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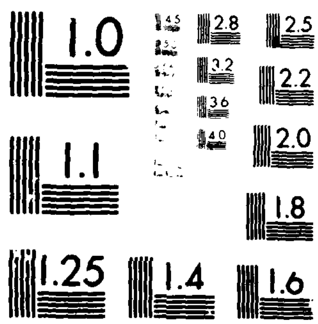

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

SVIC NOTES

Information is transferred during technical meetings by presentations, preprints of presented papers or subsequent publication of papers in technical journals. Most technical journals require a critical review of a paper prior to publication.

The technical review serves two purposes. First it screens out the unacceptable papers. Second, and perhaps more importantly, it helps the authors prepare a better technical paper through the medium of constructive criticism.

I believe that the technical paper review process is effective but if it errs it tends to do so slightly on the side of being over-selective. Occasionally a sound technical paper might be rejected for publication because it discloses no new concepts and therefore it doesn't advance the state of our technical knowledge. Sometimes we get hung up on the term "new concept" and we might literally interpret it to mean a startling new development. However, as an example, the authors of technical papers that apply state of the art techniques that were developed for the solution of one type of problem to the solution of a totally different type of problem also disclose new concepts and they also advance the state of our knowledge. These papers deserve to be published. Part of the problem also lies in our literal interpretation of the evaluation criteria. Most criteria explicitly state that the technical material shall convey some new concept to the reader; however most of the same criteria also imply that papers which include useful information for the practitioners in the field are just as acceptable for publication.

Therefore, assuming that the content of a technical paper being reviewed is sound, its acceptability for publication should not be judged solely on the basis of the newness of its content. After all, how many technological breakthroughs can we have? Rather we should consider whether it contains information that will be useful to the practitioner in the field.

R.H.V.

EDITORS RATTLE SPACE

Looking back on thirty-five years of interest and involvement in shock and vibration, I would like to comment on some ways in which the scene has changed, particularly in the areas of vibration measurement and isolation in which I have been mostly engaged.

A few decades ago we measured vibration with mechanical vibrographs, optical vibrometers and electrical transducers, often designed and 'home made' for a particular measurement problem. For frequency analysis we inspected recorded waveforms to identify the few more obvious components and, on rare occasions, made a Fourier analysis by a tedious graphical method. Today we can purchase small high quality transducers suitable for wide ranges of frequency and environment, and use them with instrumentation that presents frequency spectra and statistical data of the vibration while it is happening.

Formerly our main worry was misbehavior of the relatively large measuring devices and the difficulty of calibrating them in the days before electrodynamic vibrators and small monitoring transducers. Nowadays the very ease with which accurate and comprehensive measurements can be made is the hazard, for it can divert attention from the real needs of the problem - what to measure, and where - and leave us with an indigestible volume of data from which to recognize and extract what is significant and relevant to the problem in hand.

In vibration isolation practice the helical springs, rubber isolators and materials of a few decades ago are now available for far wider ranges of load and environment. We have new materials, and new kinds of isolators, for example the air spring, and we can achieve active vibration isolation by using servo systems.

Along with this development of improved hardware there have been advances in vibration isolation theory. However, with the exception of the relatively small number of vibration specialists and consultants, the designers of mountings seem to be using the same elementary theory of the single degree of freedom system that was used a few decades ago. This is demonstrably inadequate, even in such routine mounting designs as those for machinery and equipment installations in buildings.

This failure to make use of well-established theory is partly the result of a more general malaise. Too many authors write papers to increase their status in the peer group and to attract continued funding of their projects. Consequently, too many papers present trivial modifications of earlier theoretical papers and extensions of mathematical models to include parameters that cannot be clothed in realistic numerical values. Such papers are unconcerned with or give only lip service to practical application. We need more papers that present theoretical results in a way that can be understood and applied by the practitioner. We need more investigators willing to attack real problems - when necessary in situ with the attendant inconvenience, frustration, and physical discomfort - to show how theory can be applied to solve particular classes of problems.

J.A.M.

DYNAMIC TESTING - HOW FAR WE'VE COME
HOW MUCH FURTHER TO GO*

A.J. Curtis**

Abstract - This paper provides an overview of dynamic test techniques and extrapolates the route of past technical developments to predict likely future capabilities. In parallel, shortcomings of these techniques vis-a-vis desired capabilities are examined to detect where improvements are most needed and/or can most readily be achieved. Particular attention is devoted, on the one hand, to the future of the most sophisticated techniques of digital control, and on the other hand, to the simplicity desired for screening tests.

It is simple to accept an invitation to address a plenary session on a topic such as dynamic testing because I have been closely associated with the field for a number of years. It is even easy to write an abstract with a nice ring to it. Then comes a moment of truth:

- dynamic testing is a broad and many faceted topic
- the topic should be approached humbly
- only selective topics can be addressed.

Dynamic tests can be categorized with a 2 x 3 matrix of field and laboratory viz-a-viz vibration, acoustics, and shock. The six types of dynamic tests are subjects of one or more papers at this 50th Symposium. Even if consideration is restricted to laboratory vibration tests, a plethora of tests with differing purposes and, therefore, differing requirements and techniques, remain.

Since this 50th Symposium spans approximately 30 years of very rapid technological development, it is perhaps useful to begin with a review of the evolution of dynamic and, in particular, laboratory vibration testing. This review is followed with an introduction of test purposes and test condition matrices so that the reader will understand why certain tests are or should be performed in certain ways. A philosophic and hardware-directed discussion of a few needed developments in this field -- in particular, vibration screens -- concludes the presentation.

The reader has perhaps sensed that the paper is biased toward the vibration testing of avionics. However, the writer believes that, with little change of emphasis, the same techniques and problems apply equally well to shock testing and acoustic testing of all types of equipment in all types of vehicles and to testing the vehicles themselves.

EVOLUTION OF VIBRATION TESTING

About a dozen vital ingredients are necessary to perform a vibration test. These are listed in the left hand column of Table 1. Although it is useful to follow the development of each ingredient during the past 30 years, their interaction and the very sophisticated systems now in use are perhaps of greater interest. It should be pointed out that, with only one or two exceptions, all the hardware listed in Table 1 is still in use. Exact dates cannot be given for each development because most evolved from a single specialized facility to general usage over a period of several years. However, the key years were the late 1950s, during which random vibration became viable and acceptable, and the early 1970s, when the advent of digital control caused a revolution.

The left hand side of Table 1 represents the era of propeller-driven aircraft. Low-frequency somewhat sinusoidal vibration was generated and measured using mechanical shakers and simple data acquisition

This paper is adapted from a plenary lecture delivered at the 50th Shock and Vibration Symposium in October, 1979, in Colorado Springs

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MOTION GENERATOR	MECHANICAL ECCENTRIC	MECHANICAL INERTIAL	ELECTRO-DYNAMIC →	(HYDRAULIC ACTUATOR) →	
POWER SOURCE	ELECTRIC MOTOR →		M/G SET. →	ELECTRONIC POWER AMPLIFIER →	
CONTROL SYSTEM	NONE	NONE	TECHNICIAN →	ANALOG SERVO →	DIGITAL SERVO →
CONTROL TRANSDUCER		VELOCITY METER →	CRYSTAL ACCELEROMETERS →		
CONTROL STRATEGY	SINGLE PT →			AVERAGE, PEAK SEL. →	RESPONSE CONTROL →
DATA ACQUISITION	OSCILLOGRAPH OSCILLOSCOPE, METER →		MAGNETIC TAPE →		
SPECTRAL CAPABILITY	SWEPT OR FIXED SINE →			RANDOM →	COMPLEX, UNLIMITED
UPPER FREQUENCY	≈ 60 Hz →		≈ 500 Hz →	≈ 2000 Hz →	
DATA ANALYSIS	EYEBALL →		SWEPT FILTER →	COMB FILTER →	FFT →

Table 1. Evolution of Vibration Testing

devices, which were adequate for the relatively simple equipment of the day, especially since it was almost invariably mounted on vibration isolators. As acoustic and vibration environments encountered in jet aircraft, missiles and rockets became more severe and more complex - and as equipment became more complex and vibration isolation less effective - swept sinusoidal vibration tests to higher frequencies made possible by electrodynamic shakers were found wanting.

Fortunately, concurrent with Morrow and Muchmore's basic work on the need to perform random vibration, the mathematical theory was available from the field of communications. Also available were such technical advances as crystal accelerometers, magnetic tape recorders for repeated playback, audio spectral analyzers, and electronic power amplifiers. Further, it became evident that placing a velocity meter at the end of an armature opposite a test object is neither a realistic nor safe way to control a vibration test. It also became clear that a single arbitrarily chosen location to control the vibration is not much better, and more elaborate test control strategies became fairly standard. Most important, however, it became obvious that using a human servo to equalize a swept analyzer was inadequate -- customers do not appreciate buying a test item for destruction during equalization and another for test. Thus, analog servo control of a comb filter equalizer/analyzer became a standard procedure until it was superceded by digital control systems. Such systems can perform not only random and sinusoidal vibrations but also shock and, indeed, almost any time-history of interest. In addition, digital systems have the *inherent capabilities* to analyze, process, and store the results of a test accurately, repeatably, and efficiently.

One development not listed in Table 1 profoundly influenced the performance of shock and vibration tests. It was the introduction in 1959 of the slip-plate or slip-table, which permitted testing of a test item in its normal orientation for all directions of excitation and allowed three axes of test with one fixture.

TEST PURPOSE MATRIX

It is all very well to have the capability to perform sophisticated tests to exacting standards. However, if the purpose of the test is not clearly understood, a cost-ineffective and perhaps even counter-productive test can result. It is suggested that the purpose of any test can be placed in one of three categories. First, the purpose may be to understand the structural characteristics of the test item; e.g., a modal test. Second, the purpose may be to determine the adequacy of the design; short term and long term adequacies translate into functional performance and fatigue life respectively. Third, the purpose may be part of a quality assurance program, which includes reliability and quality. Reliability involves an attempt to measure the long term failure rate provided the majority of flaws have been removed by quality tests. Table 2 is a matrix of the categories vs the type of test. The type of test is listed in chronological order, although not all programs include all tests. With few exceptions, the purpose of a test can be associated easily with the type of test. Recently, however, increasing emphasis has been placed on reliability growth and reliability demonstration tests using realistic vibration environments; the result can easily be that a single test is performed for too many and for counteracting purposes. These are indicated by the question marks in Table 2. It is to be hoped that clear understanding of both the commonalities among and the distinctions between the purposes of design and reliability, and quality tests will be achieved in the near future. Experience indicates that the present confusion is particularly acute with respect to production sampling tests.

TEST CONDITION MATRIX

After the purpose of a test has been established, test conditions can be selected, in principle at least, in a straightforward manner. In Table 3 the same types of tests discussed above are listed against the four major test parameters which, in a broad sense, determine the test conditions. These parameters include the assembly level of the test item; the degree to which it is necessary to simulate the operational environment; the use of time-acceleration in the test; and the degree to which the frequency spectrum of the environment must be simulated. Production acceptance tests or screens differ from all other tests. These differences are discussed in detail in a later section.

FUTURE DEVELOPMENT

It is appropriate at this point to look ahead at the most pressing problems associated with testing. The following discussion concerns three hardware/software developments needed to reduce testing costs and four shortcomings of technology.

The control of a vibration test is somewhat like the flight of an airplane. During "take-off", as the test level increases to a maximum, the controller is busy measuring the system transfer function and adjusting for nonlinearities. At level, or "cruise altitude", little effort is required to make minor adjustments to the drive signal from time to time. When the test is stopped, for whatever reason, the controller is again busy assuring a safe shutdown of power. Thus, the full capability of digital controllers is used only during brief periods of most vibration tests. It would appear conceptually feasible to make better use of digi-

		DESIGN ADEQUACY		PRODUCT ASSURANCE	
TEST I.D.	STRUCTURAL CHARACTERISTICS	FUNCTIONAL PERFORMANCE	FATIGUE LIFE	RELIABILITY	QUALITY
DESIGN DEVELOPMENT	√	√	—	(RELIABILITY GROWTH)	—
FLIGHT WORTHINESS	—	√	—	—	√
DESIGN VERIFICATION	√	√	√	—	—
DESIGN QUALIFICATION	—	√	√	(RELIABILITY DEMO)	—
PRE-PRODUCTION (FIRST-ARTICLE)	—	√	(?)	(?)	√
PRODUCTION SAMPLING	—	(?)	(?)	√	√
PRODUCTION ACCEPTANCE (SCREENING)	—	—	—	(?)	√

Table 2. Test Purpose Matrix

TEST I.D	PREFERRED ASSEMBLY LEVEL	SIMULATION	ACCELERATION	SPECTRUM SIMULATION
DESIGN DEVELOPMENT	COMPONENT	LOOSE	NOT USUALLY	LOOSE
FLIGHT WORTHINESS	COMPONENT - MAYBE SYSTEM	PROBABLY NOT	NO	LOOSE
DESIGN VERIFICATION	SYSTEM	YES	YES(?)	YES
DESIGN QUALIFICATION	SYSTEM	YES	YES	YES
PRE-PRODUCTION (FIRST-ARTICLE)	SYSTEM	YES	MAYBE	YES
PRODUCTION SAMPLING	SYSTEM OR COMPONENT	YES	NO	YES
PRODUCTION ACCEPTANCE SCREENING	COMPONENT	NO	YES, IN ATYPICAL SENSE	NO

Table 3. Test Condition Matrix

tal controllers by using one controller to tend several shakers, particularly for such long tests as reliability development/demonstration or endurance tests. Of course, only one "take-off" or "landing" could be attempted at any instant.

In a somewhat similar fashion, digital control systems have the inherent capability to improve the performance of response control tests. At present, although digital controllers can handle swept-sine response control tests, random vibration tests require an iterative procedure, as do analog systems. Again, only a SMOP (Small Matter of Programming) would enable the controller to calculate the frequency location and depth of notches required in the input spectrum and to update these calculations from time to time as the test proceeds. Of course, slower take-offs would be required while these notches are calculated initially.

The third hardware development required involves broadband vibration: if it is to be employed economically as a manufacturing screen on a large scale, low cost alternatives to the present sophisticated state-of-the-art systems must be developed. Note that it is the entire system costs, not just vibration facility costs and labor costs for appropriate skill levels to run and maintain the facility that are involved.

Let us turn now to less specific but perhaps more profound needs. It is possible to perform complicated tests safely, accurately, and with reasonable economy. But how well do test results reflect what would have happened in the field? Would a failure on the shaker happen in the field? Or would it happen again on the shaker? Why are so many failures in the field charged to dynamic environments, rightly or wrongly, even though the equipment passed qualification tests based on envelopes of field data? The questions indicate that there is considerable room for improving the state of the art -- and the word art is used without reservation. Four areas are most in need of improvement.

First, it is suggested those involved in testing should be aware of the limitations of testing in general: it is all too easy to yield to pressure to calculate some kind of a number and run some kind of test without knowing what is being done or why. Just as serious is the fact that profound conclusions are drawn from results that a real understanding of the processes involved would rapidly disprove.

Secondly, some progress must be made in the area of undue conservatism and over-specification in order to successfully design functionally adequate, reliable, cost-effective equipment that is not too heavy, too large, too costly to manufacture, and too complicated to maintain. The undue conservatism of enveloping is too often readily acknowledged but countered with complaints of lack of data. More data can never reduce an envelope, however. An alternative entailing some calculable risk must be sought and embraced.

One facet of the problem of over-specification and conservatism is the effect of impedance match and/or mismatch. Specifying maximum levels as inputs at fixed-base natural frequencies must be avoided because studies have shown that they are the frequencies at which minimum levels occur. A solution might be that only the overall level is controlled after equalization with a dummy mass, or perhaps flexible fixtures must replace the massive super-stiff structures now in use. That the required level on a 10 pound test item cannot be obtained with a 40,000 pound shaker should be indicative of unrealism.

The three areas for improvement cited above are old friends that the audiences of this Symposium have encountered for years. In the last three to five years, however, a new challenge has been growing, and some progress in its solution can wait no longer. The challenge is that the testing community must effectively adapt and innovate test requirements, test methods, and test facilities to accommodate environmental qualification; reliability development and/or demonstration; Mission Profile Testing (CERT); and manufacturing screening. This entire process is presently receiving a great deal of emphasis, not always by experienced individuals. It would be unfortunate if the end result of a great deal of effort and expenditure of resources was little or no improvement in the field.

SCREENING VIBRATION REQUIREMENTS

The last few paragraphs above touched on several problem areas -- i.e., opportunities -- whose mitigation would constitute a significant contribution to vibration testing. It is appropriate to discuss what the writer considers to be the most topical opportunity of the day; namely, definition of the requirements for vibration screens.

A vibration screen is a manufacturing process that, along with other screens such as thermal cycling, is applied to components of a system prior to delivery from the manufacturing plant. Note that this phraseology does not mean the screen must be applied on a system basis; rather, the screen is applied to those parts of the system that can be practically and usefully screened at some level of assembly. Note also that a screen is a process and not a test. Failures generated by screens indicated good results -- opposite to the customary view of failure during a test.

The sole purpose of the screen is to identify flaws or defects in the equipment prior to shipment so that the flaws do not become failures in the field. This is illustrated in Figure 1, which portrays the flaws

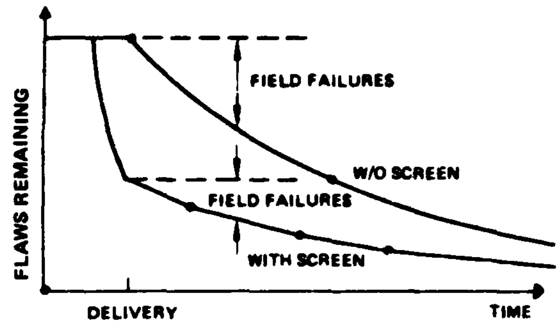

Figure 1. Flaws Remaining Versus Time

remaining in a piece of equipment versus time. At any time, initial flaws minus flaws remaining equal cumulative failures. The exponential curves are derived from the premise that the rate of flaw precipitation, or failure rate, is proportional to the number of flaws remaining in the equipment. The curves have been substantiated by analysis of both field and factory failure data.

It should be noted that, if a screen removes a significant proportion of initial flaws, the total number of failures that will have to be repaired in the field is also significantly reduced. Remember, however, that the curves shown in Figure 1 represent an average over all S/N's of that equipment; thus, as field time becomes large, the two curves become almost indistinguishable. In other words, long-term reliability is not noticeably improved, particularly if repair and maintenance processes create new flaws.

One more concept must be introduced: not all flaws are precipitable by all environments. Figure 2 shows the degree of coincidence of precipitable flaws in the production environment U_P and the field environment U_F.

If the above models are accepted, it becomes possible to make some statements about screening conditions in general, and vibration in particular. First, it is not necessary and may well be undesirable that the screen simulate the field environment. Figure 2 shows that it is necessary to simulate the <u>effects</u> of the field environment so that U_P and U_F are as coincident as possible. However, Figure 1 shows that simulating the field environment -- i.e., one hour of screen is

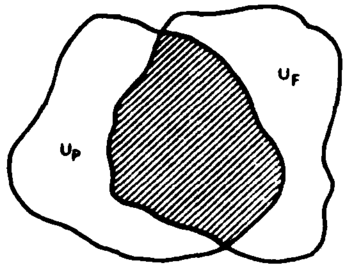

Figure 2. Degree of Coincidence of Precipitable Flaw Populations

equal to one hour in the field -- is inadequate. If the screen is to be reasonably efficient and economic, it must precipitate the same population of flaws as the field environment but at a much faster rate; the screen is thus, in a special sense, an accelerated test.

Even though the field environment is not simulated, Figure 2 is most likely to be satisfied if some of the field characteristics are reproduced. Experience indicates and there is a consensus that broadband vibration excitation is necessary for a screen to be efficient. Note that the vibration is broadband and not necessarily random. The key point seems to be that all modes, or at least the most important ones, are excited simultaneously.

Now consider the spectrum, which is defined by three parameters: the area under the curve, i.e., rms acceleration; the overall band width or frequency range; and the actual shape of the spectrum, i.e., is it continuous and how much variation from maximum to minimum.

