 865 1227 709
710 1221 1402 1023 864 985 1627 1039
960 1183 1404 1705 1717
1333 1747

Earthquake Response
230 791 682 213 1744 675 656 1648 679
1401 1532 623 1645 959
843
1183
1403
1533
1563

Earthquakes
933 657

Eigenvalue Problems
430 561 502 1893 994 1365 926 688 1059
780 1366 778
1530

Eigenvalues
use Eigenvalue Problems

Elastic Analysis
581 1376

Elastic Foundations
1440 471 1123 1614 266 117 438 829
1707

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Engine Vibration
613 475 1047 1878

Engines
872 139
1879

Environmental Effects
1772 193

Environment Simulation
16

EPSOLA (Computer Program)
1718

Equations of Motion
690 1693 1775 556 158 999
1360 1783 1199

Equipment Mounts
1470 71 715 1837
671

Equipment Response
541 542 655 1426 1837 48

Equivalent Sound Levels
1082 1433 1637

Error Analysis
40 321 1076
1220

Exhaust Noise
1879

Exhaust Systems
1235

Experimental Data
230 901 52 793 384 225 1186 507 608 1019
710 1131 402 973 434 565 1666 797 658 1149
1790 1491 592 1533 524 805 1097 1568 1249
1641 634 1655 1608 1629
1755 1628
1885 1858

Experimental Results
use Experimental Data

Explosion Detection (Nuclear)
use Nuclear Explosion Detection

Explosion Effects
980 236
1040

Explosions
936

- F -

Failure Analysis
1090 1211 92 893 1348
702 953
973

Fan Blades
use Fans

Fans
350 1791 602 543 604 225 606 617 348 349
470 1871 1382 1013 744 605 746 1257 468 469
1840 1792 1663 834 745 826 1347 1348 1229
1870 1872 1794 1505 1506 1507 1349
1665 1666

Fast Fourier Transform
761 42 1193 954 546 1047
1274

Fast Fourier Transformation
use Fast Fourier Transform

Fatigue Life
860 242 1063 834 455 126 647 58 399
1132 456 1459
1759

Fatigue (Materials)
1760

Fatigue Strength
use Fatigue Life

Fatigue Tests
571 1015 1596
941

Fiber Composites
953 57 939
1153

Finite Difference Method
1626

Abstract
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Finite Difference Technique
 280 294 845 746 197 108 269
 1825 1678 459

Finite Difference Theory
 use Finite Difference Technique

Finite Displacement Method
 873

Finite Element Technique
 270 131 432 303 504 95 126 47 508 769
 320 441 862 1073 694 705 336 437 708 829
 490 731 1132 1363 944 1065 426 927 768 849
 850 851 1282 1353 1064 1215 696 1527 848 909
 970 1161 1442 1703 1284 1465 996 1617 898 1299
 1020 1321 1622 1554 1525 1066 1707 998 1439
 1320 1441 1584 1575 1116 1218 1529
 1370 1461 1685 1526 1458 1669
 1490 1501 1785 1606 1528
 1550 1671 1646 1708
 1580 1721 1696
 1620 1886

Finite Strip Method
 1642 1644

Flexibility Methods
 1

Flexible Couplings
 513 514 285
 815

Flexible Foundation
 1643 188 1509

Flexible Rotors
 951 485 367
 1051 1587

Flexural Vibrations
 120 1621 962 303 124 435 576 117 278 419
 1060 1822 573 264 585 686 417 308 1309
 1600 963 1304 705 1306 1467 708
 1790 1123 1314 1315 1836 958
 1384 1355

Floating Bodies
 use Floating Structures

Floating Structures
 531 812 1283 764

Floors
 1322 1486 128

Flow-Induced Excitation
 use Fluid-Induced Excitation

Flow-Induced Vibration
 use Fluid-Induced Excitation

Fluid Drives
 1206

Fluid-Filled Containers
 100 1141 1542 1576 1577 428 1149
 110 1826 578
 700 1578
 1460

Fluid-Film Bearings
 970 1191 1193 1194 415 416 558 559
 1130 1884 1195
 1885

Fluid Film Damping
 1751 805

Fluid Hammer
 698

Fluid-Induced Excitation
 200 111 302 243 454 185 286 287 278 109
 810 201 352 453 1584 945 296 577 808 589
 1350 561 452 763 1624 975 536 807 828 689
 1460 811 842 1033 1664 1575 696 947 948 949
 1810 831 1412 1813 1795 846 1107 1278 1459
 841 1762 1875 946 1137 1308 1579
 931 1812 976 1577 1558 1689
 1761 1106 1578
 1811 1456 1618
 1576

Fluid-Induced Vibrations
 use Fluid-Induced Excitation

Fluid Mechanics
 1703

Flutter
 470 591 722 833 444 95 286 377 8 279
 910 691 762 1173 734 445 696 907 298 299
 862 1483 1294 725 726 927 628 809
 1482 1683 1256 1147 808 859
 1522 1793 1296 1197 1479
 1712 1326 1327