It is the writer's opinion that the efficiency of the screen will be tolerant of variations in the spectrum providing:

- the spectrum is reasonably continuous, with no wide holes, over a frequency range embracing a number of modes of the item being screened
- the overall level is appropriate
- the spectrum shape is essentially unspecified and uncontrolled

The above provisions are not likely to make a vibration test engineer (or specification writer) comfortable. After all, he has spent his career trying to meet tight tolerances on spectral density requirements and/or attempting to build fixtures with identical inputs at a number of attachment points, as required by the specification. Now somebody wants to discard all that and control the overall level. This will allow the test item to load down the fixture! But it may also avoid overstressing the equipment and using up its fatigue life. And for every valley, a peak must appear at some other frequency if the area is to be preserved. How do we know that peak won't cause a failure? We don't know for sure. But peaks occur only where it is easy to drive the system, which is not at damaging frequencies.

The only other requirements on the conditions are that:

1. The flaws are precipitated rapidly
2. No inappropriate design failures are induced. Appropriate design failures would be:
   a. Design failures discernible only from testing a large population
   b. Previously detected design failures inadequately corrected
   c. Design improvement inadequately verified; e.g., value engineering changes
3. An adequate yield of the proper type of flaws is obtained. This can be measured before delivery with final information obtained only from field failure data
4. No flaws are induced

Note that the screen conditions are independent of the field environment and the design specification. However, it does seem reasonable that there be some loose correlation. In other words, the more severe the field environment, the more rugged should be the design, this probably means that a more severe screen is needed to precipitate the flaws. Conversely, there is no universal screen. In fact, the adequacy of the screen can be judged only by the end result; unfortunately, such judgment is entirely too late.

If the above remarks have any merit, it is to indicate that the development of appropriate vibration screens will be very difficult, and that a different screen will probably be required for every new project. Some success can be achieved only with a flexible approach to specification and adjustment through analysis of failure types and quantities.

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 articles about shock response spectrum and maximax response; and vibration of periodic structures.

Dr. Y. Matsuzaki of the National Aerospace Laboratory, Jindaiji, Chofu, Tokyo, Japan has written a review of the recent literature on the shock response spectrum and the greatest maximum or maximax, response of structures subjected to shock loads.

Dr. G. SenGupta of The Boeing Commercial Airplane Company, Seattle, Washington has written a paper which presents an overview of some recent applications of periodic structure theory.

SHOCK RESPONSE SPECTRUM AND MAXIMAX RESPONSE

Y. Matsuzaki*

Abstract - This is a review of recent literature on the shock response spectrum and the greatest maximum, or maximax, response of structures subjected to shock loads.

A previous article [1] outlined the principal development of the shock response spectrum (SRS) of linear and nonlinear systems from an analytical point of view. This paper is an update of the literature primarily from 1977 to 1979. The SRS approach is simple, well established, and easy to apply, particularly to single-degree-of-freedom systems. Although the SRS is widely used as a practical tool in engineering applications, little information has appeared in the available literature. Nevertheless, there has been certain progress in shock analysis and design. SRS has been applied to large structures with many degrees of freedom and the maximax (greatest maximum) response of a linear structure has been predicted from information on the upper limit of the load energy or the response energy transmitted by the load. The loading condition for the maximax response is specified more grossly -- i.e., by the energy -- than for the SRS. The maximax response is considered a useful alternative for design and analysis.

SHOCK RESPONSE SPECTRUM (SRS)

The SRS is a plot of the peak response of a single-degree-of-freedom oscillator to a specific shock excitation; it is well defined and easily obtained for a simple structure. In certain situations, many degrees of freedom are required to represent the response of the structure because of its complexity. Even with structures having many degrees of freedom the upper bound for the maximum total response can be estimated from superposition of the individual maximum responses for each normal mode if the response is expressed in terms of the normal modes. But this is not always the case. When the structure is composite, the normal modes of the substructures are often used and are coupled in the total response.

Trubert and Salama [2] have presented a procedure for obtaining the SRS of a spacecraft mounted on a launch vehicle. The spacecraft is modeled by S normal modes and the launch vehicle by L normal modes. The equations governing the response of the total system are given by a set of coupled (S+L) equations. The coupled (S+L) equations are changed into a simplified version of the (SxL) equations; in each equation one spacecraft mode is coupled with one launch vehicle mode. An explicit closed form of the individual bound in each spacecraft mode is derived for the equivalent impulse force acting on the launch vehicle. The bound on the total response is obtained by summation over the individual bounds.

For design of a large structure, the SRS is specified at only a limited number of locations. However, the response at some other location must often be evaluated. Crimi [3] developed an iteration method for synthesizing the time history from the SRS. After the response time history is synthesized from the prescribed SRS at one location, the response elsewhere in the structure can be calculated by using a relationship between the displacements at the two locations under consideration [3].

Let S (ω) denote a given SRS of the acceleration. Suppose that the SRS of the synthesized acceleration $\ddot{x}$ is required to coincide with $S(\omega)$ at N points with frequencies $\omega_1, \omega_2, \ldots, \omega_N$. The synthesized acceleration is assumed in the form of

$$\ddot{x} = \sum_{i=1}^{N} C_i \exp(-\omega_i \zeta t) \sin(\omega_i t\sqrt{1-\zeta^2}) \qquad (1)$$

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The C_i's are constants to be determined by iteration; ζ is a free parameter (ζ=0.1 is recommended).

Let $S_C(C_1, C_2, \ldots, C_N)$ denote the SRS of $\ddot{x}$ as calculated from equation (1). The initial values for C_i's are given as

$$C_1^{(1)}=S(\omega_1)/S_C(1,0,0,\ldots,0),$$

$$C_2^{(1)}=S(\omega_2)/S_C(0,1,0,\ldots,0), \text{ etc.}$$

The iteration formula is

$$C_k^{(n+1)}=C_k^{(n)}$$

$$+w[\{S(\omega_k)-S_C^{(n)}\}/(\bar{S}_C^{(n)}-S_C^{(n)})]\Delta C_k \qquad (2)$$

where ΔC_k is a specified fraction of $C_k^{(n)}$ such as $(0.05C_k^{(n)})$, w is the weighting factor for stable convergence (w=0.5), and

$$S_C^{(n)}=S_C(C_1^{(n)},\ldots,C_N^{(n)})$$

$$\bar{S}_C^{(n)}=S_C(C_1^{(n)},C_2^{(n)},\ldots,C_k^{(n)}+\Delta C_k,\ldots,C_N^{(n)})$$

The iteration is continued until $|C_k^{(n+1)}-C_k^{(n)}|$ becomes smaller than a prescribed value. Crimi [3] also presented a procedure for numerical determination of the response of the structure at some point from the response at some other point.

In earthquake engineering, many investigations [4-11] have been carried out for analyzing the seismic response spectrum and developing its practical use. Among the investigations is a characterization of the response spectrum from a probabilistic point of view. A rational approach for the seismic motion must be based on a stochastic process; the loading specification of the response spectrum is deterministic. For a stationary Gaussian model, Kaul [11] examined a relationship between the power spectral density function (PSDF), $\Phi(p)$, of the ground motion and the response spectrum, $S(\omega)$, of a single-degree-of-freedom system of natural frequency ω and damping ζ. Explicit expressions for these quantities have been derived by introducing some simplifying assumptions. When the PSDF of the process is specified, the maximum response, $S(\omega)$, which is, by definition, exceeded only r times out of 1 in a large number of samples of time response of duration T, is given by

$$S(\omega)=[-2m_0\ln\{-\frac{\pi}{T}(\frac{m_0}{m_2})^{1/2}\ln(1-r)\}]^{1/2} \qquad (3)$$

where

$$m_n(\omega)=\int_{-\infty}^{\infty}p^n\psi(p,\omega)\,dp$$

$$\psi(p,\omega)=[\{\omega^4+4\omega^2\zeta^2p^2\}/\{(p^2-\omega^2)^2$$

$$+4\omega^2\zeta^2p^2\}]\ \Phi(p)$$

An inverse relationship between $\Phi(\omega)$ and $S(\omega)$ is approximated by

$$\Phi(\omega)=\frac{2\zeta}{\pi\omega}S^2(\omega)/[-2\ln\{-\frac{\pi}{\omega T}\ln(1-r)\}] \qquad (4)$$

Procedures for obtaining the exact relationships have been presented [11].

For a high-speed cam-driven mechanism, primary and residual SRS were extensively studied and presented in charts [12, 13]. The effects of linear or nonlinear damping for a single- or two-degrees-of-freedom system were taken into account. Programs for a pocket calculator for computing the SRS of a simple system have been developed [14].

THE GREATEST MAXIMUM (MAXIMAX) RESPONSE

Attention has recently been given to predicting the maximax response of a structure from information on the upper bound of total energy. In some situations, the energy of the load or the energy of the response of the structure can be guessed with more confidence than the load shape or frequency spectrum.

Drenick [15] and Shinozuka [16] evaluated the greatest maximum response of a structure subjected to a load, f(t), with a total energy less than or equal to a specified value M^2.

$$\int_{-\infty}^{\infty}f^2(t)\,dt=\frac{1}{2\pi}\int_{-\infty}^{\infty}|F(\omega)|^2d\omega\leqslant M^2 \qquad (5)$$

$F(\omega)$ is the Fourier transform of $f(t)$. The response, $g(t)$, of the linear structure is written as

$$g(t) = \int_{-\infty}^{\infty} h(t-\tau)\, f(\tau)\, d\tau$$

$$= \frac{1}{2\pi}\int_{-\infty}^{\infty} H(\omega)\, F(\omega)\, e^{i\omega t} d\omega \qquad (6)$$

where $h(t)$ and $H(\omega)$ are, respectively, the impulse response of the structure and its Fourier transform. Assume that

$$\int_{-\infty}^{\infty} h^2(t)\, dt = \frac{1}{2\pi}\int_{-\infty}^{\infty} |H(\omega)|^2 d\omega = N^2 \qquad (7)$$

are finite for a practical problem. Obtain, by virtue of the Schwartz inequality,

$$|g(t)| \leqslant \frac{1}{2\pi} \int_{-\infty}^{\infty} |H(\omega)| \cdot |F(\omega)|\, d\omega$$

$$\leqslant \left[\frac{1}{2\pi} \int_{-\infty}^{\infty} |H(\omega)|^2 d\omega \right]^{1/2} \left[\frac{1}{2\pi} \int_{-\infty}^{\infty} |F(\omega)|^2 d\omega \right]^{1/2}$$

Therefore,

$$\text{maximax } |g(t)| = MN \qquad (8)$$

If $|F(\omega)|$ is available instead of M^2, the estimate of the upper bound can be more precise. The least favorable excitation producing the maximax response is

$$f(t) = \frac{M}{N} h(-t) \qquad (9)$$

When the frequency band or the duration of the excitation is finite, the upper bound of the response is evaluated essentially in the same way as above [15].

Youssef and Popplewell [17] proposed a more sophisticated approach for predicting the maximax response by restricting both the duration and the frequency band of the response for practical purposes. Theoretically such a restriction violates the uncertain principle.

Let E_g be the total energy of the response $g(t+T/2)$ of duration T from $-T/2$ to $T/2$, and E_{gB} be the energy of the band limited response of bandwidth Ω, which is the smaller of the bandwidths of the loading function and impulse response. The least favorable response can be considered to be one with the most energy in the frequency band $|\omega| \leqslant \Omega$. The problem is reduced to determining the response at which

$$\nu = E_{gB}/E_g \qquad (10)$$

is a maximum. The band limited response is written as

$$g_B(u) = \frac{1}{2\pi} \int_{-\Omega}^{\Omega} G(\omega)\, e^{i\omega u} d\omega$$

$$= \frac{1}{2\pi} \int_{-\Omega}^{\Omega} e^{i\omega u} \int_{-T/2}^{T/2} g(v)\, e^{-i\omega v} dv\, d\omega \qquad (11)$$

$$= \int_{-T/2}^{T/2} g(v) \sin \Omega\,(u-v) / \left\{\pi(u-v)\right\} dv$$

Use equation (11) and the Parseval theorem.

$$\nu = E_{gB} / E_g$$

$$= \int_{-T/2}^{T/2} g(t) \int_{-T/2}^{T/2} g(v) \sin \Omega\,(t-v) / \qquad (12)$$

$$\left\{\pi(t-v)\right\} dv dt / \int_{-T/2}^{T/2} g^2(t)\, dt$$

The maximum value of ν is obtained when g is proportional to the characteristic function, ψ_0, corresponding to the maximum characteristic value, λ_0, of the integral equation

$$\lambda_i \psi_i(t) = \int_{-T/2}^{T/2} \psi_i(v) \sin\Omega(t-v) / \left\{ \pi(t-v) \right\} dv \qquad (13)$$

The characteristic function ψ_i's are given by the prolate spheroidal wave functions. The largest eigenvalue, λ_0, is associated with the first prolate spheroidal wave function of zero order.

The maximum value of the least favorable response is therefore given as

$$\max g_0(t) = \sqrt{E_{g0}/\lambda_0} \max \psi_0(t+T/2) \qquad (14)$$

E_{g0} is the energy of the least favorable response and $\sqrt{E_{g0}/\lambda_0}$ is a normalization factor of the eigenfunction ψ_0. The maximax response for all excitations with the same energy E_f is

$$\text{maximax } g_0(t)$$

$$= \sqrt{\max|H(\omega)|^2 E_f/\lambda_0} \max \psi_0(t+T/2) \qquad (15)$$

because $\max E_{g0} = \max|H(\omega)|^2 E_f$.

Youssef and Popplewell [18] extended their approach to estimate the maximax response of a multi-degree-of-freedom system. They also performed numerical comparisons between the maximax responses calculated by equations (8) and (15) for several typical loads [19].

CONCLUDING REMARKS

The shock response spectrum approach has been applied to a large and complex structure, the response of which is represented by many degrees of freedom. It is necessary to establish an efficient SRS procedure, one that is applicable to the analysis and design of such a structure, because a total transient response analysis of the structure is time consuming. The successful development of the efficient procedure depends on choosing approximations that are suitable only for the structure and the load under consideration. In other words, no general method exists for effectively predicting the SRS of the complex structure. In earthquake engineering, considerable effort has been devoted to developing the seismic response spectrum and its practical use.

The concept of the shock response spectrum is simple and has been developed fully. Little might be expected insofar as further theoretical development is concerned although practical problems in application remain. The SRS is rather insensitive to the shape of the loading function. The simple excitation is often assumed; for instance, an impulse function. However, the more precise the information available on the load, the more accurate the prediction of the maximum response will be. Under certain conditions the energy involved in the shock process can be estimated with more certainty than the shape of the loading. Attempts have been made to calculate the greatest maximum response of the structure to a load specified by an upper limit of the load energy or the response energy. It is of practical significance to be able to compare the maximum responses predicted by several approaches based on information about different load energies.

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VIBRATION OF PERIODIC STRUCTURES

G. SenGupta*

Abstract - Many practical engineering structures can be regarded as periodic; that is, they consist of many basic periodic units. Aircraft fuselages, ship hulls, tall multi-storied buildings, periodically supported pipes, composite materials, and heat exchanger tube banks in a nuclear reactor are examples. Application of periodic structure theory simplifies analysis of dynamic responses of such structures and reduces computer costs. This paper presents an overview of some recent applications of periodic structure theory.

Application of periodic structure theory -- well known to solid state physicists and electrical engineers [1, 2] -- to predicting vibration responses of engineering structures due to broad band pressure fluctuations is relatively recent. Work until 1975 has been reviewed [3]. This paper describes theoretical and experimental work conducted since then and outlines the direction of future developments.

BASIC THEORETICAL BACKGROUND

Previous work on periodic structures concentrated on such periodically supported beams and plates as skin-stringer panels, rib-skin structures, doubly periodic structures, and orthogonally stiffened plates. A limited amount of work has also been done on frame stiffened cylinders. All these periodic structures exhibit some common characteristics: they behave as band-pass filters, responding and radiating noise very efficiently in certain frequency bands and not so efficiently in other frequency bands. These bands can be studied by developing matrix equations that determine the characteristic propagation constant (μ) of the structure. For a flexural wave traveling from one bay to the next, the amplitudes at two points (Figure 1a) separated by the periodic distance (ℓ) are related as

$$w_2 = w_1 e^{-\mu}$$

where (μ) is the propagation constant. In general, this constant is complex. The real part (δ) is associated with the decay of a structural wave as it propagates along a structure. The imaginary part (γ) is associated with the phase change of the wave as it travels from one periodic unit to the next. The frequency bands in which the real part is zero are called the free propagation zones; other frequency bands are called attenuation zones. Figure 1a shows a typical propagation constant-vs-frequency plot for a periodically supported infinite beam.

Analysis of the free vibration modes of a finite periodic structure shows the relationship between natural frequencies and the propagation constant [4]. Conditions at the extreme ends of a finite, periodic structure allow only certain discrete values of the propagation constant. These, in turn, dictate the distribution of the natural frequencies. At the natural frequencies, one-half or one-quarter of the primary pseudo-wavelength or an integral multiple fitted exactly within the total length of the structure. From this work, a simple and useful graphical method for finding the natural frequencies of periodic skin-stringer structures with any number of spans has been developed; an example is shown in Figure 1b. An interesting extension of this analysis has been published [5].

In general, more than one propagation constant exists at a given frequency. For a given number of standing waves in a direction perpendicular to the direction of the propagating waves, the number of propagation constants is equal to the number of degrees of freedom of the structure at each periodic support location. The location and width of the propagation zones are determined by such structural parameters as the dimensions and material properties of the skin panel and the stiffeners.

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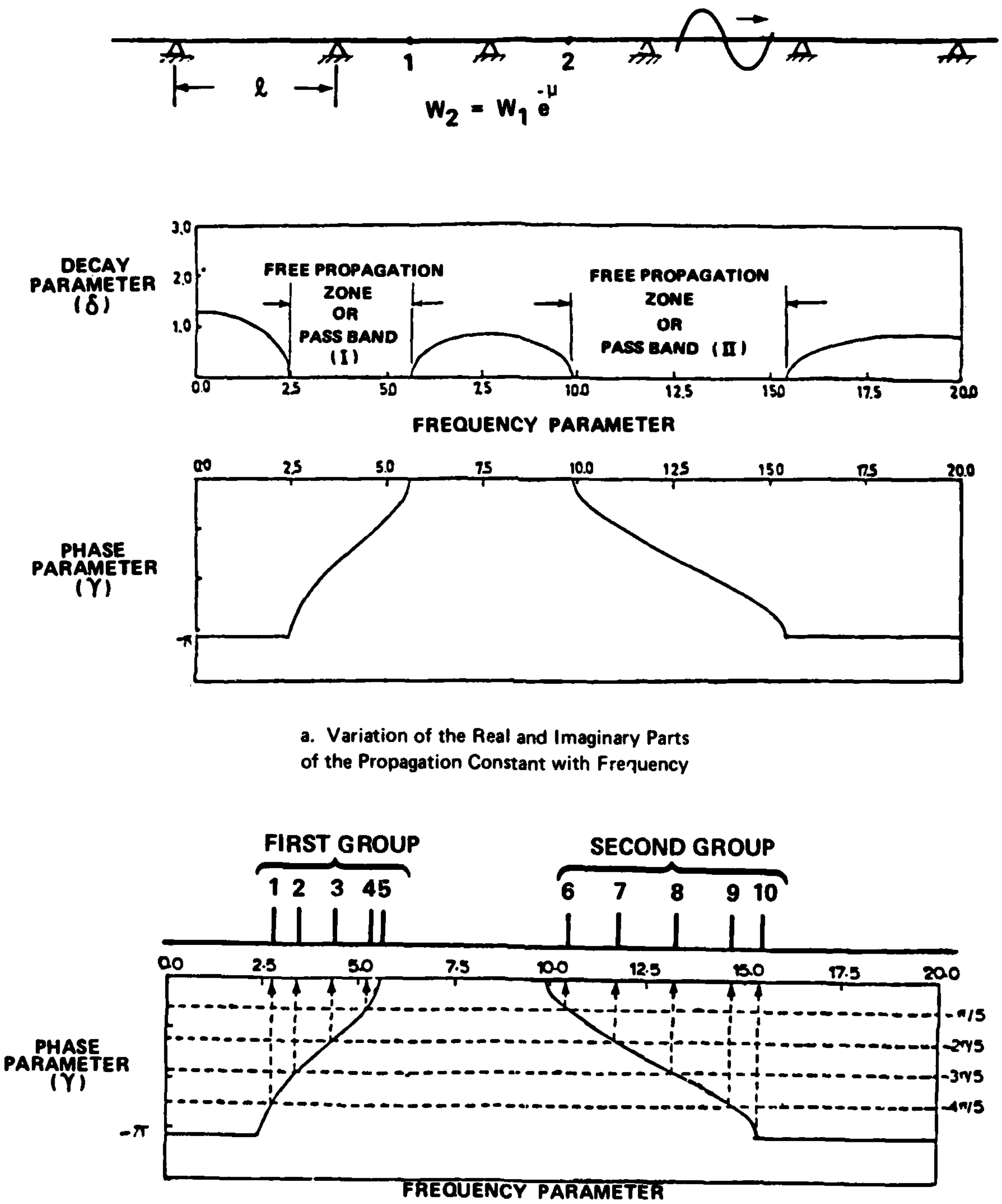


a. Variation of the Real and Imaginary Parts of the Propagation Constant with Frequency

b. The First Two Groups of Natural Frequencies of a Five-Bay Beam Clamped at Both Ends [4]

Figure 1. Wave Propagation in Periodic Beams

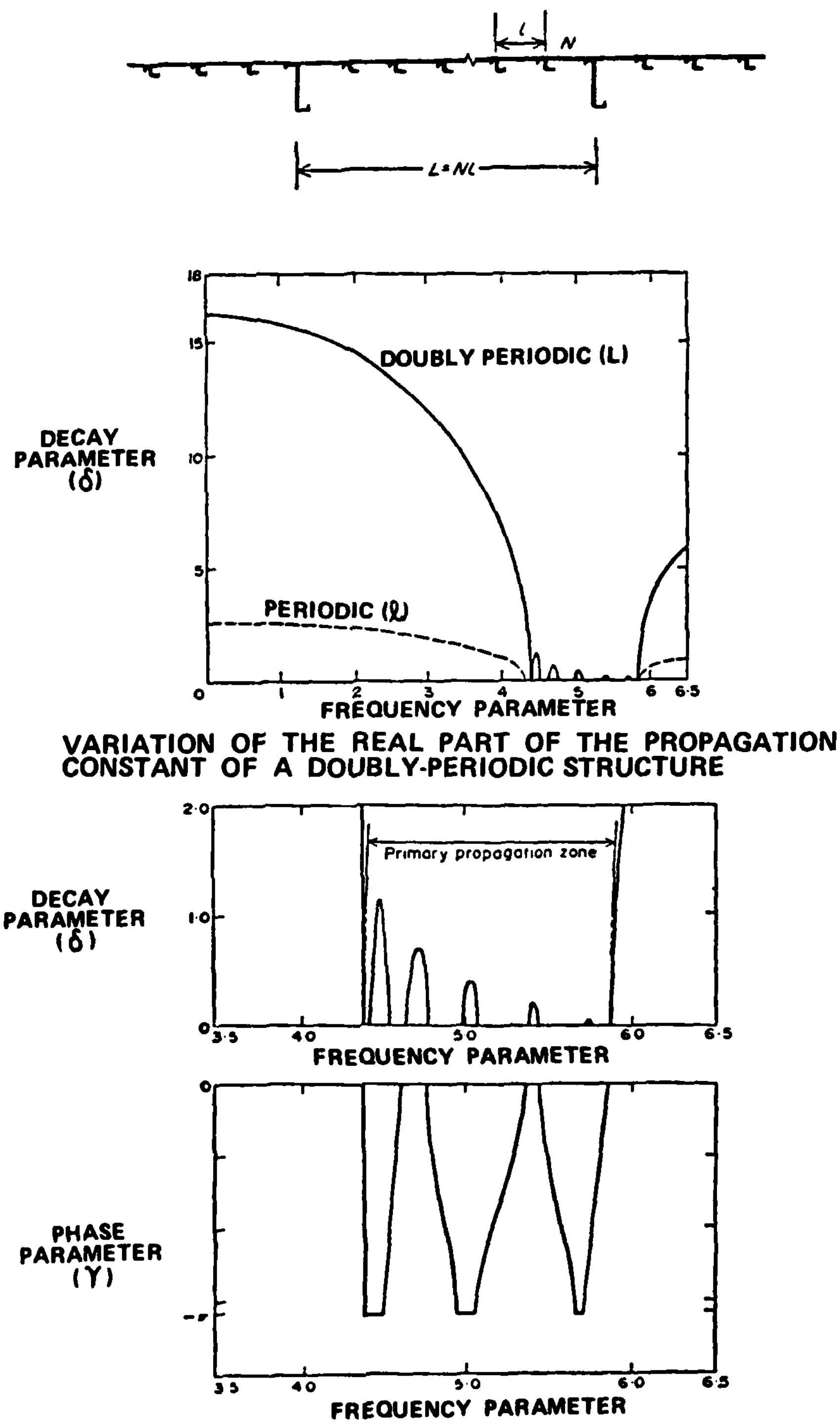


Figure 2. The Details of the Primary and Intermediate Propagation Zones of a Doubly-Periodic Structure [6]

In a doubly-periodic structure vibration response involves repetition of a basic periodic structure. Such structures are used in control surfaces and tail planes of aircraft. It has been found [6] that the free propagation zones for these structures are distributed in a pattern that is to some extent doubly periodic in appearance (Figure 2). Wide band primary propagation zones split into a number of narrow band intermediate propagation zones; the number of intermediate propagation zones within the primary propagation zone is equal to the number of spans in the basic periodic unit.

An asymptotic analysis of periodic structures has been published [7]. Free wave propagation in two-dimensional periodic plates has been analyzed [8, 9], and a solution for problems of wave propagation and forced vibration in ribbed plates has been presented [10]. Wave propagation in cylindrical shells with finite regions of structural discontinuity in the form of periodically spaced frames has been discussed [11].

APPLICATIONS

Examples of recent applications of the periodic structure theory to various structural vibration and noise problems are discussed below.

Aircraft Fuselage Structural Vibration and Interior Noise

Reduction of cabin noise and vibration by intrinsic structural tuning. The concept of intrinsic structural tuning, which was introduced previously [3], has been developed and verified experimentally. Development involved consideration of the response of a periodic skin-stringer structure, simply supported at the frames, to a highly correlated and coherent near-field engine noise environment. For typical skin-stringer structures, the frequency of peak response is very close to the natural frequency (f_p) of the individual skin-bay, clamped along the stringers and simply supported along the frames. The reason is that discontinuities are provided by the stringers. Reflection and transmission of flexural energy of the skin due to the stringers depends on the stringer stiffness during bending.

The dynamic bending stiffness of the stringer is a function of frequency. At the natural frequency (f_s) of the stringer, its dynamic bending stiffness is zero, because the static stiffness term is cancelled by the inertia term. Therefore, if stringer and panel dimensions are chosen such that the condition $f_s = f_p$ is satisfied, the panel response at f_p should be reduced substantially. If the stringers and panels are designed so that they satisfy the usual static strength requirements and are also tuned to each other according to the preceding equation, the structure should be efficient under both static and dynamic loading conditions. This is the basis of the intrinsic structural tuning concept [3, 12].

The concept was initially verified using analytical methods. The effect of structural tuning on the dynamic response of a stiffened panel was studied by changing the stringer spacing and by changing the stringer cross section. When the structure was tuned, the response near the frequency f_p was reduced, but two other modes responded strongly (Figure 3). The lower-frequency mode (mode 1) was such that the adjacent skin bays and the stingers vibrated in phase. The higher-frequency mode (mode 2) was such that, although the adjacent skin bays vibrated in phase, the skin and stringers vibrated out of phase.

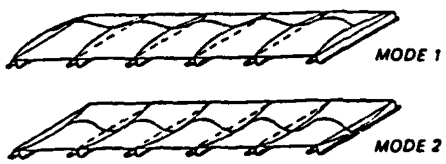


Figure 3. The Two Principal Modes of an Intrinsically Tuned Panel

With damped stringers (Figure 4) the responses of these two modes were reduced substantially. The rms response of the structure could be reduced further when the structure was fine-tuned; i.e., when the responses of the preceding two modes were equal. An optimum stringer damping value existed, and response increased if stringer damping was increased beyond this optimum level. If the stringer damping loss factor was infinitely large, the stringers did not respond, and there was a strong reflection of skin bending waves due to the stringers. Modes 1 and 2 then converged, giving rise to a strong response at the classical stringer bending mode frequency; i.e., at the frequency f_p.

Figure 4. Use of Constrained Viscoelastic Layer Damping on the Stringers

Details of the experimental program have been reported [12]. The principal results of laboratory and field tests are shown in Figure 5, which shows the variation of noise radiated by the most dominant low-frequency mode as a function of stringer spacing. With no damping treatment, the radiated noise level decreased by about 3 dB as the stringer spacing was reduced from 22.8 cm (9 in.) to 19 cm (7.5 in.). With a further reduction of stringer spacing, the level of radiated noise remained essentially at the same level. Thus, for an undamped structure, the tuning condition defines the point of diminishing return; reduction of cabin noise by structural modifications of the fuselage involves increasing its structural stiffness. Further reductions are possible by damping the stringers. Under damped conditions the radiated noise level, measured in decibels, decreased almost linearly as stringer spacing was reduced.

These results show that, with undamped conditions, there is a limit to the noise reduction possible by changing structural parameters. This limit can be achieved by designing the structure so that the skin panel and stringers are tuned to each other. However, further noise reduction is possible: if structural dimensions are selected so that the uncoupled skin panel frequency is higher than that of the uncoupled stringer frequency; if damping is applied on the stringer frames. The skin then acts as a relatively stiff member supported on relatively flexible stringers, and damping of the stringers effectively reduces the response. By contrast, skin damping would be less effective in reducing the peak response of the panel having 13-cm (5 in.) stringer spacings. The low-frequency response of this panel is controlled primarily by stringer resonance. The acceleration and stress responses of these panels also follow trends similar to those shown in Figure 5.

An interesting discussion on wave propagation in a bar reinforced with resonant members has been published [13]. This study also shows that, in certain frequency bands, the vibration amplitude of the reinforcing members can exceed that of the bar itself; vibration damping of the reinforcing members can therefore be useful.

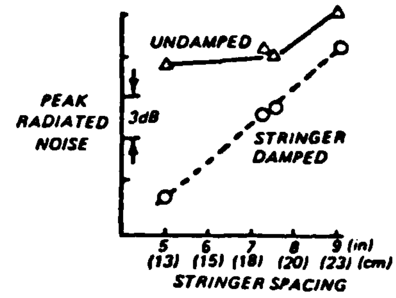


Figure 5. Reduction of Peak Low-Frequency Noise Radiation [12]

Reduction of low frequency cabin noise during cruise conditions. The discussion above had to do with an unpressurized aircraft, but the methods can be used to reduce low frequency cabin noise and sonically induced stresses during takeoff.

At cruise speeds in-plane loads due to cabin pressurization play a significant part in determining the structural response of the fuselage to noise and boundary layer turbulence.

The effects of pressurization loads on the response of periodic structures has been considered [14]. Two structural models were used: a periodic skin-stringer panel and a periodic frame-stiffened cylinder. Results indicated that in the so-called stiffness controlled region (below about 600 Hz) noise transmission in a pressurized fuselage stiffened by the stringers and frames can be governed by the resonances of the stiffeners. Thus, it is now possible to identify the key structural elements controlling low frequency structural response. Analysis of the structural response of the fuselage using the skin-stringer model shows that cabin noise in the 200-500 Hz band is controlled by structural vibration modes in which the skin, under the influence of pressurization loads, acts as a stiff member supported on relatively flexible stringers. The responses of these models to broadband, random pressure fluctuations are not very sensitive to changes in skin damping

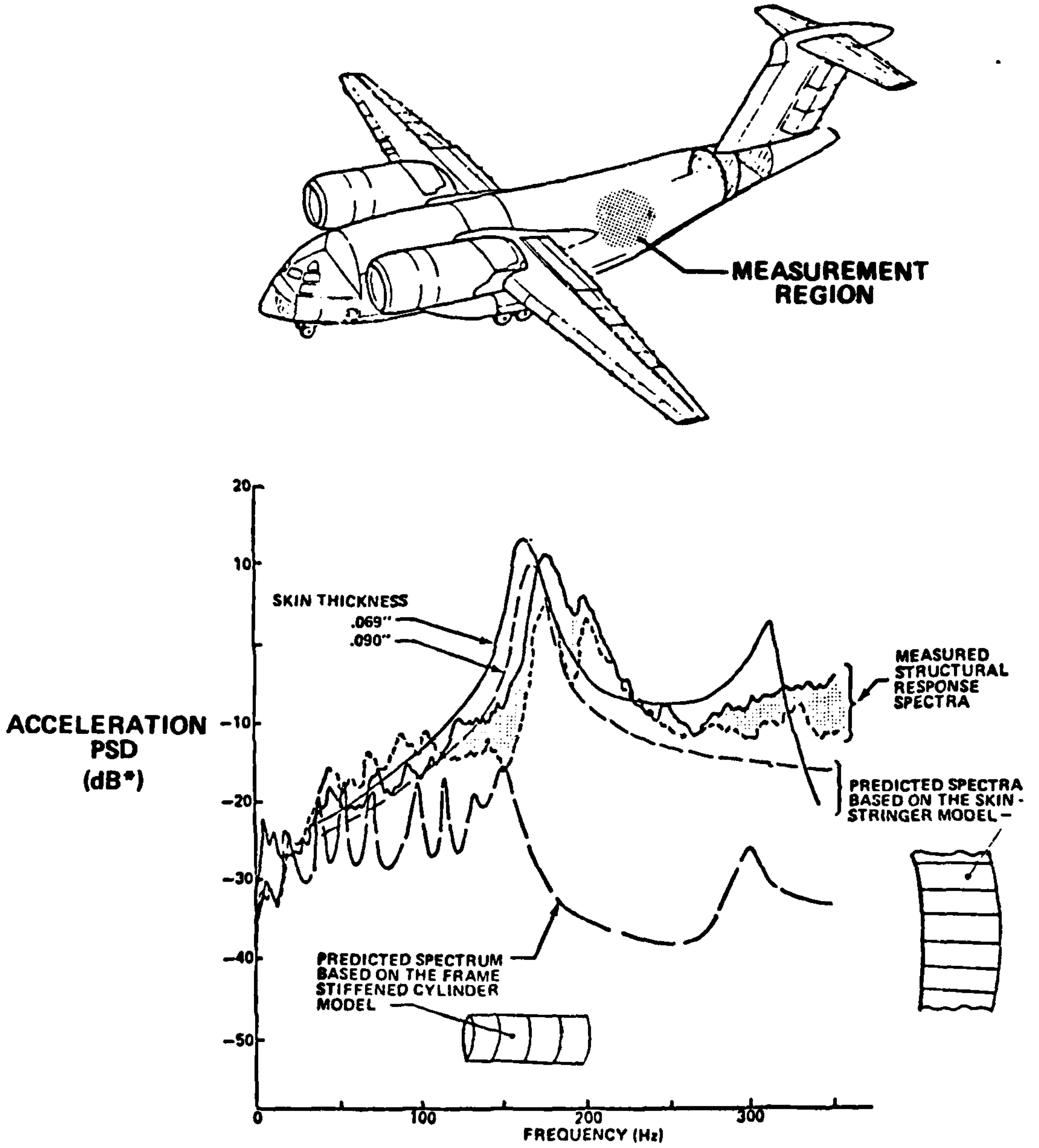


Figure 6. Comparison of Predicted and Measured Structural Response of an Aircraft Fuselage [15]

(*0dB = 1g^2/Hz)

loss factor, skin thickness, and stringer spacing. However, application of damping on the stringers should be an effective way to reduce cabin noise in the 200-500 Hz band.

Cabin noise and structural response below 250 Hz have been analyzed in terms of the vibration modes of a pressurized, frame-stiffened cylinder. Below 250 Hz, structural response to broadband, well correlated, random pressure fluctuations can be governed by frame resonances, with the shell acting as an attached mass. Application of damping treatments on the frames should therefore be effective in reducing the fuselage structural response below 250 Hz.

Comparison of predictions and the measured data on a full-scale aircraft. The predicted response of a fuselage structure to broadband random aero-acoustic excitation has been compared with measured data on a full-scale aircraft. Two periodic structural models, applicable in two different frequency ranges, were considered [15]. Figure 6 summarizes the data taken during ground runs with the aircraft unpressurized. The frequency of the peak response was accurately predicted by the skin-stringer model. The secondary peaks (below about 100 Hz) observed in the measured data were also predicted to be associated with frame resonances. The discrepancy between the measured and the predicted levels was largely due to the uncertainties regarding the fuselage structural damping loss factor and the convection and correlation properties of the excitation field, particularly at low frequencies; another cause was the nonhomogeneous excitation over the fuselage surface and the departure of the actual aircraft structure from the idealized theoretical model. Nevertheless, this comparison established the validity of the periodic structure theory for predicting the response of a highly complex aircraft structure to an equally complex aero-acoustic environment.

Control of cabin noise in a prop-fan aircraft by structural filtering. Reduction of low frequency cabin noise in prop-fan aircraft requires an improved design of the fuselage, so that the structure itself acts as an efficient noise barrier. It might be possible to design the fuselage so that it acts as a band pass filter, filtering out the discrete excitation frequencies. The structural filtering concept is derived from the fact that any periodic system exhibits certain filter-like characteristics. The existence of stop and pass bands in periodic skin-stringer and skin-frame structures has already been demonstrated [4, 16]. However, the feasibility of using a periodic fuselage structure as a filter for discrete frequency excitations had not been explored before. It has now been achieved [17] with a fuselage design and selection of a number of propeller blades and RPM that allow the discrete excitation frequencies to fall outside the pass bands of the periodically stiffened fuselage (Figure 7). If the excitation frequency falls within a pass band, a maximum phase mismatch should occur between the excitation and the structural waves.

The concept, still in initial stages of development, requires further analytical and experimental verification before it can be implemented in an aircraft design.

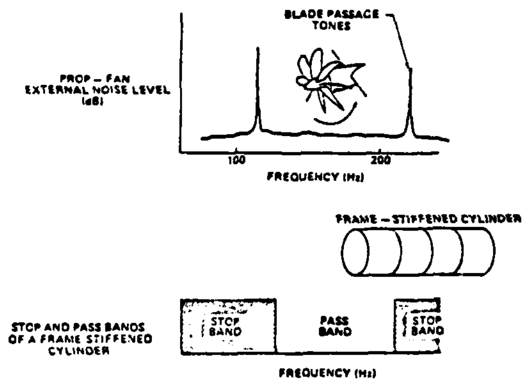


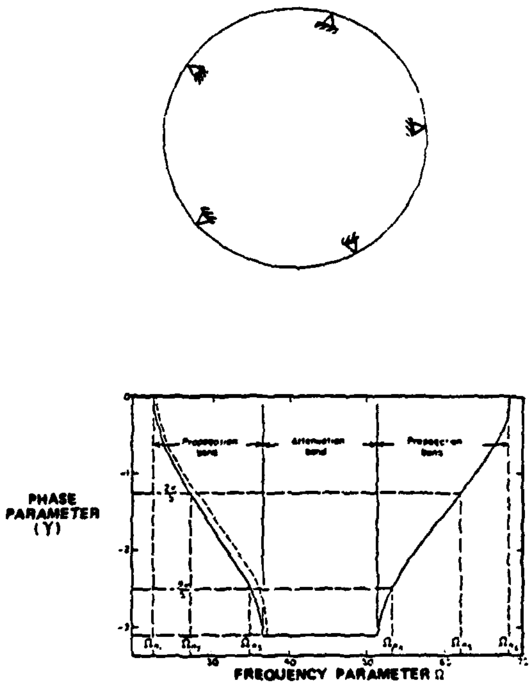
Figure 7. The Structural Filtering Concept: Proper Selection of Structural Parameters Filters Out the Discrete Excitation Tones [17]

Other Applications

Vibration of circular rings on periodic supports. The problem of free vibration of a circular ring on periodic supports has been studied using various methods [18-20]. The periodic structure theory was successfully applied to this problem by Mallik and Mead [21]. Two types of support were considered: those that prevent both radial and circumferential displacements and those that prevent only radial displacement.

Figure 8 shows the variation of the phase parameter (i.e., the imaginary part of the propagation constant) for a ring on five supports of the first type. Because only one degree of freedom is allowed at the support, a single propagation constant can exist at a given frequency. From Figure 8, it is seen that the natural frequencies of this structure can be found by using a graphical method similar to that described above [4]. For a ring on supports of the second kind, the number of propagation constants at a given frequency is two.