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Foams											
1631	1773					1009					
Forced Vibration											
1210	581	632		165	1286	228	849				
	631	852		1865		858	1089				
	1571	882				1518	1199				
		962				1708	1209				
		1212				1888	1369				
						1809					
Forging Machinery											
1471				1495							
Fossil Power Plants											
					897						
Foundations											
				666	737	868	139				
							1599				
							1649				
Four Bar Mechanisms											
				1305							
Fourier Analysis											
	1263	44									
Fourier Series											
						557					
Fourier Techniques											
	use	Fourier Analysis									
Fourier Transformation											
170	1231	82		914							
				1214							
Fourier Transforms											
	use	Fourier Transformation									
Fracture Properties											
830											
1770											
Framed Structures											
	562	563	414	835	1646	657	128	1799			
	1532	693	1644			1647					
		1023									
		1533									
Frames											
980			424		836		979				
			1304								
Free Vibration											
760	631	1122	1143	264	195	1346	847	268	309		
1700	1611		1283	424	835	1826	1317	848	1439		
				1444				1888			
Freight Cars											
	611		473	1494		1186	1187	878	1659		
	1181		1873	1864							
Frequency											
	1291										
Frequency Analyzers											
650	1771		1274		816						
Frequency Equation											
						87		419			
Frequency Response Method											
	130		1454					888			
	170							1108			
	1500							1118			
Friction											
	901										
Fuel Storage Tanks											
								1328			
Fuel Tanks											
						1855					
Fundamental Frequency											
120	1821	582		704		1316			119		
1800											
Fundamental Mode											
				1303							
- G -											
Galerkin Method											
1300						1365			1299		
Gas Bearings											
	271	272				486	1127	1128			
	971										
Gas Turbine Engines											
						223	154				
							1754				
Abstract											
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699
Volume 10											
Issue:	1	2	3	4	5	6	7	8	9	10	11
											12

Gas Turbines

1028 1029
1508

Gear Boxes

866

Gear Drives

1110 1804

Gears

10 1031 1112 1413 564 565 566 567 568 395
1801 1452 694 837 838
1802

Geometric Effects

1650 1651 399
1740 429

Geometric Imperfection Effects

701 982 1324
1802

Girders

370 1831 264

Gliders

734

Graphic Methods

468

Grids (Beam Grids)

783

Grinding Machinery

1503 1504

Grinding (Material Removal)

743 1179
1503

Ground Effect Machines

1360 1361 172 484 877 748
1861

Ground Motion

791 1742 74 1828 1749
1764

Ground Shock

1601 1244 46

Ground Vehicles

480 221 362 173 164 465 67 18 439
1662 174 327 638 479
384 1557 918 639

Ground Vibration

1487

Guard Rails

530 1843 356 357 1098
716
1546

Guided Missiles

628

Guideways

161
1351

Gyroscopic Effects

1050

- H -

Half Plane

1585

Half-Space

962 1615 1247 1298
1318

Hamiltonian Principle

631

Hammers

1495

Handbooks

use Manuals - Handbooks

Hardened Installations

50 61 54 48 49

Hardened Structures

use Hardened Installations

Harmonic Balance Method

1517

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Holographic Techniques
303 544 216 1117 359
824

Honeycomb Structures
571 1844 137

Hospitals
390

Housings
1767 1529

Hovercraft
use Ground Effect Machines

Hulls
370

Human Hand
1343

Human Head
use Head (Anatomy)

Human Organs
use Organs (Biological)

Human Response
740 171 1342 143 134 145 146 67 218 219
1340 1331 1562 183 144 235 1176 217 798
1560 1341 1652 463 464 1175 1656 918
1860 1491 1653 1395 1078
1861 1558

Hunting Motion
473

Hydraulic Dampers
440 1494

Hydraulic Equipment
1072 1474 915
1165

Hydraulic Servomechanisms
1795

Hydraulic Systems
720

Hydraulic Valves
948

Hydrodynamic Excitation
170 812 785
1580 1752

Hydrofoil Craft
371

Hydrostatic Drives
905

Hysteretic Damping
663 665 868 619
1323 1838 1569

- | -

Impact Dampers
use Shock Absorbers

Impact Load Prediction
1203

Impact Response (Mechanical)
1320 711 152 153 84 85 1796 1247 878 1679
661 312 83 1805 1407 1148
1298
1808

Impact Shock
86 779
1406

Impact Testing
use Impact Tests

Impact Tests
795 356 797
796

Impellers
890

Inclusions
1233

Induction Motors
1677

Industrial Facilities
1560 1381 1393 1535 1476 328
1536 1008

Abstract
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

[illegible]

134

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Multistory Buildings

1020 781 342 864 865 1836 127 1538 229
1322 1334 1647 1799
1644 1857

Musical Instruments

215 216 549
1126

Myklestad Method

411

- N -

NASTRAN (Computer Programs)

1611 643 644 645 646 647 708
1685 927 1718

Natural Frequencies

310 61 12 103 274 15 106 137 418 189
320 101 512 113 504 105 296 267 438 429
490 411 1462 263 704 125 306 437 1778 569
780 421 1622 283 994 215 686 707 1788 729
1190 731 1892 563 1144 305 706 1287 829
1290 1251 1463 1284 515 1437 1019
1310 1521 1643 1794 556 1777 1339
1551 1813 1844 1445 1609
1465 1779
1785

Naval Ships

1514

Noise Barriers

1240 132 1773 325 1006
1832 1843

Noise Control

use Noise Reduction

Noise Generation

840 1031 192 343 224 225 1306 347 328 689
1870 1381 222 543 344 1235 1476 427 388 869
1511 1052 354 1236 1506 567 518 969
1562 384 1395 617 568 1429
1682 1394 1505 1117 638
1347 728
1507 1508

Noise Measurement

350 221 32 1713 604 545 36 817 518 639
680 1011 672 1733 1594 1265 386 1557 818 1079

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Noise Measurement (Continued)

1160 1081 822 1715 436 1428 1849
1850 1241 1382 546 1638 1859
1271 1732 1266 1848
1851 1852 1716
1736

Noise Meters

use Sound Level Meters

Noise (Sound)

1653

Noise Prediction

610 521 1732 1083 1006 1737 1238 219
840 1847 1738 949
1080 1239
1379
1739
1859

Noise Propagation

1085 1676

Noise Reduction

220 21 132 333 324 355 326 327 328 329
330 331 292 753 494 395 466 387 718 469
720 351 332 1163 674 385 476 427 948 519
750 1161 422 1223 744 475 586 467 1008 589
1010 1201 492 1293 884 495 606 477 1068 719
1030 1511 612 1373 1164 605 806 717 1168 749
1160 1561 652 1393 1474 745 816 727 1478 759
1180 1841 752 1633 1714 855 1086 1007 1508 1009
1560 1871 1012 1663 1005 1166 1087 1069
1840 1042 1085 1206 1167 1539
1870 1052 1165 1396 1207 1559
1162 1235 1476 1237 1869
1302 1325 1516 1477
1352 1505 1536 1537
1842 1515 1666
1862 1535
1872 1675
1845

Noise Source Identification

751 612 33 34 25 1086 1237 1389
652 1433 814 385
884 605

Noise Tolerance

463 464

Nondestructive Testing

use Nondestructive Tests

Nondestructive Tests												Nuclear Power Plants (Continued)											
1681				886	1387	408						1400	1352	1183		1876		988	1259				
					1597													1038	1399				
																		1408					
Nonlinear Analysis												Nuclear Reactor Components											
use Nonlinear Theories												1670	111	1672	1673	1094	1875	1617		1459			
Nonlinear Damping													1671		1624			1667		1669			
1090				1756																1809			
Nonlinear Programming												Nuclear Reactor Containment											
1702												170	882										
Nonlinear Response												Nuclear Reactors											
1320	1041		1313		1816		1518	1469				231				945	1036	1037	1668				
			1613									661				1035		1877					
												881											
Nonlinear Springs												Nuclear Reactor Safety											
				1704																28			
Nonlinear Systems												Nuclear Weapons											
1090	1091		773	1104				39				50									49		
			1213					1519															
Nonlinear Theories												Nuclear Weapons Effects											
510		413	774	115	96	1327	8	579															
1370		633		1525	1016			1648															
1520		1523		1695				1678															
Normal Density Functions												Numerical Analysis											
												500	501	502	1703		1626	377	1458	499			
												730	1661					1367		769			
												1060								1609			
												1640								1789			
Normal Modes												1670											
	241	772		994	635	1706	577	648				1740											
	651				1375		777	1338				1830											
	1291																						
Nozzles																							
					1236							- O -											
Nuclear Explosion Damage												Off-Highway Vehicles											
50								49												1869			
Nuclear Explosion Effects												Off-Shore Structures											
1281				935			48	1629				1632	333	764				1107	1198	1579			
							1628	1749				1762		1064									
														1694									
Nuclear Fuel Elements												Oil Film Bearings											
1670	1041	882						1669				1751		1884									
	1671																						
Nuclear Power Plants												Optical Methods											
1040	1042	1043	1044	1455	916	937	698	1039				90											

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Optimization									Parameter Identification Technique (Continued)								
770	771	772	1443	1804	1215	1446	1287	1789	1581	1192	644	1425	1176	1867	1868	1219	
1220	1061	1522	1863			1586	1807			1372							
	1821	1702								1712							
Optimum Control Theory									Parametric Excitation								
1170		1182					7		1600		1054	1785		1517		409	
Optimum Deisgn									Parametric Resonance								
	1501				1705			529				1125					
	1821							1119									
Organs (Biological)									Parametric Response								
1490	1171			194				1489	350	431		774	1695	1336			
	1461											1524					
Orthotropic Plates									Parametric Vibration								
	1642								510	1072	1603		1226	1457			
									920								
Orthotropism									Passenger Vehicles								
	992	113				1466		119		172	1163				888		
Oscillation									Pavements								
1640	371	442	443				288	289	1681		614		886	887			
							458							1697			
Oscillators									Pendulums								
40		1212		1104				499		1072		274					
500				1364													
Overhead Cranes									Penetration								
	1831															59	
									Periodic Excitation								
									1621		1104	1125	226			39	
									1801								
									Periodic Response								
Packaging Materials									270	1051	1253	174	875	786		38	1089
	152	153		1345			878		1751	1513		1865	1356		1088		
Panel-Cavity Response									1801	1813			1806		1178		
				245								1836		1518			
														1708			
														1838			
Panels									Periodic Structures								
760	571	1102	243	324	95	96	97		1531		555		1397	1228			
1310			673	674		286											
						696											
Parachutes									Perturbation Theory								
				794					500	3	4	705	1816	847		229	
										1523	634			1397			
										1703	984						
Parameter Identification Technique									Phase Data								
	•1371	1022		184	615	636	337	168	19					1237			
Abstract																	
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896					
Volume 10																	
Issue:	1	2	3	4	5	6	7	8	9	10	11	12					