An interesting feature of this work has been the discovery of the existence of two different modes at a given natural frequency. One is symmetrical and the other is antisymmetrical about a diameter passing through a support. The number of normal modes in a given propagation zone is thus equal to the number of bays, although the number of natural frequencies in that band can be less than the number of spans. The periodic structure theory simplified the solution.



MONO-COUPLED ELEMENTS:
—— = EXACT ---- = APPROXIMATE

Figure 8. Propagation Constants vs. Frequency for a Ring on Five Supports [21]

Chen [22] used the periodic structure theory to study the coupled twist-bending waves of a multi-spanned curved beam and a graphical method [4] for predicting the natural frequencies of the structure under different boundary conditions.

Wave propagation in a periodically supported pipe carrying fluid: Another interesting application of the periodic structure theory involves wave propagation in and vibration response of a periodically supported pipe carrying fluid [23]. Due to the Coriolis force resulting from fluid flowing in a curved path, the speed of propagation of flexural waves depends on the direction of propagation. Figure 9 shows the variation of the propagation constant with frequency for waves going in opposite directions.

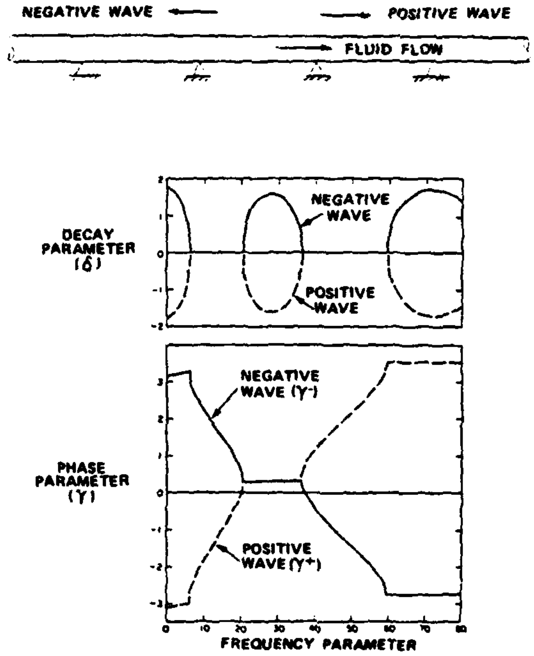


Figure 9. Variation of Propagation Constants with Frequency of a Periodically Supported Pipe Carrying Fluid

This difference in wave speeds means that no classical normal mode exists. However, the natural frequencies at which the structure can be strongly excited by a convected pressure field can be predicted. These frequencies are associated with the difference between the propagation constants, the following relationship exists at these frequencies

$$\gamma^{+}-\gamma^{-}=\gamma^{*}=\frac{2j\pi}{N},\ j=0,1,2\ldots N$$

where γ^{+} and γ^{-} are the imaginary parts of the propagation constants of the waves traveling in opposite directions, N is the number of bays, and j is an integer. Thus the graphical method [4] can be used to determine these frequencies (see Figure 10).

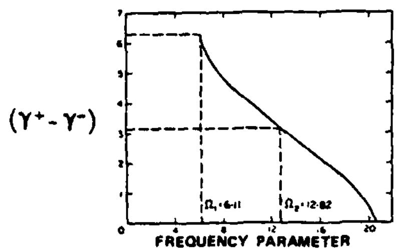


Figure 10. Variation of the Difference of Phase Parameters in the First Propagation Band of a Periodically Supported Pipe Carrying Fluid [23]

Application to heat exchanger tube banks of nuclear reactors. Flow-induced vibration in heat exchanger tube banks is of concern, particularly in high performance heat exchangers used in nuclear reactor systems. The periodic structure theory has been applied to such problems [24, 25]. The effects of liquid on the dynamic behavior of a row of circular cylinders has been studied [24]. The hydrodynamic forces associated with cylinder motions were obtained from potential flow theory. A method of solution based on the periodic structure theory was presented for free and forced vibrations of a row of cylinders. Propagation and attenuation zones were predicted. Natural frequencies were obtained from the graphical method [4].

Chen [25] extended his work to a group of heat exchanger tubes arranged in various patterns. Propagation and attenuation zones were again predicted. In each free propagation zone were 2K natural frequencies for a group of K tubes; these frequencies were distributed near the frequency of the corresponding single tube. The factor of 2 arises due to the fact that each tube can vibrate in two orthogonal directions.

Vibrations of a compliant surface designed as a periodic structure. The dynamic response of some tentative compliant surfaces designed for possible reduction of skin friction drag has been investigated [26]. Among the structural models considered was a ribbed membrane backed by a polyurethane on PVS plastic. This model was simplified as a beam on a viscoelastic foundation and on a set of evenly spaced supports. Another structural model considered was a membrane mounted over a series of pre-tensioned wires, evenly spaced, with the entire membrane backed by an air cavity. The space-harmonic approach [27] was used. It was concluded that suitable choices of membrane thickness and periodic length would allow a periodic compliant surface to be designed with a resonant frequency and a mean square response that provides a favorable interaction with a turbulent boundary layer, thereby reducing skin friction drag reduction.

Prediction of loss factors and resonant frequencies of periodic damped sandwich plates. The periodic structure theory was successfully applied [28] to a problem concerned with predicting loss factors and resonant frequencies of periodically stiffened, damped sandwich plates. In previous work the boundaries were considered either as simple supports or as clamped, and could not be applied to the problem of stiffened sandwich plates. It has been shown [28] that the periodic structure theory can be used to study the effects of regular stiffening on damped sandwich plates. Computed results show how loss factors and resonant frequencies are affected by stiffeners and their attachment rivets, by stiffener spacing, and by the shear stiffness of the sandwich core.

Wave propagation in buildings modeled as periodic structures. Wave propagation and vibration characteristics of single vertical transmission paths of building structures of spatially periodic nature have been studied [29]. The forced harmonic response at element junctions was derived for finite periodic structures with arbitrary end conditions. Single wave-carrying beams were loaded periodically by lumped loads or by transverse beams of either finite or infinite length. In general longitudinal waves and to some extent flexural waves were important. A simple practical technique was developed for evaluating the propagation constants; measurements on a finite structure were in good agreement with theoretical predictions. The results of this study are useful in predicting dynamic response of tall buildings.

Another interesting application of the periodic structure theory deals with sound transmission through two parallel plates connected by identical periodically spaced frames, as is typical of walls in residential buildings [30].

A simple analysis has been presented for estimating the reduction in vibration levels of an infinitely long beam resting on a finite number of periodic supports [31].

Approximate methods for predicting the response of periodic structures. Approximate methods [32, 33] for studying wave propagation in periodic structures have been extended to infinitely long beams [34] and to finite, periodic beams [35]. The space-averaged response of a periodically-supported beam subjected to convected loading can be predicted accurately by assuming approximate mode shapes to describe the complex wave function [34]. The assumed modes should ideally satisfy four wave boundary conditions. If they satisfy only the geometric boundary conditions, the accuracy of prediction is acceptable. If they also satisfy the force wave boundary conditions, the accuracy is very high. The method can be adapted to study the vibration response and wave motion in nonuniform periodic beams and periodically stiffened plates and cylinders subjected to convected pressure fields. This method was extended [35] to finite periodic structures by taking into account the reflection of flexural waves from the extreme ends of the finite structure. The method was also used to predict sound radiation from periodic structures [36].

Combination of matrix methods and the periodic structure theory. For such simple structures as periodically stiffened beams, plates, rings, and shells, closed form solutions can be used to define the displacements and forces within each periodic unit. The periodic structure theory is used to simulate the coupling between adjacent bays. For many real complex structures such closed form solutions are not readily available; instead, such matrix methods as the finite element methods are used. Analysis of a long periodic structure by the conventional finite element method is difficult because of the large computer storage requirement. Smearing the frames and stringers does not adequately simulate the structural discontinuities provided by these elements to the structural waves of the skin.

Combining the periodic structure theory with various matrix analytical methods is useful in such situations because it reduces the computer storage requirement. Such methods have been proposed [37-42, 44, 45].

One method for analyzing periodic structures based on a matrix difference equation approach [39] is similar to earlier work [37, 38]. The advancement is recognition of the existence of two types of displacement variables -- i.e., symmetric and antisymmetric about the plane of symmetry of the periodic unit -- and elimination of certain force variables. The linear characteristic equation is of the same order as the original quadratic equation; thus the matrix order is half of an earlier one [39]. The equations can therefore be solved more readily. The method was applied to an aircraft engine duct vibration problem [39] and has been extended so as to avoid the inversion of large matrices [41].

An alternative way of predicting the response of periodic structures is based on the Z-transform method [40]; the same results can be obtained by applying the basic transfer matrix recurrence relationships and Sylvester's theorem [43]. The formulation [40] has the advantage of accommodating not only end excitations but also external forces at the boundary interconnecting the various substructures. An additional advantage is that only the eigenvalues rather than eigenvectors of the transfer matrix of typical substructures are required. It is also claimed that additional computational savings are achievable for symmetric substructures.

The method [40] was extended [44] to predictions of the response of finite periodic structures by modal analysis. The approach takes full advantage of the system periodicity and allows determination of eigenvalues of a complete structure and the response of the system to arbitrary excitations, harmonic or nonharmonic in the time domain.

The periodic structure theory has been used to simulate the response of continuous periodic structures [45]. The continuous structure is divided into an arbitrary number of small identical subunits. Each subunit is treated as a periodic unit. The response of the complete system is obtained from the limiting case, in which the length of the subunit is vanishingly small. This method has the potential to accurately simulate a large continuous structure without unduly increasing the computational effort. The method should be useful in analyzing high frequency, short wavelength vibrations of continuous structures subjected to loading functions that vary arbitrarily along the length of the structure.

Application of periodic structure theory to composite materials. Dynamic properties of composite material consisting of periodic arrays of fibers in a support medium can be conveniently and accurately studied by the periodic structure theory. Nelson and Navi [46] discussed harmonic wave propagation in composite materials; they idealized the composite material as a periodic lattice-type structure. The method is used to generate the frequency spectra for both a fiber-reinforced composite plate and an infinite composite medium; the dispersive effects that exist in periodic media when the half wavelength-to-lattice dimension ratio approaches unity can thus be indicated. The existence of pass bands and forbidden bands (corresponding to the free propagation and attenuation zones of a periodic structure) for fiber-reinforced viscoelastic materials has been discussed [47].

Wave propagation in viscoelastic composites reinforced by orthogonal fibers has been discussed [48]. A method similar to the periodic structure theory was used to obtain the dispersion characteristics of waves propagating in the medium.

Dynamics of rotationally periodic structures. Vibrations of such structures as bladed turbine discs, alternator end windings, and cooling towers with legs have been studied [49, 50]. The periodic structure theory was combined with the finite element method to analyze rotationally periodic structures. It was shown that every natural frequency (except those for which the deflection is the same at corresponding points on every substructure) is associated with a pair of orthogonal mode shapes having eigenvalues $\{u\}$ and $\{\bar{u}\}$. The complex vector $\{z\} = \{u\} + i\{\bar{u}\}$ is also an eigenvector of the equation of motion and represents a rotating normal mode. For forced vibration any arbitrary oscillatory force can be represented by a series of rotating forces. Each force has a fixed relationship between the amplitude and phase of the forces acting on adjacent substructures. This relationship can be used to perform a series of calculations for the response of one substructure. An interesting example shows the substantial savings in computer costs that can be achieved.

Vibration of disordered periodic structures. Because most structures are only approximately periodic, no review of their vibration can be regarded as complete without a discussion of the effects of departure from perfect periodicity. Wave propagation in a semi-periodic structure has been discussed [51]. A semi-periodic structure is defined as one consisting of a repeating basic periodic unit that includes two or more spans of unequal length. The effect of the semi-periodicity on the width of the free propagation zones (Figure 11) and structural response has been studied [51]. An optimum ratio of about 2:3 of the two unequal spans was found. For this span ratio the response of the beam was minimum.

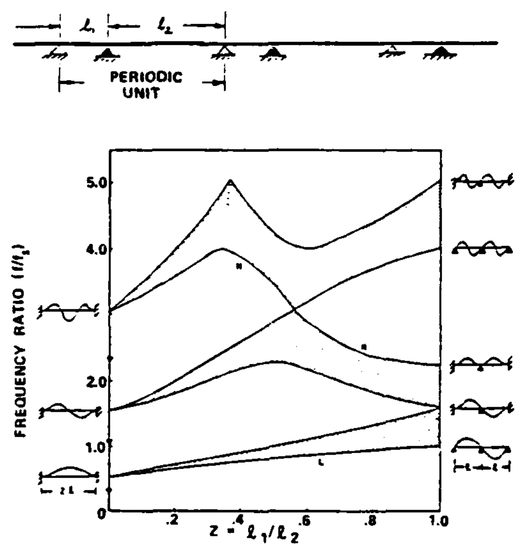


Figure 11. Variation of the Natural Frequency Bands of a Semi-Periodically Supported Beam with Span Ratio [51]

Wang and Lin [52, 53] studied the free and forced vibration of a disordered periodic beam. The lack of periodicity was simulated by random span-length deviations of a beam on multiple supports. A perturbation method was used. For lightly damped systems the response of the disordered periodic structure near the natural frequencies can be considerably larger than that of the perfectly periodic system. Hence overlooking the disorder may be nonconservative. As the system damping is increased, the nonconservative factor becomes less severe. This was found to be the case for point loading and convected loading. Furthermore, certain modes that were not excited in a perfectly periodic system were strongly excited in a disordered system.

Vibration and transient response of viscoelastic plates on non-periodic elastic supports have been studied [54, 55]. The restoring forces of the elastic supports were regarded as unknown external forces applied to the beam. The solution was obtained from the correspondence principle by applying the Laplace transform to the constitutive equation and the equation of motion of the elastic plate. This method should also be useful for assessing the effect of the lack of periodicity on the vibration response of a stiffened structure.

Flexural wave motion in periodic systems with multiple disorders has recently been considered [56, 57]. In such systems a basic periodic unit is assembled from several sections that are not identical to each other and thereby introduce disorders to the system. The results indicate that the primary propagation zones are divided into as many intermediate propagation zones as the number of elements in the disordered repeating unit (Figure 12). The situation is somewhat similar to the case of doubly periodic structures [6].

Further work by Mead and Lee on disordered systems is in progress [58].

CONCLUSIONS

The periodic structure theory is currently being applied to a variety of engineering problems ranging from reduction of structural response and noise transmission through aircraft fuselage to vibration of tall buildings and response of heat exchanger tube banks in nuclear reactors. Theoretical predictions have been verified by experiments on a full-scale aircraft. Significant advances in the development of efficient analytical methods will improve understanding of the dynamic response of many different structures at a substantial saving of computer costs. It is hoped that this method will be even more widely applied as more engineers learn to use it.

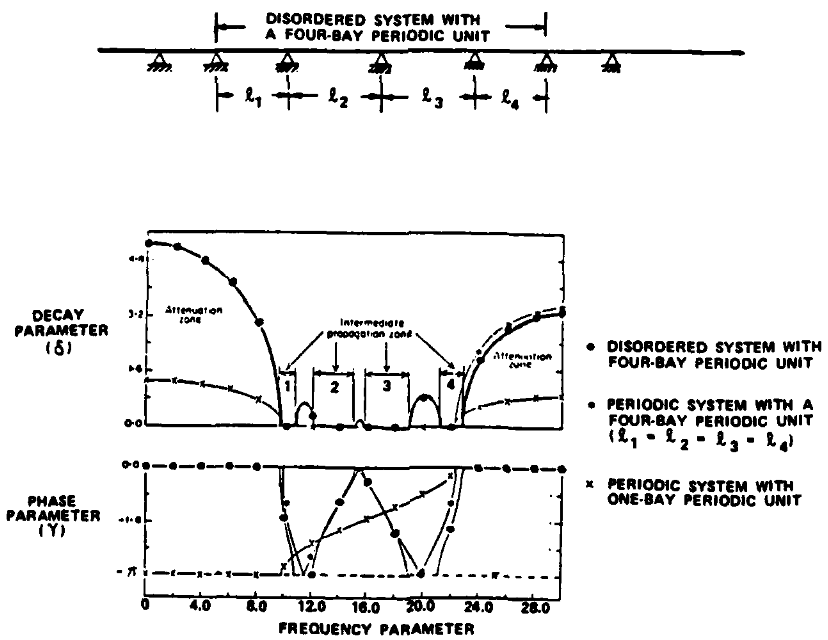


Figure 12. Comparison of Propagation Constants of a Disordered and a Periodic System [57]

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BOOK REVIEWS

ELASTIC WAVES AND NON-DESTRUCTIVE TESTING OF MATERIALS

Y.H. Pao, Editor
AMD-Vol. 29, ASME; New York, NY, 1978

This 29th book in the series of Applied Mechanics Symposia volumes published by ASME contains the texts of eight papers presented at the Winter Annual Meeting held in San Francisco, December 15, 1978.

The first of these papers is by R.S. Sharpe, "Industrial Development of Non-Destructive Testing of Materials by Ultrasound"; it is a review of the state-of-the-art of industrial use of ultrasound non-destructive testing (NDT). The author makes a strong case for closer cooperation between industrial users and academic researchers in order to surmount some crucial obstacles that exist in the way of efficient and economical use of ultrasound as an NDT tool.

The other papers deal with four different aspects of ultrasonic NDT. "The Scattering of Elastic Pulses and the Non-Destructive Evaluation of Materials" by W. Sachse and S. Golan and "Diffraction of Elastic Waves by Cracks - Analytical Results" by J.D. Achenbach, A.K. Gantesen and H. McMaken deal respectively with recent experimental and theoretical works in the diffraction of ultrasonic pulses by defects. The former is a comprehensive review of how the spectral analysis of the measured scattered signal from such smooth shapes as circles and ellipses can be used to characterize the sizes and properties of the defects. The latter reviews the work on geometrical theory of diffraction of elastic waves by cracks that have been done by the first author and his co-workers. The article also gives references to other works on diffraction of elastic waves by various obstacles, other than cracks, and should be of use to interested readers.

The other three areas covered in this symposium were acoustic imaging, acoustic emission, and acousto-elasticity. G.J. Posakony reviews the various ultrasonic imaging techniques that have been developed or are in the process of development for the characterization of interfaces and flaws. There are three papers on acoustic emission. J.G. Spanner gives an overview of various industrial uses and recent developments. The other two papers deal with laboratory simulations and theoretical developments in the modeling of sources of acoustic emission and the analysis of the radiation. N.N. Hsu and S.C. Hardy discuss the experimental aspects, and Y.H. Pao gives a comprehensive account of the theoretical developments, particularly in the use of generalized rays.

The last article by G.S. Kino, titled "Acustoelasticity" treats the determination of material properties of materials by ultrasonics. Also discussed is the determination of the stress-intensity factor by examination of the far-field scattered amplitude.

Overall, this volume is a welcome addition to the applied mechanics symposia series and should prove useful to both practitioners and others with an interest in ultrasonic NDT.

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HANDBOOK OF NOISE ASSESSMENT

D.N. May, Editor
Van Nostrand Reinhold Co., 1978

This book is a valuable addition to Van Nostrand Reinhold's "Environmental Engineering Series", which also includes two other noise control books.

Unlike other volumes that treat noise assessment as a prelude to detailed discussions of noise generation and control, Handbook of Noise Assessment concentrates solely on assessment. It provides useful information on how much noise is too much noise and is the first book to cover in a single volume both the effects of noise on man and the noise levels considered acceptable by various authorities and regulatory agencies.

The book is divided into two parts: Part I, "Psychological Effects Assessment," covers the assessment of noise for the annoyance it causes. Sounds that cause us physical damage are few in comparison with those that do no more than annoy us. The majority of people who are bothered by traffic and aircraft noise, construction noise, or a neighbor's air conditioner are not threatened with loss of hearing or other damage to their health.

Part II, "Physical Effects Assessment," covers the assessment of noise for its physical effects. The effects in question are hearing damage, sleep interference, non-auditory system effects on health, and work disturbance. These effects differ from annoyance in two ways: they are more objectively assessed, and they are essentially independent of situation.