Piezoelectricity 241 1172	Pneumatic Shakers 202 73											
Pile Driving 1487	Pneumatic Springs 1863											
Pile Foundations 950	Pneumatic Tools 1432 1004 226											
Pile Structures 1762	Pogo Oscillation use Pogo Effect											
Pipeline Transportation 1454	Point Source Excitation 1541											
Pipelines 1f .0 291 103 1454 985 986	Poisson's Ratio 1781 1782											
Pipes (Tubes) 100 1141 102 573 104 427 98 920 1392 697 1308 1460 987	Polyurethane Resins 322 1102											
Piping Systems 101 843 1094 655 986 1037 198 99 1601 1033 985 698 1809 1455 988	Porous Materials 1572 1234											
Pistons 381 474 1808	Power Plants (Facilities) use Electric Power Plants											
Plain Bearings 1129	Power Spectra 1351 732											
Plastic Properties 1750	Power Transmission Belts 900 901											
Plates 120 121 122 113 114 115 306 117 118 119 300 301 302 203 304 305 706 297 238 299 430 711 432 303 704 575 846 307 298 579 580 1321 872 703 844 845 996 507 708 1549 830 1391 992 833 1384 855 1316 707 908 1819 920 1142 1824 925 1466 847 1468 1829 1550 1315 1556 1467 1818 1820 1465 1566 1707 1735	Power Transmission Systems 1110 1152 1363 1204 1696 1207 898 279 1804											
Pneumatic Equipment 1839	Prediction Techniques 193 1856 1896											
Pneumatic Machine Drives 1660	Pressure Gages 1114											
	Pressure Vessels 1346 198											
	Prestressed Structures 402											
	Printing 1355											
Abstract Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896												
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Probability Theory
400 1211 1216 1819
1090

Propeller Blades
691 973 826

Propeller Induced Excitation
493 1684

Propellers
492 543 744
1293

Propulsion Systems
1841 1847 729
1699

Protective Shelters
782 1244 1565 1567

Pulleys
901

Pulse Excitation
1750 13 1504 1425 1367 979
593
703

Pumps
1030 1031 1032 63 254 1496 347 609
1590 1033 874 747
1474 1257

- Q -

Quasi-Moment Dampers
742

- R -

Radio Telemetry
825

Rail Transportation
610 876 878 719
750 749
879

Railroad Cars
160 1181 163 1864 165 156 157 148 639
880 1873 879
1180 1659

Railroad Tracks
471 155 827 879

Railroad Trains
10 222 158
472

Railroad Vehicles
use Railroad Trains

Railroads
166

Rails
use Railroad Tracks

Railway Vehicles
use Railroad Trains

Random Decrement Technique
208

Random Excitation
40 111 1092 1093 654 465 1216 1447 208 79
150 941 1242 1213 885
1090 1091 1782 1243
1781

Random Response
1614 336 38

Random Vibration
992 243 227 58 1519
1063

Rayleigh-Ritz Method
832 1315 1338

Rayleigh Waves
677

Reciprocating Engines
1001

Recording Instruments
1270

Rectangular Bars
87

Abstract
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Rotary Compressors

607

Rotary Inertia Effects

use Rotary Inertia Effects

Rotary Presses

1306

Rotary Wings

590 1651

515 536

1650

1606

Rotating Structures

832 1053 684 575 1257 958 1259

952 1263 1284

1262 1513

Rotatory Inertia Effects

560 1291 312 293 294 1285 686 578

570 1462 1784 1825

1892 1794

Rotor-Bearing Systems

951 892 1193 184 485 486 187 368 369

1191 1192 1753 1194 1195 1196 367 489

1512 1883 1884 1885 1356 487 769

1882 1586 1887

1886

Rotor Blades

690 811 422 274 615 1296

Rotor Blades (Rotary Wings)

use Rotary Wings

Rotor Blades (Turbomachinery)

421

Rotor-Induced Vibration

37

Rotors (Machine Elements)

190 621 622 623 754 185 186 187 368 369

490 691 1592 893 874 365 366 667 488 619

590 891 1892 1683 1664 615 616 1257 618 1699

620 1521 1834 685 1357 958 1889

890 1891 1665 1358

1050 1888

1190

Runway Roughness

1014

138

Runways

1681

886

- S -

Safety Belts

use Seat Belts

Safety Restraint Systems

1095

1409

Saint Venant's Principle

1625

Sand

59

Sandwich Laminates

use Sandwich Structures

Sandwich Panels

use Panels or Sandwich Structures

Sandwich Structures

571 82 324 435

SAP (Computer Programs)

782

Satellite Antennas

use Spacecraft Antennas

Satellites

770 771 772 1055 626

1072

Saws

1540

883

1449

Scaling

800 881 43 1514 676 798 509

820 1593 1276 759

799

1429

Seals (Stoppers)