A review of the chapter titles indicates the scope of the book. Each topic is covered in depth, and in an easy-to-understand-way. Chapter titles are:

1. Basic Subjective Responses to Noise
2. Noise of Surface Transportation to Nontravelers
3. Noise of Air Transportation to Nontravelers
4. Recreational Vehicle Noise to Non-users
5. Noise of transportation to Travelers
6. Interior Noise Environments
7. Noise in Hospitals
8. Exterior Industrial and Commercial Noise
9. Construction Site Noise
10. Noise In and Around the Home
11. Occupational Deafness and Hearing Conservation
12. The Nonauditory Effects of Noise on Health
13. Noise and Sleep: A Literature Review and a Proposed Criterion for Assessing Effect
14. Effects of Noise on Human Work Efficiency

It should be recognized at the onset that the book is oriented toward assessment of the acoustical environment, and not toward design. It is one of the few books that is restricted to noise solutions; within this defined scope the coverage of the topic is excellent. The book is truly a "handbook" by virtue of its completeness. Virtually all types of noise sources are analyzed: air transportation, ground transportation, construction, industry, hospitals, offices, and the home. Effects assessment covers the gambit from sleep interference to hearing loss. To achieve this diversity, Dr. May utilized the talents of 13 contributing authorities.

Several chapters present excellent summaries of typical sound levels for various noise sources. In perhaps no other reference can one find typical noise levels for a 747 aircraft, a jackhammer, and a water closet. Absent, however, are typical sound levels for industries and manufacturing equipment.

Despite the fact that Dr. May and several of the contributing chapter authors reside outside of the United States, virtually all EPA health effects criteria and noise data assessments are given, as are all "classical" noise criteria by numerous investigators; in addition, the book includes assessment techniques and criteria of other nations, particularly the United Kingdom and Canada.

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PROBABILISTIC ANALYSIS AND DESIGN OF NUCLEAR POWER PLANT STRUCTURES

C. Sundararajan, Editor
Publication PVP-PB-030
American Society of Mechanical Engineers
New York, 1978

This book is a compilation of seven papers presented at a symposium during the 1978 Winter Annual Meeting of the American Society of Mechanical Engineers. The symposium was organized by the Design and Analysis Committee of the Pressure Vessels and Piping Division, ASME.

The editor points out in the Foreword that, even though material parameters, applied loads, and structural strengths are subject to uncertainties, common practice is to use deterministic design procedures. These procedures usually result in conclusions that are expressed in terms of factors of safety, design margins, or some other unique value. The basic issue addressed by the book is the fact that designers ultimately make decisions based on deterministic guidelines, despite the fact that the parameters involved in the decision are probabilistic in nature.

Suppose, for instance, that the strength of a structural member and the applied load each can be approximated by a normal distribution with the same maximum stress value. Dividing the two maxima gives a factor of safety of unity, which could be construed to imply no margin of safety. In reality, however, failure would occur only 50 percent of the time. Application of the same reasoning to higher safety factors (based on probabilistic phenomena) indicates that a high safety factor alone does not guarantee safe design. The failure probability could range from acceptably low values to unacceptably high ones.

Perhaps the most important use of probabilistic methods is to permit comparisons of different designs or different approaches. Another possibility is to use probabilistic methods to screen alternate designs in order to select the most cost-effective approach.

The seven papers in the volume provide a sampling of probabilistic techniques applied to design. Titles and authors include:

- A. Haldar, "A Probabilistic Evaluation of Turbine Missile Damage Potential"
- Y.K. Wen, "Stochastic Seismic Response Analysis of Hysteretic Multi-Degree-of-Freedom Structures"
- I.H. Chou and J.A. Fischer, "Liquefaction and Probability"
- C.O. Smith, "Shrink Fit Stresses in Probabilistic Form"
- J.M. Thomas and D.C. Peters, "Probabilistic Decision Model for Structure Subjected to Crack Growth and Fracture"
- A.K. Gupta, "Combination of Dynamic Loads"
- J.C.S. Yang and D.W. Caldwell, "A Method for Detecting Structural Deterioration in Piping Systems"

A special comment concerns the Yang and Caldwell report on probabilistic methods directed at crack detection in piping systems. Their approach is based on use of ambient vibrations as a source of excitation, coupled with acceleration or strain measurements. Data are processed using spectral analysis, autocorrelation techniques, and random decrement techniques. The basic assumption is that a fatigue crack creates additional degrees of freedom in a structure. Over time the eigenfrequency of the failure mode becomes detectable using the methods described in the paper. Results of a preliminary experiment on a piping system with an induced flaw (saw notch) are reported.

Total length of the book is 117 pages. The price was not specified. The book consists basically of a compilation of the seven papers, which apparently were not retyped. Except for some awkward mathematics (one equation occupies an entire page), a scattering of typographical mistakes, and one paper that could have been more thoroughly edited, the book is nicely done and useful.

The chief value of the book is that it provides a number of practical examples of the application of probabilistic techniques to nuclear facility design. Long used in the design of aircraft structures, in which high strength to weight ratios are critical, the application of probabilistic techniques to nuclear power plants is timely. These methods offer the potential of increased safety against dynamic loads as well as more cost-effective designs.

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SPECTRUM

Comment on "Current Methods for Analyzing Dynamic Cable Response"
(H.J. Migliore and R.L. Webster, SVD, 11 (6), pp 3-16, June 1979)

The authors have given an extensive history and development of cable problems, with particular attention to undersea applications. Near the end of their article they state, "An area of study that is apparently not receiving sufficient attention is calculating the initial configuration of a cable system. Because of the strong geometric nonlinearity, it is difficult to obtain a stable numerical description of the dead loaded state." On the same topic they add "..., but a general purpose, robust method compatible with the versatility of the discrete element methods has not yet been developed." They conclude that "Much work remains to be done before reliable and comprehensive computer programs for cable structures can be placed in the hands of an unsophisticated user [115]."

The purpose of this comment is to point out the existence of another publicly available program [116], not mentioned by the authors, which may be used to solve fluid-immersed cable dynamics problems and which appears to have resolved some of the aforementioned difficulties.

This program is a general purpose linear and nonlinear finite element code. It has considerable effort directed at underwater effects acting on pipes and cables [117]. Included are: buoyancy effects, Reynold's number dependent drag coefficients, added mass effects, internal fluid in pipes, wave and current motions, and conditional surface and bottom constraints. The cable element may be with or without bending stiffness. Static, modal, transient dynamic, and harmonic response analyses are available. Geometric nonlinearities include stress (geometric) stiffening and/or a large displacement procedure allowing rotations up to 90° [118].

This user's experience with ocean cable analyses using this program has been quite favorable. Numerically stable, dead weight catenary-like suspensions, as well as other configurations, are easily achieved in a few iterations from any arbitrary initial (unstressed) configuration. It is straightforward to continue from a stressed static or dynamic configuration to a nonlinear transient dynamic analysis, a modal analysis about the stressed configuration, or a linear harmonic response analysis.

Postprocessing routines create plots of cable configurations, graphs of tensions, displacements or other variables vs. time, mode shapes, and harmonic response curves, either in a batch mode or interactively at a CRT terminal.

This program was recently used to simulate an actual experiment at sea in which a cable was payed out from a cable laying ship. Dynamic cable tensions, caused by ship response to wave action, were measured by a deck dynamometer; they agreed to within 1% of computed values.

One concludes that this program offers an easy to use, general purpose, robust ocean cable dynamics capability that should satisfy the needs of many engineers working in this area.

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PREVIEWS OF MEETINGS

26TH INTERNATIONAL INSTRUMENTATION SYMPOSIUM

May 5-8, 1980
Seattle, Washington

The 26th International Instrumentation Symposium will be presented by the Aerospace Industries Division and the Test Measurement Division of the Instrument Society of America. The Symposium will be held 5-8 May 1980 in Seattle, Washington.

Several of the upcoming sessions are listed below.

Sessions 2.4 & 2.9: *INSTRUMENTATION IN BLAST ENVIRONMENTS I & II*
Chairman: *Captain Ga. / Shannon*
Air Force Weapon Laboratory
Developer: *Joe Ayala*
Air Force Weapon Laboratory

The papers to be presented describe techniques and systems used in the laboratory and field experiment to measure the severe environment generated by explosive sources or its effects. State-of-the-art advances for these types of measurements will be discussed. Specifically, papers will be presented describing instrumentation associated with measurement techniques used for High Explosives Simulation and Nuclear Underground Testing.

Sessions 2.5 & 2.10: *MICROCOMPUTER APPLICATIONS I & II*
Chairman Session I: *Russel B. Spencer*
ANCO Engineers, Inc.
Chairman Session II: *Warren Cannon*
ANCO Engineers, Inc.
Developer Session I&II: *Josef F. Schneider*
Air Force Weapon Laboratory

Numerous examples are discussed on applications of micro (mini) computers that automate or control data acquisition, instrumentation, test, analysis, and laser tracking systems as well as production processes. Data conversion methods are treated in general and a survey of options is presented.

Session 3.3: *INSTRUMENTATION & MACHINERY APPLICATIONS I*
Chairman: *William R. McWhirter, Jr.*
David W. Taylor Naval Ship R&D Ctr.
Developer: *Henry R. Hegner*
MANTECH of New Jersey

This session will present instrumentation techniques as applied to land vehicles and weapons during maintenance, quality control, impact, and proof testing.

Session 3.8: *VIBRATION*
Chairman: *Phil Turner, Endevco*
Developer: *Clyde Staley*
G.E. Spacecraft Division Dynamics

A variety of papers are included covering the full range of vibration instrumentation and data analysis. Excitation and measurement instrumentation for experimentally evaluating the environment and dynamic characterstics of systems are described. Emphasis is placed on new analysis equipment using digital techniques.

Session 4.2: *ACOUSTIC EMISSION*
Chairman: *Hans Bandervelbt*
Naval Sea Systems Command
Developer: *Charles McGogney*
Federal Highway Department

Acoustic emission technology has seen advances along two fronts. First, instrumental developments have occurred which utilize a part of the acoustic emission signal, such as count or count-rate. These are used to monitor in service structures. Second, investigations have been directed at establishing relationships between specific micro-failure processes in the material and characteristics of the detected acoustic emission. The presentations in this session will address both of these areas.

Session 4.10: ***INSTRUMENTATION & MACHINERY APPLICATIONS II***
Chairman: ***Henry R. Hegner***
MANTECH of New Jersey

Developer: ***William R. McWhirter, Jr.***
David W. Taylor Naval Ship R&D Ctr.

This session will present instrumentation techniques as applied to gas turbine engines, thrust augmentors, and hoist and elevator systems.

Session 2.7: ***BASIC TELEMETRY SYSTEMS***
Charles Rosen, Microcom Corporation

This paper will describe a variety of telemetry transmission systems and combinations of multiplexing schemes. A number of tables and constants are provided to reduce calculation time when used in telemetry system design.

SHORT COURSES

MARCH

FINITE ELEMENT METHOD AND COMPUTER GRAPHICS IN STRUCTURAL MECHANICS

Dates: March 10-14, 1980
Place: The George Washington University
Objective: This course is designed for engineers and scientists who are required to perform detailed stress analysis of complex structures without homogeneous and isotropic properties. The course will cover the theory and applications of finite elements for discrete structural systems and continua. Topics to be covered will primarily consist of the linear and nonlinear behavior of structural frames, plates, and shells. Emphasis will be on computer applications and computer graphics techniques.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773 or TELEX 64374.

FIXTURE DESIGN FOR VIBRATION AND SHOCK TESTING

Dates: March 10-14, 1980
Place: St. Petersburg, Florida
Objective: The relative merits of various types of shakers and shock test machines are briefly considered, with most emphasis on electromagnetic shakers. The seminar will be devoted to practical and proven simplified design and fabrication techniques. An important area to be covered is that of evaluating a fixture once it is built.

Contact: Wayne Tustin, Tustin Institute of Technology, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 10-14, 1980
Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 17-21, 1980
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. Emphasis is also on electrical measurements of mechanical and thermal quantities.

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

DIGITAL SIGNAL PROCESSING

Dates: March 11-13, 1980
Place: San Diego, California
Dates: October 21-23, 1980
Place: Atlanta, Georgia
Objective: The mathematical basis for the fast Fourier transform calculation is presented, including frequency response, impulse response, transfer functions, mode shapes and optimized signal detection. Convolution, correlation functions and probability characteristics are described mathematically and each is demonstrated on the Digital Signal Processor. Other demonstrations include spectrum and power spectrum measurements; relative phase measurements between two signals; and signal source isolation.

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

BOUNDARY INTEGRAL EQUATION METHODS

Dates: March 17-22, 1980
Place: University of Arizona, Computer Center
Objective: The objective of this short course is to introduce the Boundary Integral Equation Method (BIEM) as an efficient numerical tool for the solution of various types of ground-water problems. The course is designed to provide a working knowledge of the BIEM so that the participants will be able to use and modify the existing computer programs and to develop their own programs for their specific problems.

Contact: Professor James A. Liggett or Professor Phillip L.-F. Liu, School of Civil and Environmental Engrg., Cornell University, Hollister Hall, Ithaca, NY 14853 - (607) 256-3556/256-5090 respectively

BLASTING AND EXPLOSIVES SAFETY TRAINING

Dates: March 26-28, 1980
Place: Albany, New York
Dates: April 23-25, 1980
Place: Atlanta, Georgia
Dates: May 14-16, 1980
Place: Reno, Nevada
Dates: June 4-6, 1980
Place: St. Louis, Missouri
Dates: June 18-20, 1980
Place: Tucson, Arizona
Dates: September 10-12, 1980
Place: Atlantic City, New Jersey
Dates: September 24-26, 1980
Place: Des Moines, Iowa

Objective: This course is a basic course that teaches safe methods for handling and using commercial explosives. We approach the problems by getting at the reasons for safety rules and regulations. Helps provide blasters and supervisors with a practical understanding of explosives and their use - stressing importance of safety leadership. Familiarizes risk management and safety personnel with safety considerations of explosives products and blasting methods.

Contact: E.I. du Pont de Nemours & Co. (Inc.), Applied Technology Division, Wilmington, DE 19898 - (302) 772-5982/774-6406.

EXPLOSION HAZARDS EVALUATION

Dates: March 31-April 4, 1980
Place: Southwest Research Institute

Objective: This course covers the full spectrum of problems encountered in assessing the hazards of accidental explosions, in designing the proper containment as necessary, as well as developing techniques to reduce incidence of accidents during normal plant and transport operations. Specific topics to be covered are: fundamentals of combustion and transition to explosion; free-field explosions and their characteristics; loading from blast waves; structural response to blast and non-penetrating impact; fragmentation and missile effects; thermal effects; damage criteria; and design for blast and impact resistance.

Contact: Wilfred E. Baker, Southwest Research Institute, P.O. Drawer 28510, San Antonio, TX 78284 - (512) 684-5111, Ext. 2303.

APRIL

ASPECTS OF DAMAGE TOLERANCE

Dates: April 7-11, 1980
Place: UCLA

Objective: The concept of damage tolerance can and is being applied to the whole spectrum of engineering materials. The methods of application include the provision of parallel load paths, unloaded standby structures, crack-stopping features and slow crack-growth routes. There are, in the case of metals for example, metallurgical factors which can be exploited to achieve each of these goals and there are microstructural manipulations which can be used to advantage in ceramic, glass and composite components and structures. These factors and their modifications by environmental attack account for the core lectures in this course.

Contact: Continuing Education in Engineering and Mathematics, P.O. Box 24901, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

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

Dates: April 7-11, 1980
Place: Dayton, Ohio

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis, also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

MACHINERY VIBRATION ANALYSIS

Dates: April 9-11, 1980
Place: Chicago, Illinois
Dates: June 18-20, 1980
Place: Houston, Texas
Dates: August 26-28, 1980
Place: Las Vegas, Nevada
Dates: December 10-12, 1980
Place: New Orleans, Louisiana
Objective: The course covers causes, effects, detection, and solutions of problems relating to rotating machines. Vibration sources, such as oil and resonant whirl, beats, assembly errors, rotor flexibility, whip, damping, eccentricity, etc. will be discussed. The effect on the overall vibration level due to the interaction of a machine's structure, foundation, and components will be illustrated.

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

ACOUSTICS AND NOISE CONTROL

Dates: April 14-18, 1980
Place: The University of Tennessee Space Inst.
Objective: This is an introductory course dealing with the fundamentals of vibration and noise control. The equations governing the vibrations of continuous systems and sound propagation will be developed and certain elementary solutions derived to illustrate the basic characteristics of the wave motion. Sound propagation in the atmosphere, acoustic filters and resonators, and the attenuation of sound in rooms and ducts by acoustic treatment will be discussed. Fundamental measurement techniques and statistical parameters applicable to the description of noise will be presented.

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

APPLICATIONS OF TIME SERIES ANALYSIS

Dates: April 14-18, 1980
Place: Institute of Sound and Vibration Research, University of Southampton, UK
Objective: To provide a comprehensive treatment of time and frequency domain analysis methods for transient and stationary random signals summarizing essential theory and giving engineering applications. To present theories and some applications related to non-stationary processes, system identification and response of non-linear systems to stochastic excitation. To apply the theory to well conceived practical problems utilizing the computers in the Data Analysis Centre enabling participants to experience how new methods may be related to present day industrial requirements.

Contact: Dr. Joseph K. Hammond, Institute of Sound and Vibration Research, University of Southampton, Southampton, Hampshire, England, S09 5NH - 559122, Ext. 467.

THE SIXTH ANNUAL RELIABILITY TESTING INSTITUTE

Dates: April 14-18, 1980
Place: The University of Arizona, Tucson
Objective: To provide reliability engineers, product assurance engineers and managers and all other engineers and teachers with a working knowledge of analyzing component, equipment, and system performance and failure data to determine the distributions of their times to failure, their failure rates, their reliabilities and their confidence limits; small sample size, short duration, low cost tests, and methods of analyzing their results; accelerated testing; test planning; electrical overstress and electrostatic failure protection; Bayesian testing; suspended items testing; sequential testing; and others.

Contact: Dr. Dimitri Kececioglu, Aerospace and Mechanical Engineering Dept., The University of Arizona, Bldg. 16, Tucson, AZ 85721 - (602) 626-2495/626-3901/626-3054/626-1755.

MAY

MACHINERY VIBRATION ANALYSIS SEMINARS

Dates: May 6-7, 1980
Place: Cherry Hill, New Jersey
Dates: June 17-18, 1980
Place: Oak Brook, Illinois
Dates: July 9-10, 1980
Place: New Orleans, Louisiana
Dates: August 12-13, 1980
Place: Sheraton Inn-Newark Airport, NJ

Dates: October 1-2, 1980
Place: Houston, Texas
Dates: December 9-10, 1980
Place: Atlanta, Georgia
Objective: These two day seminars on machinery vibration analysis will be devoted to the diagnosis and correction of field vibration problems. The material is aimed at field engineers. The sessions will include lectures on the following topics: basic vibrations; critical speeds; resonance; torsional vibrations; instrumentation, including transducers, recorders, analyzers, and plotters; calibration; balancing and vibration control; identification of unbalance, misalignment, bent shafts, looseness, cavitation, and rubs; advanced diagnostic techniques; identification of defects in gears and antifriction bearings by spectrum analysis; and correction of structural foundation problems.

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

SECOND INTERNATIONAL SEMINAR IN PIPING DESIGN AND PIPE STRESS ANALYSIS

Dates: May 12-16, 1980
Place: Texas A&M University
Objective: This seminar addresses engineers, stress analysts, piping designers and others whose daily functions are related to piping design and stress analysis. The seminar aims to keep participants abreast of rapid changes underway in the petrochemical and power industries with a focus on the latest additions, deletions and modifications of related piping codes. Seminar faculty with recognized expertise will discuss basic philosophy and requirements of piping codes, industry design practice and approximate as well as computer methods of static and dynamic analysis. The seminar places practical emphasis on topics in rotating equipment, piping dynamics, high pressure technology, failure prevention and field troubleshooting.

Contact: Dr. M. Henriksen, Seminar Director, Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843 - (713) 845-3723.

JUNE

FINITE ELEMENT ANALYSIS

Dates: June 3-6, 1980
Place: Charlottesville, Virginia
Objective: This course is intended to combine an introduction to engineering finite element analysis with a survey of advanced applications. Topics to be covered include solid mechanics, fluid dynamics, and heat transfer. Many engineering examples will be given throughout the course to assist in understanding the material.

Contact: VIBCO Research Inc., P.O. Box 3307, University of Virginia Station, Charlottesville, VA 22903 - (804) 924-3982.

VIBRATION AND STRESS ANALYSIS USING EXPERIMENTAL TECHNIQUES

Dates: June 4-5, 1980
Place: Cincinnati, Ohio
Objective: This seminar will discuss/demonstrate the use of experimental testing methods to identify and solve complex vibration and stress problems. Recent advancements in the test area have provided test engineers and technicians with increased capabilities to acquire, store, and process experimentally obtained data to successfully map the performance and dynamic load data; to determine the dynamic characteristics; and to integrate with analytical modeling techniques for correlation and direction in model development. Both data acquisition and data analysis techniques will be thoroughly discussed and actually demonstrated.

Contact: Mrs. Gayle Lyons, SDRC Seminar Coordinator, Structural Dynamics Research Corporation, 2000 Eastman Drive, Milford, OH 45150 - (513) 576-2594.

MACHINERY VIBRATIONS SEMINAR

Dates: June 24-26, 1980
Place: Mechanical Technology, Inc.
Latham, New York
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. Paul Babson, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2371.

ADVANCED DYNAMIC ANALYSIS FOR MODAL TESTING USERS

Dates: June 25-26, 1980
Place: San Diego, California
Dates: July 9-10, 1980
Place: Cincinnati, Ohio
Objective: This seminar has been organized to provide the serious user (advanced and beginner alike) with a complete knowledge of the capabilities and applications of the SDRC Testing Software Package (MODAL, MODAL-PLUS, SABBA and FATIGUE). The emphasis will, therefore, be on advanced software capabilities and their use to solve dynamics problems. Applications will come from the vehicle, construction and mining equipment, and rotating equipment areas; but, will be of general interest to any engineer working in the area of experimental dynamics.

Contact: Mrs. Gayle Lyons, SDRC Seminar Coordinator, Structural Dynamics Research Corp., 2000 Eastman Drive, Milford, OH 45150 - (513) 576-2594.

JULY

INTRODUCTION TO THE VIBRATION AND STRESS ANALYSIS OF PRESSURE ACTUATED VALVES FOR GAS COMPRESSORS USING FINITE ELEMENT METHODS

Dates: July 21-22, 1980
Place: Purdue University
Objective: The course content is general to many fluid machinery systems utilizing pressure actuated flexible valves, however, class examples will emphasize small, high-speed, refrigerant compressors. Interest is directed to the development of suitable mathematical models for the prediction of the dynamic motion of the flexible valve during the compressor cycle and the resultant stress field in the valve. Participants should be familiar with the mathematical simulation philosophy for compressors. Extension of the valve modeling to more detailed descriptions compatible with the general compressor simulation will be presented.

Contact: James F. Hamilton, Ray W. Herrick Laboratories, School of Mech. Engrg., Purdue University, West Lafayette, IN 47907.

AUGUST

NOISE ANALYSIS

Dates: August 6-7, 1980
Place: Cincinnati, Ohio
Objective: This seminar will provide engineers concerned with noise analysis and control an introduction to the most current technology in this area. The session will be dedicated to presenting the latest noise analysis procedures, and the various noise control measures which can be employed, primarily related to product noise. Topics discussed will include: physical acoustics, psycho-acoustics, time series analysis, source identification, structural frequency response, noise control, absorption, barriers, isolation, stiffening, and damping.

Contact: Mrs. Gayle Lyons, SDRC Seminar Coordinator, Structural Dynamics Research Corp., 2000 Eastman Drive, Milford, OH 45150 - (513) 576-2594.

FATIGUE ANALYSIS

Dates: August 13-14, 1980
Place: San Diego, California
Dates: September 10-11, 1980
Place: Cincinnati, Ohio
Objective: The growing understanding of the important factors in the fatigue failure process coupled with the accumulation of new, correctly obtained,

fatigue test data and material property and behavior data, has led to the practical application of fatigue analysis methods. The vast improvements in stress analysis, both computerized design analysis (finite element methods, etc.) and experimental testing techniques (digital Fourier analysis, cycle counting methods, etc.) have enabled engineers and designers to get a more fundamental understanding of fatigue. The seminar will address the topics of cyclic stress-strain behavior of metals, fatigue properties of metals and cumulative damage procedures.

Contact: Mrs. Gayle Lyons, SDRC Seminar Coordinator, Structural Dynamics Research Corp., 2000 Eastman Drive, Milford, OH 45150 - (513) 576-2594.

SEPTEMBER

MODAL ANALYSIS

Dates: September 17-19, 1980
Place: Cleveland, Ohio
Objective: This seminar will provide information on new techniques for identifying dynamic structural weaknesses. The sessions include the use of state-of-the-art instrumentation and software for creating a dynamic structural model in the computer. Techniques will be demonstrated for mode shape calculation and animated displays, computation of mass, stiffness and damping values and modal manipulation methods.

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

OCTOBER

VIBRATION TESTING

Dates: October 6-9, 1980
Place: San Diego, California
Objective: Topics to be covered are: exciters, fixtures, transducers, test specifications and the latest computerized techniques for equalization, control, and protection. Subjects covered include dynamics and dynamic measurements of mechanical systems, vibration and shock specifications and data generation. Demonstrations are given of sine random and shock testing and of how test specifications are met.

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

NOVEMBER

MACHINERY VIBRATION IV

Dates: November 11-13, 1980
Place: Cherry Hill, New Jersey
Objective: Lectures and demonstrations on vibration measurement rotor dynamics and torsional vibration are scheduled. General sessions will serve as a review of the technology; included are the topics of machine measurements, modal vibration analysis, and vibration and noise. The rotor dynamics sessions will include: using finite element, transfer matrix, and nonlinear models; vibration control including isolation, damping, and balancing. The sessions on torsional vibration feature fundamentals, modeling measurement and data analysis, self-excited vibrations, isolation and damping, transient analysis, and design of machine systems.

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

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

INSTITUTE OF ENVIRONMENTAL SCIENCES (IES) ANNUAL TECHNICAL MEETING AND EXPOSITION

May 11-14, 1980
Marriott Hotel, Philadelphia, PA

Latest revisions to the environmental test standards MIL-STD-810D and MIL-STD-781D, new environmental stress screening procedures, environmental test tailoring, and the application of combined environment reliability testing (CERT) are among the topics to be addressed at the IES Annual Technical Meeting and Exposition, May 11-14, 1980, at the Marriott Hotel, Philadelphia, Pennsylvania.

Other topics of interest include low-cost systems for random vibration testing, the design of shock/vibration test fixtures, and high-g shock and vibration testing procedures.

The theme of the Technical Meeting "Life Cycle Problems and Environmental Technology," has significance for a diverse variety of technical disciplines. Life cycle profiles describe the complete range of stress conditions to which a product or piece of equipment will be subjected. They also determine the period of time over which economic costs/benefits are calculated.

Today's economic constraints, product reliability demands, and major advancements in both electronic and structural technology have fostered a new evaluation of environmental testing techniques. This Technical Meeting of the IES will present the latest environmental technology and the interrelationships of the engineering disciplines involved.

The Technical Meeting includes a 3-day equipment exhibition featuring: environmental test control, monitoring and data processing instrumentation; environmental testing hardware (climatics, dynamics, combined environments); pollution monitoring instrumentation; contamination detection and control equipment; and environmental measurement sensors.

For further information, contact: Institute of Environmental Sciences, 940 East Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561.

INTER-NOISE 80

Announcement and Call for Papers

"Noise Control for the 80's" will be the theme of INTER-NOISE 80, the ninth International Conference on Noise Control Engineering which will be held at the Hotel Inter-Continental, Miami, Florida, USA on December 8-10, 1980. The Conference will include technical sessions consisting of invited and contributed presentations on world-wide noise-control technology, as well as noise clinics and an exhibition of the latest equipment and instrumentation for noise control. A series of lectures on various aspects of "Noise Control for the 80's" will be presented by recognized specialists in the field. The emphasis throughout INTER-NOISE 80 will be on practical solutions to important noise control problems. A bound copy of the Proceedings will be available to participants at final registration and by mail to others after the close of the Conference.

CONTRIBUTIONS INVITED

Contributed papers are welcome as are case histories of solutions to noise control problems. Abstracts of contributed papers and contributions to the noise clinics should be approximately 400 words in length. Three copies of each abstract should be submitted as soon as possible to James G. Seebold, Technical Program Chairman, Institute of Noise Control Engineering, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603, USA. The deadline for the receipt of abstracts is May 12, 1980.

SPONSORSHIP

INTER-NOISE 80 is sponsored by the International Institute of Noise Control Engineering (INTERNATIONAL/INCE) and is organized by the Institute of Noise Control Engineering of the United States of America, Inc., (INCE/USA) in cooperation with the

Acoustical Society of America and other leading professional and governmental organizations.

ABSTRACTS INVITED

Contributions in all areas of noise control engineering for the technical program of INTER-NOISE 80 are welcome. Of particular interest are the following topics: machinery noise reduction at the source, mining machinery noise control, engine noise control, control of valve noise, rapid transit system noise control, impulse and impact noise, noise control in industry, shipboard noise control, noise emission measurements, aircraft noise, identification of noise sources, active noise attenuators, labeling, noise standards and enforcement, acoustical data banks, noise control in buildings, community noise control, and appliance noise control.

Abstracts should be informative rather than descriptive and be typed double-spaced on standard letter paper. The text of the abstract should be approximately 400 words in length, including equations and references. Authors should include name, complete mailing address, phone number, and they should indicate the program topic to which the abstract is directed. Abstracts are due on May 12, 1980. Authors will be notified by June 20, 1980 of the acceptance of their abstracts. They will then receive special masters on which their manuscripts must be typed. The firm deadline for receipt of manuscripts is August 15, 1980. Abstracts and manuscripts should describe new material that has not previously been presented at a conference or published in a journal. Instructions relating to the presentation of accepted papers will be sent to each author.

CONTACT

INTER-NOISE 80
P.O. Box 3469
Arlington Branch
Poughkeepsie, NY 12603, USA

ABSTRACT CATEGORIES

MECHANICAL SYSTEMS

Rotating Machines
Reciprocating Machines
Power Transmission Systems
Metal Working and Forming
Isolation and Absorption
Electromechanical Systems
Optical Systems

STRUCTURAL SYSTEMS

Bridges
Buildings
Towers
Foundations
Underground Structures
Harbors and Dams
Roads and Tracks
Construction Equipment
Pressure Vessels
Power Plants

VEHICLE SYSTEMS

Ground Vehicles
Ships
Aircraft
Missiles and Spacecraft

BIOLOGICAL SYSTEMS

Human
Animal

MECHANICAL COMPONENTS

Absorbers and Isolators
Springs
Tires and Wheels
Blades
Bearings
Belts and Conveyors
Gears
Clutches
Couplings
Fasteners
Linkages
Valves
Seals

STRUCTURAL COMPONENTS

Strings and Ropes
Cables
Bars and Rods
Beams
Cylinders
Columns
Frames and Arches
Membranes, Films, and Webs
Panels
Plates
Shells
Rings
Pipes and Tubes
Ducts
Building Components

ELECTRIC COMPONENTS

Controls (Switches, Circuit Breakers)
Motors
Generators
Transformers
Relays
Electronic Components

DYNAMIC ENVIRONMENT

Acoustic Excitation
Shock Excitation
Vibration Excitation
Thermal Excitation

MECHANICAL PROPERTIES

Damping
Fatigue
Elasticity and Plasticity

EXPERIMENTATION

Measurement and Analysis
Dynamic Tests
Scaling and Modeling
Diagnostics
Balancing

ANALYSIS AND DESIGN

Analogs and Analog
Computation
Analytical Methods
Modeling Techniques
Nonlinear Analysis
Numerical Methods
Statistical Methods
Parameter Identification
Mobility/Impedance Methods
Optimization Techniques
Design Techniques
Computer Programs

CONFERENCE PROCEEDINGS AND GENERAL TOPICS

Conference Proceedings
Tutorials and Reviews
Criteria, Standards, and
Specifications
Bibliographies
Useful Applications

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

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 434, 515, 517, 525, 526, 538, 608, 630, 644)

80-414

Misalignment Effects on the Stability of the Flow Between Eccentric Rotating Cylinders

A.S. Zarti, B. Robati, and F.R. Mobbs
Univ. of Leeds, Leeds, UK LS2 9JT, ASLE Trans., 22 (4), pp 361-364 (Oct 1979) 6 figs, 10 refs

Key Words: Rotors (machine elements), Cylinders, Rotating structures, Alignment

This paper discusses flow visualization and outer cylinder torque measurements which have been used to investigate the influence of axial misalignment on the development of sub-critical vortices and Taylor vortices in the flow between eccentric rotating cylinders.

80-415

Interaction Between a Rotor and Its Foundation

J.W. Lund
The Technical Univ. of Denmark, 2800 Lyngby, Denmark, Machinery Vibrations III, Proc., Boxborough, MA, Sept 18-20, 1979, 12 pp, 2 figs
Sponsored by the Vibration Inst., Clarendon Hills, IL

Key Words: Rotors (machine elements), Interaction: structure-foundation, Method of impedance matching

The interaction between the rotor and the foundation is analyzed by the method of impedance matching at the bearings. A coordinate system is introduced with the z-axis along the rotor axis, the x-axis giving the vertical displacement, and the y-axis giving the horizontal displacement.

80-416

Evaluation of Rotor-Bearing System Dynamic Response to Unbalance

R.E. Thaller and D.W. Ozimek
Aeronautical Systems Div., Wright-Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 41-53 (Sept 1979) 7 figs, 8 tables, 2 refs

Key Words: Rotor-bearing systems, Unbalanced mass response, Air conditioning equipment

A complete investigation of the vibration environment within air conditioner rotating machinery referred to as an Air Cycle Machine (ACM) is needed to effectively increase ACM reliability. To assist in the selection of design changes which would result in improved ACM performance, various design modifications are incorporated into a baseline ACM configuration. For each design change, testing is conducted with the best balance achievable (baseline) and with various degrees of unbalance. The purpose is to establish relationships between unbalance (within the context of design changes) and the parameters associated with design goals. The results of rotor dynamics tests used to establish these relationships are presented herein.

80-417

Torque-Induced Lateral Vibrations in Rotating Machinery

R.L. Eshleman
Vibration Institute, Clarendon Hills, IL, Machinery Vibrations III, Proc., Boxborough, MA, Sept 18-20, 1979, 6 pp, 11 figs, 8 refs

Key Words: Rotating structures, Shafts, Lateral vibration, Torsional excitation, Whirling

Recent rotating machinery failures, the causes of which could not be explained by conventional lateral vibration theory, have motivated this review of the technology associated with torque-induced lateral vibrations.

80-418

Engine Crankshaft Torsional Vibration Control

L.E. Williams
Wallace Murray Corp., 1125 Brookside Ave., Indianapolis, IN 46206, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 113-151, 51 figs, 4 refs

Key Words: Crankshafts, Torsional vibration, Vibration dampers

This paper discusses the effects of a harmonic balancer, crankshaft tuner, engine dampener, front pulley timing wheel, and an engine crankshaft vibration damper on torsional vibration control. In the presentation, a survey of the subject, "A Practical Treatise on Engine Crankshaft Torsional Vibration Control," by Robert C. Bremer, Jr., is used as a basis for providing a general overview of the characteristics of vibration, damping and related technology.

80-419

Contribution to the Calculation of the Dynamic Behavior of Industrial Turbocompressor Circuits

H. Voss

Gutehoffnungshuette Sterkrade A.G., West Germany, In: Von Karman Inst. for Fluid Dyn. Off-Design Performance of Gas Turbines, Vol. 2, 34 pp (1978)
N79-28564

Key Words: Compressors, Turbocompressors, Dynamic response, Computer programs

A calculation method is developed which can predict the required turbocompressor circuits performance from data on the various individual components. The method is based on a components indexing system which, after numeric editing of the plant to be investigated, forms a circuit matrix. The program contains a set of indexed components which are treated by a processing computer using digital programming techniques. Initial comparison of precalculations and measurements indicate agreement. Two examples are presented.

80-420

Packaging the Drive System for a Quiet Portable Air Compressor

G.W. Holland and R.J. Halama

Sullair Corp., 3700 E. Michigan Blvd., Michigan City, IN 46360, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov. 13-15, 1979, pp 207-214, 9 figs, 11 refs

Key Words: Compressors, Noise reduction

Effective January 1, 1978 EPA noise regulations for portable air compressors required the average sound pressure level at 7 meters not to exceed 76 dBA. The design of a compressor package requires special focus on system components to achieve noise levels of such a low magnitude. The basic concept used to quiet the compressor drive system is to enclose the entire unit inside a sheet metal housing. The various noise sensitive components associated with an engine powered unit must be selected on the basis of desired overall noise level. These include, basically, the engine itself, isolation mounts, fan, air filters, mufflers, and sound absorbing material. As a result of stringent performance requirements placed on these components, the necessary sound levels have been achieved.

80-421

Some Theoretical and Experimental Investigations of Stresses and Vibrations in a Radial Flow Rotor

A. Grasso, J.J. Blech, and G. Martinelli

Fiat Aviazione S.p.A., Turin, Italy, In: AGARD. Stresses, Vibrations, Struc. Integration and Eng. Integrity (including Aeroelasticity & Flutter) (Apr 1979)
N79-27158

Key Words: Compressors, Finite element technique

The problem of an integrally bladed radial compressor under the influence of a centrifugal force is considered. Two calculation methods based also on finite element method are proposed. The first adopts a mixed three dimensional and two dimensional analysis, using plate elements for blades and axisymmetrical ring for the disk coupled by substructuring technique. The second implements axisymmetric anisotropic ring elements for the blades and the isotropic ring elements for the disk. A dynamic analysis of the blade with the finite element method is also presented. As an example the various methods are applied to the centrifugal compressor design of the FIAT 6803 engine and compared with results of experimental investigation.

80-422

Problems Involved in Starting and Shutdown of Gas Turbines: Thermodynamic and Mechanical Aspects

J.-L. Guiette and A. VanGucht

Ateliers de Constructions Electriques de Charleroi, Belgium, In: Von Karman Inst. for Fluid Dyn. Off-Design Performance of Gas Turbines, Vol. 2, 95 pp (1978)
N79-28565

Key Words: Compressors, Gas turbines, Transient response

A calculation method for the transient performances of the turbine and compressor is given and the assumptions are pointed out. Although simplifications are introduced, the work involved in determining start up and shutdown characteristics is considerable. The accuracy of the calculation method is considered satisfactory.

80-423

Unstable Flow Regimes, Including Rotating Stall, Surge, Distortions, Etc.

J. Fabri

Office National d'Etudes et de Recherches Aerospatiales, Paris, France, In: Von Karman Inst. for Fluid Dyn. Off-Design Performance of Gas Turbines, Vol. 1, 22 pp (1978)

N79-28560

Key Words: Turbines, Gas turbines, Time-dependent parameters, Mathematical models

A time dependent model of the response of the total flow to the aerodynamic solicitations at conditions favorable for the onset of stall is analyzed. Simplified special cases are discussed. Theory and experiment compare accurately in some limited cases.

80-424

Experimental Investigation of Dynamic Characteristics of Turbine Generators and Low-Tuned Foundations

S.P. Ying, M.E. Forman, and R.R. Drumm

Gilbert/Commonwealth, Jackson, MI 49201, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 69-77 (Sept 1979) 11 figs, 5 refs

Key Words: Turbines, Boilers, Foundations, Resonant response

Two 820 MW turbine-generator (T-G) units with low-tuned concrete foundations are investigated experimentally during both startup and normal operating conditions. The dynamic response of the turbine generators and their foundation systems is characterized by resonance curves obtained during the startup transient and by vibration mode shapes at the normal operating condition. The experimental results are compared and discussed with some previous theoretical studies.

80-425

The Impact of Noise Regulations on Propeller Design

SAE Paper No. 790593, 10 pp, 19 figs

Key Words: Rules and regulations, Propeller noise

The paper introduces the characteristic differences in performance of the new aerofoil section with more conventional ones and looks at the design of a range of propellers to illustrate the trade between noise, performance and weight with each type.

80-426

Lateral and Tilt Whirl Modes of Flexibly Mounted Flywheel Systems

C.W. Bert and T.L.C. Chen

School of Aerospace, Mechanical and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 35-46 (Sept 1979) 5 figs, 2 tables, 18 refs

Key Words: Flywheels, Whirlings, Critical speeds

High-performance, composite-material flywheel systems under current development for energy-storage purposes differ from turbine and compressor systems in that the flywheel rim is flexibly attached to the hub. Thus, for whirling with gyroscopic action, an axisymmetric flywheel system has four degrees of freedom, two associated with lateral translation and two with tilting. In the Sandia Livermore spintest facility, the above system was driven by an air turbine which added two more degrees of freedom. A six-degree-of-freedom analysis of such a system is presented here and applied to two versions of a specific design presently being developed.