620

Seat Belts

921

1048

Abstract

Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896

Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Secondary Waves										Shafts (Machine Elements)										
1582 1233 124										345										
Seismic Design										Shakers										
390	291	1022	393	394	655	836	1547	788	659	202 1533 66 258 1419										
790	391	1222	1023	1024	985	916		1038	739											
	1221		1333	1044	1025	986		1538	1149	Shear Strength										
				1094	1335	1336			1399	317										
				1174	1405	1876			1799											
					1745					Shells										
										920 1321 572	1624	575	947	108	699					
Seismic Excitation										1000 1461 1542	1794	925		428	999					
660	791	1332	393	654	655	1036	737	658	79	1550	1824			998	1309					
700			1043	1584				1828	709						1308					
710			1583	1744					1649						1788					
Seismic Response										Shells of Revolution										
1400	231	232	1323	1644	1245	1026	697	1858	229	170		105'	106	437	108	429				
1610	541	792	1743		1455		897		339	580		1145		1617						
1670	881						1647		609			1825								
							1877		649											
									789	Ship Anchors										
										372										
Seismic Response Spectra										Shipboard Equipment Response										
341 42										1245 506										
Seismic Waves										Ship Hulls										
41 1722 1543 1544 1225										1362	1684	1685				189				
Self-Excited Vibrations										Ship Noise										
121	122	123	1884	185	756	1137	598	89												
	282	743		685	1866		1868	1359		589										
				755																
Semitrailers										Ship Structural Components										
150					1185			179		625										
180										Shipboard Equipment Response										
Series (Mathematical)										188										
1503										Shipping Containers										
Servomechanisms										683				1657						
595										Ships										
Shaft Couplings										1281	494	495	1406	757	758	209				
904 815											624	775		917	1198	1199				
Shafts										Shock Absorbers										
1120	491	552	433	554	365	186	187	538	1119	440 1251	713	224	826		588					
		1072	553	684	685	1356	1437	1358	1599	1630 1471		1154								
		1152	603	1834	925	1436				1631		1184								
		1892			1195					Shock Absorption										
					1665					1831	1153									

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

[illegible]

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Spur Gears	Steepest Descent Method											
1802	1807											
Squeeze Film Bearings	Steering Effects											
	1028	1129	480	482	173	364	439					
	1128		1880									
Squeeze Film Dampers	Steering Gear											
1051 1152 1753 754	368	369	162									
1891 1752 1754	488											
Stability	Step Functions											
1720	2	1523	474	155	157	478	489	5				
	1882	1753		485	487		599					
			1185									
Stability Analysis	Stick-Slip Response											
use Stability	1344											
Stability Methods	Stiffened Panels											
912	1297	1140										1609
1062		Stiffened Plates										
						1312	783	307	309			
								1467	849			
Standards	Stiffened Shells											
640	1713	1266	1267	638	639	1827						
Standards and Codes	Stiffened Structures											
20 671 1042 1223 864 865 916 1547 1538												137
781 1222 1373 1714 1535 1536												
1413 1715 1716												
Statistical Analysis	Stiffness											
1410	54	565	1706	1368	1131							1498
		1265			1801							
Statistical Energy Methods	Stiffness Coefficients											
503	775	950 301 1174 415 887 148 429										
								1127	318			
								1128				
								1568				
Steady State Excitation	Stiffness Methods											
use Periodic Excitation	461 1322 437 128 19											
Steady-State Response	Stochastic Processes											
use Periodic Response	150 773 1226 757 768 9											
	1093											
Steam Generators	Storage Tanks											
use Boilers	700 391 1692 1657 1328											
Steam Turbines	Stored Response Modeling											
1350 92 603 825 417 1509	1711											
Steels	Strings											
1532 1533 1645 1646 1647	1060	961	1126	967								
	1446 1447											
Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

148

Test Equipment and Instrumentation										Thickness Effects													
1420	1421	402	33	64	255		957	use Geometric Effects															
		1422	73	404	815		1417																
		1602	1423	814	1425																		
			1424																				
Test Facilities										Thrust Bearings													
	821	672	543	404	255	256	67	258	259	558													
			673	674	675	406		318	1039														
			923																				
Test Fixtures										Tilting Pad Bearings													
use Test Facilities										1882 1883 1196													
Test Instrumentation										Time-Dependent Excitation													
use Test Equipment and Instrumentation										1781 1286													
Test Models										Time Domain Method													
1020							1098	339	14														
							509																
Test Stands										Timoshenko Theory													
							955	420 1282 1783 414 1346 268 829															
Testing Apparatus										1440 1784 1818 1789													
use Test Equipment and Instrumentation										1780													
Testing Equipment										Tire Characteristics													
use Test Equipment and Instrumentation										130 861 482 183 174 586 318 129													
Testing Instrumentation										1002 364 478 439													
use Test Equipment and Instrumentation																							
Testing Machines										Tires													
use Test Equipment and Instrumentation										1002 314 315 316 317 438 319													
Testing Techniques										1662 1224 436 437													
71	1432	33	434	825	856	657	68																
681	1602	73	1434	1095	1596	1047	338																
1431	1712	823	1654					1277	1118														
		1043	1844																				
Textile Spindles										Tools													
1862										1860													
Thermal Excitation										Torpedos													
										16													
										Torque													
										1591 866													
										Torsional Excitation													
										1826													
										Torsional Response													
										940 402 1744 366 1497 1298 489													
										1892 766 1646													
										Torsional Vibration													
										1600 151 12 553 124 435 866 1287 538 419													
										871 942 903 264 585 1836 1878 429													
										1521 1262 943 554 1665 1888 1569													
										1204													
										1294													
										1814													
										1824													
Thermoviscoelasticity Theory										1708													