RECIPROCATING MACHINES

(Also see Nos. 478, 523, 576, 582, 596)

80-427

On Damping of Torsional Vibration in a Propulsion System Having a Fluid Drive

R.E.D. Bishop, W.G. Price, and P.K.Y. Tam

Dept. of Mech. Engrg., Univ. College London, Inst. Mar. Engr., T.R., pp 109-123 (1979) 9 figs, 4 tables

Key Words: Diesel engines, Marine engines, Torsional vibration, Vibration damping, Fluid drives

The magnitude of serious torsional vibration in a ship diesel propulsion system is limited by damping. The effects of the damping can be radically different, depending on whether or not that damping couples the principal modes.

80-428

Formulation of the Equations of Dynamic Motion Including the Effects of Variable Inertia on the Torsional Vibrations in Reciprocating Engines, Part I

M.S. Pasricha and W.D. Carnegie

Dept. of Mech. Engrg., The Papua New Guinea Univ. of Tech., Papua, New Guinea, J. Sound Vib., 66 (2), pp 181-186 (Sept 22, 1979) 1 fig, 15 refs

Key Words: Engines, Reciprocating engines, Variable material properties, Torsional vibration

The torsional vibration problem in reciprocating engines is described by linear differential equations with constant coefficients. In view of the importance of the subject of torsional vibration in engineering practice, the formulation of the equations of dynamic motion for a multi-cylinder engine, allowing for variable inertia, is given in the present paper.

80-429

Stresses, Vibrations, Structural Integration and Engine Integrity (Including Aeroelasticity and Flutter)

AGARD, Neuilly-Sur-Seine, France, Rept. No. AGARD-CP-248; ISBN-92-835-0235-3, 494 pp (Apr 1979)

N79-27148

Key Words: Engine vibration, Flutter

Experimental stress analysis, stress analysis techniques-life prediction, and engine structural integrity-vibration, containment are covered. Also, engine-airframe integration/compatibility and aeroelasticity and flutter are included. For individual titles, see N79-27149 through N79-27181.

80-430

Preliminary QCGAT Program Test Results

R.W. Koenig and G.K. Sievers

NASA Lewis Research Ctr., Cleveland, OH, SAE Paper No. 790596, 12 pp, 10 figs, 6 tables, 3 refs

Key Words: Engines, Aircraft engines, Noise reduction, Experimental data

NASA Lewis Research Center is conducting a program to demonstrate that large commercial engine technology can be applied to general aviation engines to reduce noise, emissions and fuel consumption and to develop new technology where required. Following a study Phase I, two contractors (AiResearch and AVCO-Lycoming) were selected to design, fabricate, assemble, test and deliver their respective Quiet, Clean General Aviation Turbofan (QCGAT) experimental engines to NASA. The QCGAT engines have now entered the test phase. This paper describes the overall engine program, design, and technology incorporated into the QCGAT engines. In addition, preliminary engine test results are presented and compared to the technical requirements the engines were designed to meet.

POWER TRANSMISSION SYSTEMS

80-431

Reliability Data for Automotive Accessory and Camshaft Belt Drives

C.O. Johnson and L.R. Oliver

Dayco Corp., Belt Technical Ctr., P.O. Box 3258 G.S., Springfield, MO 65804, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 229-233, 8 figs, 4 refs

Key Words: Belt drives, Fatigue life, Statistical analysis

A statistically designed program of automotive belt endurance testing has led to life prediction constants for SAE V-belts and a new mathematical fatigue model for synchronous belts. A graphical procedure is presented for estimating failure distribution for a specific drive on the basis of five lives obtained under field conditions.

STRUCTURAL SYSTEMS

BRIDGES

80-432

Active Control of Two-Cable Stayed Bridge

J.N. Yang and F. Giannopoulos

George Washington Univ., Washington, D.C., ASCE J. Engr. Mech. Div., 105 (EM5), pp 795-810 (Oct 1979) 5 figs, 27 refs

Key Words: Bridges, Cable stiffened structures, Active control

The feasibility of applying the active control system to two-cable-stayed bridge is demonstrated. The stochastic dynamic analysis of a two-cable-stayed bridge implemented by the active feedback control system is carried out. The control devices are connected to the existing four suspension cables so that these suspension cables also serve as active tendons. The bridge is subjected to buffeting loads, self-excited loads, and control forces. The stochastic response of the bridge with or without active control is obtained and the average power input to the active control system is derived.

BUILDINGS

(Also see No. 570)

80-433

Wind Damage Observations and Implications

J.E. Minor and K.C. Mehta

Inst. for Disaster Research, Texas Tech. Univ., Lubbock, TX, ASCE J. Struc. Div., 105 (ST11), pp 2279-2291 (Nov 1979) 12 figs, 1 table, 13 refs

Key Words: Buildings, Wind-Induced excitation, Damage

Literature containing observations of windstorm damage to buildings is condensed into descriptions of failure modes exhibited by several common building types. Failure modes are reviewed and building types that constitute the largest contributor in windstorm damage costs are identified. Wind and earthquake caused damages are compared, and observations regarding damage dissimilarities are examined.

TOWERS

(Also see No. 543)

80-434

Design, Fabrication, and Initial Test of a Fixture For Reducing the Natural Frequency of the Mod-O-Wind Turbine Tower

J.R. Winemiller, T.L. Sullivan, R.L. Sizemore, and S.T. Yee

NASA Lewis Research Ctr., Cleveland, OH, Rept. No. NASA-TM-79200, 21 pp (July 1979) N79-28727

Key Words: Towers, Turbines, Natural frequencies

The behavior of a two bladed wind turbine where the tower first bending natural frequency is less than twice the rotor speed is observed. Fixture design details are given and behavior during initial operation is described.

FOUNDATIONS

(See Nos. 424, 438)

HARBORS AND DAMS

(See No. 543)

PRESSURE VESSELS

80-435

Prediction of Fragment Velocities and Trajectories

J.J. Kulesz, L.M. Vargas, and P.K. Moseley

Southwest Research Inst., San Antonio, TX, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 171-187 (Sept 1979) 9 figs, 5 tables, 7 refs

Key Words: Pressure vessels, Fracture properties

This paper describes analytical techniques to predict the velocities of two unequal fragments from bursting cylindrical pressure vessels; the velocity and range of portions of vessels containing a fluid which, when the vessel ruptures, causes the fragment to accelerate as the fluid changes from the liquid to the gaseous phase; and the ranges of fragments subjected to drag and lift forces during flight. Finally, the paper discusses a technique for determining the range of fragments once one knows the initial flight conditions.

80-436

Blast from Bursting Frangible Pressure Spheres

E.D. Esparza and W.E. Baker

Southwest Research Inst., San Antonio, TX, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 127-139 (Sept 1979) 20 figs, 17 refs

Key Words: Pressure vessels, Internal pressure

This paper describes laboratory experiments conducted to obtain incident overpressure data from frangible spheres pressurized with two different gases and a vapor. Glass spheres under internal pressure were purposely burst to obtain time histories of overpressure using side-on pressure transducers. A scaling law for pressure spheres bursting in free-air is derived and presented. This law is simplified and used to obtain a functional relationship for the non-dimensional blast parameters. Peak overpressure, arrival and duration times, and impulse data are presented for different initial conditions and blast source energies. These dimensionless data are also compared with results of theoretical calculations and compiled data for Pentolite high-explosive.

POWER PLANTS

(Also see Nos. 632, 650)

80-437

On-Line Identification of Reactor Dynamic Characteristics from Operating Data Analysis via Dynamic Data System Methodology

M. Hsu

Ph.D. Thesis, The Univ. of Wisconsin-Madison, 246 pp (1979)

UM 7918154

Key Words: Nuclear reactors, Parameter identification technique, Computer aided techniques

On-line identification of nuclear reactor dynamic characteristics is developed to extract the dynamic features from operating data analysis at steady state in order to supplement the classical perturbation approach. The current technique for reactor operating data analysis is basically the power spectrum density (PSD) function analysis.

80-438

Nonlinear Soil-Structure Interaction

J. Isenberg, D.K. Vaughan, and I. Sandler

Weidlinger Associates, Menlo Park, CA, Rept. No. EPRI-NP-945, 25 pp (Dec 1978)

N79-28375

Key Words: Interaction: soil-structure, Nuclear power plants, Earthquake response, Mathematical models

Modeling research of constitutive properties of soil and of soil-structure interaction for nuclear power plants in earthquakes is presented. The models which are developed are general and can be used to simulate a three dimensional structural geometry, nonlinear site characteristics and arbitrary input ground shaking. The cap family of constitutive models of soils are extended to include earthquake effects. Also, the cap model is extended to include the effects of pore fluid on the seismic response of soils. Sensitivity of seismic induced soil structure interaction to the size of soil island is investigated. Two and three dimensional finite element simulations of the tests are performed and results are compared with measured data.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 491, 498, 499, 506, 510, 511, 516, 519, 607, 614, 624, 625, 626, 661, 662)

80-439

Factors Influencing Knee Restraint

C.C. Culver and D.C. Viano

Biomedical Science Dept., General Motors Research Labs., SAE Paper No. 790322, 20 pp, 5 figs, 2 tables, 11 refs

Key Words: Collision research (automotive), Human factors engineering, Mathematical models

A planar mathematical model is developed to provide means of studying factors which can influence the function of lower torso restraint via a padded lower instrument panel or knee bolster. Emphasis is also placed on determining a range of reference location, orientation and primary axis of resistance of the knee bolster so that an effective restraint may be provided for the 5th percentile female, 50th percentile male, and 95th percentile male occupant.

80-440

Improving Safety Belt Acceptability to the Consumer

P.N. Ziegler and P.R. Knaff

National Highway Traffic Safety Admn., SAE Paper No. 790681, 16 pp, 13 figs, 9 refs

Key Words: Collision research (automotive), Automobile safety belts, Human factors engineering

Beginning with 1982 models, most auto manufacturers plan to install automatic safety belts to meet new Federal requirements for passive occupant protection. To reduce the likelihood of consumer rejection and non-use of automatic as well as manual belt systems, research has been conducted to develop performance specifications for improved comfort and convenience. This paper discusses specifications and criteria to improve the safety belts by reducing comfort and convenience variables for both manual and automatic systems.

80-441

The Degree of Benefit of Belts in Reducing Injury - an Attempt to Explain Study Discrepancies

B.J. Campbell and D.W. Reinfurt

Univ. of North Carolina, Highway Safety Research Ctr., SAE Paper No. 790683, 16 pp, 6 figs, 1 table, 3 refs

Key Words: Collision research (automotive), Automobile seat belts, Human factors engineering

This paper examines seventeen safety belt studies to identify the possible causes for the disparate assessments. Factors that contribute to this disparity include differences in injury scale values, inaccuracies in reporting occupants' belt status, and variations in sampling criteria.

80-442

Assessment of Seat Belt Usage - Methods/Results/ Recommendations

H.G. Johannessen, G.F. Johannessen, and C.H. Pulley

Hamill Mfg. Co., Div. of the Firestone Tire & Rubber Co., SAE Paper No. 790682, 12 pp, 2 figs, 4 tables, 13 refs

Key Words: Collision research (automotive), Automobile seat belts, Human factors engineering

Factors that may increase and maintain seat belt usage are identified as the car occupant's perception of the effectiveness of seat belts; and the comfort and convenience of his installed system. The effects of automatic seat belts and mandatory seat belt use laws are considered.

80-443

A Comparative Analysis of Factors Impacting on Seat Belt Use

T.J. Kuechenmeister, A.J. Morrison, and M.E. Cohen

General Motors Corp., SAE Paper No. 790687, 16 pp, 3 figs, 6 tables, 26 refs

Key Words: Collision research (automotive), Automobile seat belts, Human factors engineering

A national survey of 1600 adults and 500 adolescents identified the major factors impacting on seat belt use. Particular attention was paid to the important role interpersonal interaction and instruction plays instigating and reinforcing seat belt use. The importance of interpersonal interaction was assessed relative to the impact of demographic variables, perceptions of seat belt comfort and convenience, attitudes concerning seat belt use, and the establishment of the seat belt "habit."

80-444

Selection Biases in the Sampling and Measurement of Safety Belt Use

M.G. Dworkin

Lincorp Research Inc., SAE Paper No. 790685, 16 pp, 3 tables, 8 refs

Key Words: Collision research (automotive), Automobile seat belts, Human factors engineering

This paper describes a study of observed safety belt use conducted in the Detroit area in 1977 in conjunction with an effort sponsored by the domestic auto manufacturers to increase use through mass communications techniques. The study methodology incorporated a sophisticated sample design and very stringently controlled procedures utilizing 224 observation sites. Finally, the Detroit study is compared with one conducted concurrently by NHTSA, which utilized less rigorous methods and relatively few sites.

80-445

Volkswagen Passive Occupant Protection System Progress Report - 1979

U.W. Seiffert

Volkswagenwerk AG, Wolfsburg, West Germany, SAE Paper No. 790326, 8 pp, 15 figs

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

This paper describes the most recent test results and field experience of the VW Passive Restraint System (VWRA). Finally, an update of accidents involving the VWRA are presented, demonstrating the system's effectiveness in actual use.

80-446

Safety Performance Evaluation of Seat Belt Retractors

M. Dance and B. Enserink

Road and Motor Vehicle Traffic Safety Branch, SAE Paper No. 790680, 20 pp, 1 fig, 5 tables

Key Words: Collision research (automotive), Automobile safety belts, Anthropomorphic dummies

This paper discusses seat belt emergency locking retractor performance as measured in a sample of forty-four automobile models (1976-1978) sold in Canada and subjected to 30-mph frontal barrier crash tests. Parameters such as retractor lockup time, belt payout, and belt stretch were measured and correlated with injury criteria determined using 49 CFR, Part 572 anthropomorphic dummies. The vehicles ranged from subcompacts to full-size cars.

80-447

Advanced Restraint System Concepts

W. Reidelbach and H. Scholz

Daimler-Benz AG, Stuttgart, Germany, SAE Paper No. 790321, 16 pp, 17 figs

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

The seat belt pretensioner designed to eliminate belt slack in lap/shoulder belt systems with emergency locking retractors, is described as well as the current Mercedes-Benz passive restraint system which consists of air bags deployed by means of solid propellant gas generators, knee bolsters, and an electronic crash sensor with dual level triggering function. Combinations of lap/shoulder belts, air bags, and pretensioners are presented.

80-448

An Investigation of the Potential Human and Environmental Impacts Associated with Motor Vehicle Air Bag Restraint Systems

L.J. Partridge, Jr and G.S. Young

Arthur D. Little, Inc., SAE Paper No. 790641, 16 pp, 5 figs, 3 tables

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

The air bag life cycle, including intended use, abandonment, scrapyards, junkyards, and metal melting operations, is evaluated to assess the various risks which air bag systems pose to humans, the biological environment, and the flora and fauna inhabiting these areas. These risks are estimated through the application of traditional risk analysis techniques, including failure mode and effect analysis and fault-free analysis.

80-449

Impact Sled Test Evaluation of Restraint Systems Used in Transportation of Handicapped Children

L.W. Schneider, J.W. Melvin, and C.E. Cooney

Highway Safety Research Inst., The Univ. of Michigan, SAE Paper No. 790074, 24 pp, 14 figs, 5 tables, 4 refs

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

A series of 16 sled impact tests was conducted at the Highway Safety Research Institute sled facility to evaluate the effectiveness of restraint devices and systems currently being used to transport school-bus and wheelchair-seated handicapped children. A sled impact pulse of 20 m.p.h. and 16 G's was used for all tests. Eight tests involved wheelchairs in forward-facing and side-facing orientations for head-on and 33-degree oblique impacts. Another eight tests involved forward-facing bus seats for head-on and 33-degree oblique impacts.

80-450

Dynamic Sled Testing of Child Restraints

B.J. Kelleher and M.J. Walsh

Calspan Corp., Advanced Technology Ctr., SAE Paper No. 790073, 24 pp, 24 figs, 6 tables, 13 refs

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

Child restraint performance in frontal and lateral crash simulations is presented and discussed based upon tests conducted on the Calspan HYGE acceleration sled. Differing acceleration pulses for frontal tests were used to evaluate the pulse shape effect upon the child restraint systems. Two types of three year old size anthropometric test devices (ATDs) were used and restraint systems were intentionally improperly installed in an effort to ascertain the potential hazard to the child occupant from improper installation. Data obtained include head excursion, head and chest triaxial accelerations, Head Severity Index (HSI) and Chest Severity Index (CSI) values for the ATDs. High speed movie coverage produced dummy kinematic results.

80-451

A New Concept in Child Restraint Design

T.G. Molnar and D.M. Rodwell

Cooldrive Consolidated Industries, Div. of Repco Ltd., Melbourne, Australia, SAE Paper No. 790072, 12 pp, 20 figs, 7 refs

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

A reduction in death and injury rates of child vehicle occupants is being experienced in Australia by a unique child restraint device which is compatible with all motor vehicles. Basic parameters, product development and extensive dynamic sled test programs are explained. The achieved benefits which include excellent crash performance, simplicity, versatility and public acceptance of a totally new concept are discussed.

80-452

Effectiveness of Current and Future Restraint Systems in Fatal and Serious Injury Automobile Crashes. Data from On-Scene Field Accident Investigations

D.F. Huelke, H.W. Sherman, M.J. Murphy, R.J. Kaplan, and J.D. Flora

Univ. of Michigan Medical School, SAE Paper No. 790323, 24 pp, 11 tables, 15 refs

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

Data from 101 front seat automobile occupant fatality crashes that the authors have investigated are reviewed along with 70 front seat automobile occupants who had the more severe injuries who did not die. The effectiveness of the lap belt alone, lap-shoulder belt, air bag alone, air bag with lap belt, and the passive shoulder belt are made.

80-453

Occupant Protection in a Research Safety Vehicle

G.J. Fabian

Advanced Technology Ctr., Calspan Corp., Buffalo, NY, SAE Paper No. 790325, 32 pp, 32 figs, 9 tables, 7 refs

Key Words: Collision research (automotive)

The protection afforded the occupants of the Research Safety Vehicle (RSV) being developed for NHTSA by Calspan and Chrysler is identified by giving examples of the results of staged collisions. A brief review of the objectives of the four phase RSV program, vehicle development, and ultimate goals is provided as a frame of reference for the discussion of crashworthiness.

80-454

Development of Protection Systems for Lateral Impacts

P. Ventre, J. Provensal, and G. Stcherbatcheff

Regie Nationale des Usines Renault, France, SAE Paper No. 790710, 16 pp, 14 figs, 7 tables, 6 refs

Key Words: Collision research (automotive), Anthropomorphic dummies, Experimental data

A series of 21 experimental car-to-car collisions are produced. The accelerations on the thorax and the pelvis of the dummy exposed to the impact are analyzed and related to the parameters linked to the vehicles. Two lateral collisions of a rigid, mobile barrier with a car are produced and compared to the car-to-car collisions. The parameters of the relative stiffness and of the mass of impacting vehicles and impacted vehicles are examined. The protective measures are developed for the impacted vehicle and tested in different configurations.

80-455

Lateral Impact -- Considerations for Vehicle Development

U.W. Seiffert

R & D, Volkswagenwerk AG, Wolfsburg, West Germany, SAE Paper No. 790709, 16 pp, 10 figs, 3 tables

Key Words: Collision research (automotive), Simulation

Factors to be considered in studying lateral impact are: the mass, structural design, and rigidity of the vehicles involved in the collision; the point and angle of impact; impact speeds; vehicle interior and design; and the use of restraints.

80-456

Experimental and Theoretical Study of the Rolling Noise in a Passenger Car

P. Beuzit, P. Fontanet, and J.L. Garnier

Regie Nationale des Usines Renault, France, SAE Paper No. 790673, 12 pp, 13 figs, 1 table, 1 ref

Key Words: Automobiles, Noise generation, Noise measurement, Mathematical models

This paper presents an analysis of low frequency noise production by experimental measurements and mathematical model calculations. It shows vibration coupling between train, body and cavity modes and it points out different possibilities to reduce noise in the passenger compartment.