Abstract												
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896
Volume 10												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

150

Turbine Components							Underwater Pipelines								
1510	1512		874			618				1454					
Turbine Engines							Underwater Sound								
	602			1766	1478	1769		210	1741	1254	526	527	108		
Turbines							260								
	331		354	825	1257	1509	1390								
Turbofan Engines							Underwater Structures								
	752			1046			1383								
							Urban Noise								
								463	384		387		1079		
Turbofans								1733	1734						
Turbomachinery							- V -								
540	621	622	574	805	376	607									
630	641	1032			736	539	Valves								
	1191	1592			766		840	292	1474	505	1236		609		
										1795			949		
Turbomachinery Blades							Variable Cross Section								
	91	1132	833	1895		418	419	490	282	53	964	576	847	418	
								1788	1120		413	1144	686	1137	1119
Turbulence							963								
	1811	732				689		1143			1436				
											1616				
- U -							Variable Material Properties								
Ultrasonic Tests							Variable Speed Drives								
	use	Testing Techniques					899								
Unbalanced Mass Response							Variational Methods								
190	621	892	754	1195	766	187	430	851		416		1338	619		
	641			1885			V-Belts								
	1051									765					
	1891						Vehicle Wheels								
Underground Explosions								130		1835					
	682			936			Vibrating Structures								
Underground Structures								931		974	995	1216			
60	61		985	46	47		Vibration Absorbers								
	981			936											
Underwater Explosions							use Vibration Absorption (Equipment)								
			45	506	1748		Vibration Absorption (Equipment)								
			395				1160			1836					
			1245												
Abstract															
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896			
Volume 10															
Issue:	1	2	3	4	5	6	7	8	9	10	11	12			

Underwater Pipelines											
									1454		
Underwater Sound											
210	1741			1254		526	527	108			
260											
1390											
Underwater Structures											
				1383							
Urban Noise											
		463	384					387		1079	
		1733	1734								

- V -											
Valves											
840		292		1474	505	1236				609	
					1795					949	
Variable Cross Section											
490		282	53	964		576	847	418	1119		
1120			413	1144		686	1137				
			963	1444		1136					
			1143			1436					
						1616					

Variable Material Properties											
											1599
Variable Speed Drives											
											899

Variational Methods											
430	851					416		1338	619		
V-Belts											
						765					

Vehicle Wheels											
130						1835					
Vibrating Structures											
931			974	995	1216						

Vibration Absorbers											
	use	Vibration Absorption (Equipment)									
Vibration Absorption (Equipment)											
1160						1836					

Vibration Absorption (Materials)										Vibration Response									
1102										80	701	192	583	684	1065	6	557	608	929
Vibration Analyzers										410	851	552	643	824		746	627	838	
1271										600	961	832	663				687	1558	
Vibration Control										1070	991	1292	863				787		
130	101	62	63	284	15	16	847		1499	1140	1141	1442	1073				827		
140			883	1204	395	736	1207		1509			1792	1343				1117		
1070			1353		475	1256		1589				1823					1817		
1470			1363		855	1446				Vibration Severity									
			1373		1665	1516											1416		
Vibration Dampers										Vibration Signatures									
												952	1413	644					
												1262							
Vibration Damping										Vibration Source Identification									
1330	981		1253		475	806	1047		1249								456		
						966	1887												
						1366				Vibration Spectra									
Vibration Effects										use Vibration Response Spectra									
1341	1342					456	1427	408		Vibration Tests									
							1398			20	761	72	73	14	735	276	97	258	359
Vibration Excitation										550	1421	832	683	1434		896		1349	
1491	1452	403	144	145	146		638	399		1420	1431	882	1423			1376		1639	
	1652									1510		1422				1646			
Vibration Frequencies										Vibrators (Machinery)									
					1605												346	1697	
Vibration Isolation										Vibratory Conveyors									
										use Vibrators (Machinery) or Materials Handling Equipment									
			1154	475		867				Vibratory Techniques									
Vibration Isolators																	1057		
870	1862	1863		465	1496		1028	1159		Vibratory Tools									
				1495						1860									
Vibration Measurement										Violins									
70				15	1486	457	538										1126		
90				75			1268			Viscoelastic Core-Containing Media									
140				1295															
				1555															
				1605															
Vibration Prediction										Viscoelastic Damping									
1790				1724						900		494	535				1758		
Vibration Reduction												534							
use Vibration Control										Viscoelastic Media									
Vibration Resonance																			
use Natural Frequencies																		1829	

Abstract													
Numbers:	1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	1700-1896	
Volume 10													
Issue:	1	2	3	4	5	6	7	8	9	10	11	12	

Viscoelastic Properties	153	324	1615	967	109	Waveguide Analysis	528
	293	844			1309		1378
Viscoelasticity			1066			Wave Number	
						use Frequency	
Viscoelasticity Theory						Wave Propagation	
662						940 41 662 803 994	776 57 928 919
Viscoplastic Properties						1230 961 932 1553 1574	939
1750 1601		1585				1121 1172 1573	
Viscous Damping						1572	
40 951 242	1104		1838			1582	
1252						1812	
Vortex-Induced Vibration						Weapons Effects	55 56
		246 277					
		966				Weapons Systems	
Vortex Shedding						653 54	1807 48
1810							358
Vulnerability						Wear	
	54					254	827
						Wedges	
						712 963	406
						Wheels	
						1893	1835
						Wheelset	
						880	169
						Wheel Shimmy	
							1016
						Whirling	
						491 1752	874 1885 486
							488
							618
							1358
						Wiener-Hopf Technique	
						961	
						Wind-Induced Excitation	
						300 451 682 243 244 335 676 127 498	
						400 591 862 733	1105 1256 647 1188
						450 1481	1173 1485 1857 1438
						580 1641	
						1330	
						Windmills	
							647
Abstract							
Numbers: 1-194	195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208
							1209-1363
							1364-1516
							1517-1699
							1700-1896
Volume 10							
Issue: 1	2	3	4	5	6	7	8
							9
							10
							11
							12

Wind Tunnels

1488

Wind Tunnel Tests

1020	451	524	255	676	337	678	349
1650	1481	604	275	896	517		
	1651	724	1045		1237		
					1357		

Wind Turbines

320 1122 353

Windows

127

Wing Stores

724	725	136	927	1328	859
		726			

Winkler Foundations

81 1616

Wire

1359

1569

Wobble

1053

Abstract**Numbers:** 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896**Volume 10**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
---------------	---	---	---	---	---	---	---	---	---	----	----	----

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta. Mech.	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS United Engineering Center 345 East 47th St. New York, NY 10017	
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica	JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London, W1V 0BQ, UK	Aeronaut. J.	JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.	JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus. Trans. ASME
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.	JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS Publications Office, ASCE United Engineering Center 345 East 47th St. New York, NY 10017		JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech. Trans. ASME
JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J., Engr. Mech. Div.	APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
JOURNAL OF ENVIRONMENTAL ENGINEERING DIVISION	ASCE J., Environ. Engr. Div.	APPLIED MATHEMATICAL MODELING IPC House 32 High St., Guildford Surrey GU1 3EW, UK	Appl. Math. Modeling
JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION	ASCE J., Geotech. Engr. Div.	ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS Springer-Verlag, New York, Inc. 175 Fifth Ave. New York, NY 10010	Arch. Rational Mech. Anal.
JOURNAL OF HYDRAULICS DIVISION	ASCE J., Hydraulics Div.	ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mech. Stosowanej
JOURNAL OF IRRIGATION AND DRAINAGE DIVISION	ASCE J., Irrigation Drainage Div.	ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
JOURNAL OF STRUCTURAL DIVISION	ASCE J., Struc. Div.	AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	Automobiltech. Z.
JOURNAL OF TRANSPORTATION ENGINEERING DIVISION	ASCE J., Transport. Engr. Div.	AUTOMOTIVE ENGINEER P. O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP32 GBW, UK	Auto. Engr.
AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.	BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Ball Bearing J.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
BAUINGENIEUR S. Hirtzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Bauingenieur	EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P. O. Box 277 Westport, CT 06880	Exptl. Mech.
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.	FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, W. Germany	Forsch. Ingenieurw.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.	HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHAMA NATIONAL UNIVERSITY Yokahama National University OHKA-MACHI, Minami-ku Yokahama, Japan	Bull. Fac. Eng. Yokahama Natl. Univ.	HIGH-SPEED GROUND TRANSPORTATION JOURNAL Planning Transportation Assoc., Inc. P. O. Box 4824, Duke Station Durham, NC 27706	High-Speed Ground Transp. J.
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME	HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.	HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave., West Cleveland, OH 44113	Hydraulics & Pneumatics
CHEMICAL PROCESSING Putnam Publishing Co. 430 N. Michigan Ave. Chicago, IL 60611	Chem. Processing	IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
CIVIL ENGINEERING (NEW YORK) ASCE Publications Office 345 E. 47th St. New York, NY 10017	Civ. Engr. (N.Y.)	INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
CLOSED LOOP MTS Systems Corp. P. O. Box 24012 Minneapolis, MN 55424	Closed Loop	INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.	INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminster, London SW1, UK	Instn. Mech. Engr. Proc.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News	INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P. O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.	INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engr. Matl. Des.	INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engr. Struc. Dynam.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engr. Sci.	JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 E. 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.	JOURNAL OF COMPOSITE MATERIALS Technomic Publishing Co., Inc. 750 Summers St. Stamford, CT 06901	J. Composite Matl.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.	JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engr. Math.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mech.	JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engr.	JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.	JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.	JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucester Sydney, Australia 2000	J. Inst. Engr., Australia
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.	JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1 H9, UK	J. Mech. Engr. Sci.
JOURNAL DE MÉCANIQUE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique	JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mech. Phys. Solids
JOURNAL DE MÉCANIQUE APPLIQUÉE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique Appl.	JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.	JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft	JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Space- craft Rockets	MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung Pflizerstrasse 5-7 7000 Stuttgart 1, W. Germany	MTZ Motor- tech. Z.
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval.	NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.
KONSTRUKTION Springer Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion	NOISE CONTROL VIBRATION ISOLATION Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Control Vib. Isolation
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engr.	NOISE CONTROL ENGINEERING P. O. Box 2167 Morristown, NJ 07960	Noise Control Engr.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.	NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall, Newcastle Upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinen- bautechnik	NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P. O. Box 3489 Amsterdam, The Netherlands	Nucl. Engr. Des.
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica	OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017	Mech. Engr.	OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology Osaka University Miyakojima, Osaka, Japan	Osaka Univ., Tech. Rept.
MECHANICAL ENGINEERING, TRANSACTIONS, THE INSTITUTION OF ENGINEERS, AUSTRALIA The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600	Instn. Mech. Engr., Australia, Mech. Engr. Trans.	PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Res. Comm.	PHYSICS TODAY American Institute of Physics, Inc. 335 East 45th St. New York, NY 10017	Physics Today
MECHANISM AND MACHINE THEORY Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory	POWER P. O. Box 521 Hightston, NJ 08520	Power
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr. Kyoto Univ.	POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY Library, Nagoya University Furo-Cho, Chikusa-ku Nagoya, Japan	Mem. Fac. Engr. Nagoya Univ.	PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622 New York, NY	Product Engr. (NY)
		QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mech. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MÉCANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mécanique	TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Trans. Instr. Soc. Amer.
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.	TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.	VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.	VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.	VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibro- technika
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS Society of Naval Architects and Engineers 20th and Northampton St. Easton, PA 18042	Soc. Naval Arch. Mar. Engr., Trans.	WEAR Elsevier Sequoia S.A. P. O. Box 851 1001 Lausanne 1, Switzerland	Wear
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.	ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen	ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss

ANNUAL PROCEEDINGS SCANNED

INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc.	THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.	UNITED STATES CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	U.S. Cong. Appl. Mech., Proc.
MIDWESTERN CONFERENCE ON SOLID MECHANICS, ANNUAL PROCEEDINGS	Midw. Conf. Solid Mech. Proc.	WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

CALENDAR

DECEMBER 1978

- 4-6 15th Annual Meeting of the Society of Engineering Science, Inc., [SES] Gainesville, FL (*Prof. R.L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603*)
- 10-15 Winter Annual Meeting, [ASME] San Francisco, CA (*ASME Hq.*)
- 11-14 Truck Meeting, [SAE] Hyatt Regency, Dearborn, MI (*SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096*)

FEBRUARY 1979

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

APRIL 1979

- 30-May 2 NOISE-CON 79, [INCE] Purdue University, IN (*NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 - Tel. (317) 749-2533*)
- 30-May 2 Environmental Sciences Meeting, [IES] Seattle, WA (*Dr. Amiram Roffman, Energy Impact Assoc., Inc., P.O. Box 1899, Pittsburg, PA 15230 - Tel. (412) 256-5640*)
- 30-May 3 1979 Offshore Technology Conference, [ASME] Astrodomain, Houston, TX (*ASME Hq.*)

MAY 1979

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

JUNE 1979

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

SEPTEMBER 1979

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

- 10-13 Off-Highway Meeting and Exposition, [SAE] MECCA, Milwaukee, WI (*SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096*)
- 11-14 INTER-NOISE 79, [INCE] Warsaw, Poland (*INTER-NOISE 79, IPPT PAN, ul. Swietokrzyska 21, 00-049 Warsaw, Poland*)

OCTOBER 1979

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

NOVEMBER 1979

- 4-6 Diesel and Gas Engine Power Technical Conference, San Antonio, TX (*ASME Hq.*)
- 5-8 Truck Meeting, [SAE] Mariott, Ft. Wayne, IN (*SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096*)
- 26-30 Acoustical Society of America, Fall Meeting, [ASA] Salt Lake City, UT (*ASA Hq.*)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, NJ 07645	ICF:	International Congress on Fracture Tohoku Univ. Sendai, Japan
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.	IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
AHS:	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036	IES:	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019	IFTToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME Amherst, MA 01002
AICHE:	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017	INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605	ISA:	Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222
AHS:	American Helicopter Society 30 E. 42nd St. New York, NY 10017	ONR:	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
ARPA:	Advanced Research Projects Agency	SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
ASA:	Acoustical Society of America 335 E. 45th St. New York, NY 10017	SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017	SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, NY 10017	SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, NY 10006
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202	SPE:	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203	SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, MA 02173
CCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada		

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 8404
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300.

THIRD CLASS MAIL

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DoD-316



THE SHOCK AND VIBRATION DIGEST

Volume 10, No. 12

December 1978

EDITORIAL

- 1 Director Notes
- 2 Editors Rattle Space

- 36 Annual Article Index
- 39 Book Reviews
- 42 Book Reviews: 1978

ARTICLES AND REVIEWS

- 3 Feature Article - SHOCK AND
VIBRATION ANALYSIS USING
FINITE ELEMENT TECHNIQUES
T.V. Seshadri
- 10 Literature Review
- 11 A SKETCH OF AEROACOUSTICS
R.E.A. Arndt
- 21 RECENT RESEARCH IN PLATE
VIBRATIONS. 1973-1976: COM-
PLICATING EFFECTS
A.W. Leissa

CURRENT NEWS

- 45 Short Courses
- 48 News Briefs

ABSTRACTS FROM THE CURRENT LITERATURE

- 49 Abstract Categories
- 50 Abstract Contents
- 51 Abstracts: 78-1700 to 78-1896
- 96 Annual Author Index
- 115 Annual Subject Index
- 155 Periodicals Scanned

CALENDAR