80-457

Interior Noise Reduction in a Recreational Van

E.J. O'Keefe

Specialty Composites Corp., Newark, DE, SAE Paper No. 790310, 8 pp, 2 figs, 1 table, 2 refs

Key Words: Automobiles, Interior noise, Noise reduction

A study is made to determine the effect of combinations of acoustic treatments on the interior noise levels in a 3/4 ton van. The effect of barriers, absorbers and vibration dampers in various combinations on the dBA levels are given for both idle and highway operating conditions.

80-458

Four Steps for Vehicle Ride Improvement

J.W. Martz, E.L. Peterson, G.W. Knobeloch, and G.D. Angus

Structural Dynamics Research Corp., Milford, OH, SAE Paper No. 790219, 16 pp, 33 figs, 6 refs

Key Words: Automobiles, Vibration response, Finite element technique, Building block approach

In this paper, the authors describe a new method of application of modal analysis and building block technology which has been made possible by advances in minicomputer software. Examples of recent projects performed by Structural Dynamics Research Corporation are described, which illustrate how a test engineer can identify and evaluate various fixes to a vehicle vibration problem utilizing a minicomputer based hardware-software system in his laboratory.

80-459

Increased Vehicle Energy Dissipation Due to Changes in Road Roughness with Emphasis on Rolling Losses

S.A. Velinsky and R.A. White

Dept. of Mech. and Industrial Engrg., Univ. of Illinois at Urbana-Champaign, Urbana, IL, SAE Paper No. 790653, 16 pp, 9 figs, 4 tables, 18 refs

Key Words: Road roughness, Energy dissipation, Tires, Suspension systems (vehicles)

The present investigation used vehicle axle accelerations to experimentally examine various road surfaces. Correlation with computer simulations allows the development of a deterministic road roughness model which is used to predict energy dissipation in both the tire and suspension as functions of roughness, tire pressure, and speed.

80-460

Simulation of Off-Road Motorcycle Ride Dynamics

S.H. Black and D.L. Taylor

General Electric Co., Schenectady, NY, SAE Paper No. 790261, 16 pp, 13 figs, 20 refs

Key Words: Motorcycles, Simulation, Ride dynamics

The dynamic ride response of a motorcycle is investigated using a four-degree-of-freedom computer simulation (bounce, pitch, and movement of each wheel). The simulation is nonlinear in terms of both geometry and suspension components, and is generally applicable to any type of motorcycle of reasonably standard configuration. The application to off-road motorcycles and special problems associated with simulating off-road motorcycles are discussed.

80-461

Moped Directional Dynamics and Handling Qualities

J.W. Zellner and D.H. Weir

Systems Technology, Inc., Hawthorne, CA, SAE Paper No. 790260, 16 pp, 13 figs, 2 tables, 9 refs

Key Words: Motorcycles, Ride dynamics

Analytical results describing moped lateral-directional response properties are presented. Design characteristics of four example mopeds related to directional handling are presented and compared with sample motorcycle properties. Resultant moped dynamics are quantified and compared. Using a nominal moped example, the sensitivity of the vehicle dynamics to operational and design variables, such as speed, loading and tire properties, is shown. Implications for rider/moped handling are reviewed.

80-462

Effect of Main Factors on Dynamic Properties of Motorcycle Tires

H. Sakai, O. Kanaya, and H. Iijima

Japan Automobile Research Inst., Inc., SAE Paper No. 790259, 16 pp, 29 figs, 2 refs

Key Words: Motorcycles, Tires, Ride dynamics

In this study, the influences of various factors such as internal pressure, load, tire make, width, etc., on tire dynamic properties are clarified through the experiments carried out on laboratory testing machines.

80-463

Experimental Investigation of the Transient Behavior of Motorcycles

D.H. Weir and J.W. Zellner

Systems Technology, Inc., Hawthorne, CA, SAE Paper No. 790266, 20 pp, 19 figs, 4 tables, 10 refs

Key Words: Motorcycles, Dynamic response, Experimental data

Analytical and experimental studies of the transient and oscillatory behavior of motorcycles are reported. Three example vehicles were used. The effects of adding load, changing operating conditions, and modifying the vehicle configuration are shown. The phenomenon known as cornering weave is illustrated and interpreted.

80-464

Sound Control on J I Case 90 Series Non-Cab Ag Tractors

J.D. Harris, J.E. Leffelman, and R.L. Mann

J I Case Co., SAE Paper No. 790811, 12 pp, 6 figs, 2 refs

Key Words: Tractors, Noise reduction

The application of operator's station sound control technology to two wheel drive non-cab Agricultural tractors is described. Technological feasibility of achieving less than 90 dB(A) at the operator's station was demonstrated on a J I Case Model 1370 non-cab 4 Post ROPS tractor. Results were then incorporated into the J I Case 90 Series non-cab 4 Post ROPS tractors in the early design stages.

SHIPS

(Also see Nos. 427, 501, 547, 561, 638)

80-465

Critical Evaluation of Low-Energy Ship Collision Damage Theories and Design Methodologies. Volume I. Evaluation and Recommendations

P.R. Van Mater, Jr., J. Giannotti, N. Jones, and P. Genalis

Giannotti and Buck Associates, Inc., Riverdale, MD, Rept. No. SSC-284, 92 pp (July 1978)
AD-A070 567/3GA

Key Words: Ships, Collision research (ships), Energy absorption

This is Volume I of a two-volume report describing the results of a ship Structure Committee study aimed at conducting a critical evaluation of low-energy ship collision damage theories and design methodologies. Data sources on ship collision damage are identified including model experiments and full scale information obtained from ship casualty records. The assumptions made by existing theories for analyzing low energy collisions are assessed and the collision energy absorption mechanisms are ranked. A method is proposed for extending Minorsky's original high-energy analysis to the low-energy regime. Recommendations for use of existing methods and for further research are made.

80-466

Added Mass and Damping of the Heaving Surface Effect Ship in Uniform Translation

C.H. Kim and S. Tsakonas

Davidson Lab., Stevens Inst. of Tech., Hoboken, NJ, Rept. No. SIT-DL-78-9-2040, 104 pp (Dec 1978)
AD-A070 886/7GA

Key Words: Ships, Hydrofoil craft, Mass coefficients, Damping coefficients, Computer programs

The analysis presents a practical method for evaluating the added mass and damping coefficients of a heaving surface effect ship in uniform translation. The theoretical added mass and damping coefficients and the heave response show fair agreement with the corresponding experimental values. The analysis also provides means of estimating the wave elevation of the free surface, escape area at the stern and the volume which are induced by a heaving surface-effect ship in uniform translation in otherwise calm water. Computational procedures have been programmed in FORTRAN IV language and adapted to the PDP-10 high-speed digital computer.

80-467

Foil System Fatigue Load Environments for Commercial Hydrofoil Operation

D.L. Graves

Boeing Marine Systems, Renton, WA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 29-40 (Sept 1979) 12 figs, 5 refs

Key Words: Hydrofoil craft, Fatigue life

Complexity and severity of the hydrofoil fatigue loads environment in the open sea is discussed in terms of flight vehicle environments. The random nature of wave orbital velocities, periods and heights plus boat heading, speed and control system design are considered to assess the structural fatigue requirements. Major nonlinear load events such as hull slamming and foil unwetting are key contributors to the fatigue environment. Full scale "rough water" load tests, field experience plus analytical loads work on the Model 929 JETFOIL commercial hydrofoil are carried out. The problem of developing an overall sea environment for design is discussed.

AIRCRAFT

(Also see Nos. 430, 512, 546, 599, 611, 649)

80-468

Seat/Occupant Crash Dynamic Analysis Verification Test Program

R.F. Chandler and D.H. Laananen

FAA Civil Aeromedical Inst. Oklahoma City, OK, SAE Paper No. 790590, 100 pp (Appendix: Validation Test Data, 90 pp, 6 figs, 26 refs

Key Words: Crash research (aircraft), Aircraft seats, Experimental data

The Federal Aviation Administration is developing a computer modeling program (SOMLA -- Seat Occupant Model: Light Aircraft) in an attempt to provide a practical engineering and design analysis tool for aircraft seat designers. To validate the model, two series of well-instrumented controlled tests have been completed by the FAA Civil Aeromedical Institute. These tests used two basic seat configurations, two different impact vector orientations, and two different impact levels to produce both elastic and plastic seat deformations. Measurements of seat reaction loads, seatbelt loads, and dummy accelerations were made, and the tests were documented by high-speed motion picture film. Each test condition was repeated to obtain a statistical measure of test variability. The results of these tests, and their implications regarding the development of the model, are presented.

80-469

Experimental Verification of Program KRASH -- A Mathematical Model for General Aviation Structural Crash Dynamics

G. Wittlin, D.J. Ahrens, and A.W. Bloedel

Lockheed-California Co., SAE Paper No. 790589, 16 pp, 8 figs, 5 tables, 8 refs

Key Words: Crash research (aircraft), Experimental data, Mathematical models, Computer programs

The results of four fully instrumented, full-scale crash tests involving a single-engine, high-wing light airplane are described. The tests were performed under a contract sponsored by the Federal Aviation Administration. The range of impact conditions included initial airplane roll and/or yaw, a nose-down attitude, a flared nose-up attitude and impacts onto a rigid (concrete) and a flexible (soil) surface. Photographs are presented showing the impact conditions, as well as some typical postcrash damage. The crash test models, analyzed using digital computer program KRASH, are described. Typical analysis versus test correlation results as well as a summary correlation for all four crash tests are presented. The application of Program KRASH to assess structural design concepts with regard to crash dynamics characteristics is briefly described.

80-470

Nonlinear Structural Crash Dynamics Analyses

R.J. Hayduk, R.G. Thomson, G. Wittlin, and M.P. Kamat

NASA Langley Research Ctr., Hampton, VA, SAE Paper No. 790588, 16 pp, 15 figs, 3 tables, 12 refs

Key Words: Crash research (aircraft), Nonlinear theories, Computer programs

This paper presents the results of three nonlinear computer programs, KRASH, ACTION and DYCAST used to analyze the dynamic response of a twin-engine, low-wing airplane section subjected to a 8.38 m/s (27.5 ft/s) vertical impact velocity crash condition. This impact condition simulates the vertical sink rate in a shallow aircraft landing or takeoff accident. The three distinct analysis techniques for nonlinear dynamic response of aircraft structures are briefly examined and compared versus each other and the experimental data. The report contains brief descriptions of the three computer programs, the respective aircraft section mathematical models, pertinent data from the experimental test performed at NASA Langley, and a comparison of the analyses versus test results. Cost and accuracy comparisons between the three analyses are made to illustrate the possible uses of the different nonlinear programs and their future potential.

80-471

Crash-Resistant Fuel Systems for General Aviation Aircraft

W.T. Edwards and W.M. Perrella, Jr.

Federal Aviation Admin., NAFEC, Atlantic City, NJ, SAE Paper No. 790592, 16 pp, 18 figs, 4 tables, 6 refs

Key Words: Crash research (aircraft), Fuel tanks

Testing is undertaken to examine the performance of lightweight, flexible, crash-resistant fuel cells with frangible fuel line couplings. Included in the experiments are four full-scale crash tests of a typical light twin-engined aircraft.

80-472

NASA General Aviation Crashworthiness Seat Development

E.L. Fasanella and E. Alfaro-Bou

Vought Corp., Hampton, VA, SAE Paper No. 790-591, 16 pp, 17 figs, 1 table, 15 refs

Key Words: Crash research (aircraft), Anthropomorphic dummies, Computer programs, Graphic methods

Three load limiting seat concepts for general aviation aircraft designed to lower the acceleration of the occupant in the event of a crash were sled tested and evaluated with reference to a standard seat. Computer program MSOMLA (Modified Seat Occupant Model for Light Aircraft) was used to simulate the behavior of a dummy passenger in a NASA full-scale crash test of a twin engine light aircraft. A computer graphics package MANPLOT was developed to pictorially represent the occupant and seat motion.

80-473

Crashworthiness Analysis of Field Investigation of Business Aircraft Accidents

R.G. Snyder and T.J. Armstrong

Highway Safety Res. Inst., The Univ. of Michigan, SAE Paper No. 790587, 13 pp, 9 figs, 2 tables, 17 refs

Key Words: Crash research (aircraft), Crashworthiness

Business and executive aviation represent a combined total of over 40% of the general aviation fleet, but (1977) accounted for only 8.37% of all general aviation accidents recorded. During the period 1964-1977 some 7,351 aircraft engaged in business flying, and 883 in corporate/executive operations, were involved in accidents reported by the NTSB. These accidents were reviewed utilizing the University of Michigan Computerized Accident Files to provide an overall view of the incidence and nature of business/executive aircraft accidents relative to occupant crash injuries.

80-474

Selected Topics from the Structural Acoustics Program for the B-1 Aircraft

P.M. Belcher

Rockwell International Corp., Los Angeles, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 55-68 (Sept 1979) 30 figs, 3 refs

Key Words: Aircraft, Acoustic fatigue, Design techniques

Three major elements of the structural acoustics program for the B-1 aircraft are considered: acoustic pressures measured at 280 sites on the surface of the vehicle were used to develop pressure models for a resizing of airframe components for aircraft No. 4 (A/C-4); acoustical fatigue design data for two dynamically complex structural configurations were acquired in laboratory programs, the conceptions for and executions of which entailed significant departures from the conventional; and design requirements for mechanical fasteners for configurations other than these two made use of analytical extensions of regrettably limited available information.

80-475

An Analysis of a Programmed Load Fatigue Failure

C.J. Peel

Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TR-78078; BR65871, 29 pp (July 14, 1978)

N79-29562

Key Words: Aircraft, Fatigue failure

Premature failure of an undercarriage fitting occurred during a fatigue test, in which the cylindrical barrel of the undercarriage was internally pressurized in a programmed sequence of pressures representing landing and taxying loads. An effective pressure range was calculated by comparison of the fatigue striation spacings with laboratory crack growth data. The effective pressure range was used to predict the fatigue life of a defect free undercarriage by reference to the pressure-fatigue life data in the literature.

80-476

Application of Vortex Lattice Method for the Evaluation of the Aerodynamic Characteristics of Wings With and Without Strakes

J. Singh
Dept. of Aeronautical Engrg., Indian Inst. of Tech., Bombay, India, 114 pp (1979)
N79-28145

Key Words: Aircraft wings, Vortex-induced vibration

The aerodynamic characteristics of more generalized planforms incorporating incremental vortex lift are determined by using vortex lattice method to calculate the aerodynamic characteristics for potential flows. The effects of the leading edge vortex, tip vortices, and the detached leading edge and side edge vortices over the lifting surface are considered. A flow chart and input parameters for wings with and without strakes are given for a prorram calculating the aerodynamic characteristics of a planar wing in symmetric flight in an incompressible flow. Predicted values are compared with experimental results.

80-477

Variables Characterizing the Wind Effects on the Aircraft (Grossen zur Beschreibung des Windeinflusses auf das Flugzeug)

R. Brockhaus
Institut f. Flugfuhrung, Technische Universität, Hans-Sommer-Strasse 66, 3300 Braunschweig, Z. Flugwiss, 3 (4), pp 229-234 (1979) 10 figs, 37 refs
(In German)

Key Words: Aircraft, Wind-induced excitation

A series of Euler angles between the aerodynamic and the flight path coordinates is proposed. These angles allow a very comprehensive description of the wind effects on the aircraft. In addition, exact and approximate relations are presented between the wind velocity components in the principal coordinate systems and those variables which are measurable on board the aircraft.

80-478

Engine Induced Structural-Borne Noise in a General Aviation Aircraft

J.F. Unruh and D.C. Scheidt
Southwest Research Inst., San Antonio, TX, SAE Paper No. 790626, 16 pp, 14 figs, 5 tables, 8 refs

Key Words: Aircraft noise, Engine vibration

This paper describes a study of engine induced structural-borne noise in a single engine light aircraft. Cabin noise and fuselage vibration levels are recorded during ground tests for engine-attached, engine-detached, interior-installed, and interior-removed configurations.

80-479

An Experimental Study of Propeller-Induced Structural Vibration and Interior Noise

J.T. Howlett and J.A. Schoenster
NASA Langley Research Ctr., Hampton, VA, SAE Paper No. 790625, 12 pp, 13 figs, 11 refs

Key Words: Aircraft noise, Interior noise, Propeller-induced excitation, Experimental data

This paper presents results of tests conducted to study fuselage sidewall dynamics and their effects on the cabin interior noise of a twin-engine, propeller-driven, light aircraft. Data on the dynamic behavior are obtained by slowly sweeping the RPM of one of the engines while the aircraft was stationary on the ground. This technique allowed frequency response plots of the sidewall structural accelerations to be obtained. These accelerations are compared to similar results from a test using a mechanical shaker in order to evaluate the structural dynamic response caused by the harmonics of the propeller blade passage tone. The dynamic response of the fuselage sidewall is also discussed as a noise transmission mechanism. A second mechanism for noise transmission through the fuselage sidewall is investigated by opening the copilot's window.

80-480

Noise Component Method for Airframe Noise

M.R. Fink
United Technologies Research Ctr., East Hartford, CT, J. Aircraft, 16 (10), pp 659-665 (Oct 1979) 14 figs, 17 refs

Key Words: Aircraft noise

A method is developed for predicting aerodynamic noise radiated by an airframe. Separate contributions are calculated for the clean wing, horizontal tail, vertical tail, landing gear, leading-edge slats and flaps, and trailing-edge flaps. Each noise component is predicted using scaling laws appropriate to that component, with amplitudes matched to available data. Spectra calculated by this method, the NASA

Aircraft Noise Prediction Program (ANOPP) total aircraft method, and the drag element method are compared with flyover noise data for a twin-propeller lightplane, a business jet, and a jumbo jet.

80-481

Engine-Induced Structural-Borne Noise in a General Aviation Aircraft

J.F. Unruh, D.C. Scheidt, and D.J. Pomerening

Southwest Research Inst., San Antonio, TX, Rept. No. NASA-CR-159099, 123 pp (Aug 1979) N79-29957

Key Words: Aircraft noise, Interior noise

Structural borne interior noise in a single engine general aviation aircraft is studied to determine the importance of engine induced structural borne noise and to determine the necessary modeling requirements for the prediction of structural borne interior noise.

80-482

Status of Cavity Noise Phenomena Measurement and Suppression on the B-1 Aircraft

A.G. Tipton and C.H. Hodson

Los Angeles Div., Rockwell Intl., El Segundo, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 59-66 (Sept 1979) 16 figs, 5 refs

Key Words: Aircraft, Noise reduction, Noise measurement

This paper presents an overview of the cavity noise investigation and the development of the B-1 weapons bay noise suppressor. Flight test data obtained with and without the noise suppressor are shown.

80-483

Propeller Aircraft Noise Around General Aviation Airports

F.W.J. van Deventer

Dept. of Aerospace Engrg., Delft Univ. of Tech., Delft, The Netherlands, SAE Paper No. 790594, 16 pp, 20 figs, 4 tables, 7 refs

Key Words: Aircraft noise, Propeller noise, Noise measurement, Measurement techniques, Data processing

In recent years systematic flyover noise measurements of propeller driven general aviation airplanes were performed. This paper presents a brief description of the measurement and data reduction techniques together with some results. Computation methods are given to estimate the effect of powersetting on the noise level and to approximate the shape of the noise field around these aircraft. They are used to compute Leq-contours around general aviation airports. Contour plots are used to compare the relative effects of several measures for noise reduction on the ground.

80-484

Influence of Unsteady Aerodynamics on Extracted Aircraft Parameters

M.J. Queijo, W.R. Wells, and D.A. Keskar

NASA Langley Research Ctr., Hampton, VA, J. Aircraft, 16 (10), pp 708-713 (Oct 1979) 5 figs, 4 tables, 7 refs

Key Words: Aircraft, Parameter identification technique

The effect of accounting for unsteady aerodynamics on the parameters extracted from flight data is examined. Longitudinal equations of motion have been modified, and a parameter-extraction program developed to include the effects of unsteady aerodynamics. The approach used was to model and to use that data in two parameter-extraction programs, one including and the other neglecting unsteady effects, to see if the parameters were significantly different. Flight data for a light airplane was also used with the two extraction programs for the same purpose.

80-485

Airplane Brake-Energy Analysis and Stopping Performance Simulation

M.K. Wahi

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 16 (10), pp 688-694 (Oct 1979) 9 figs, 1 table, 7 refs

Key Words: Aircraft, Braking effects, Digital simulation

A digital simulation representing airplane dynamics under braking action has been developed. The basic equations of motion represent a rigid-body airplane with the forward, vertical, and pitch degrees of freedom. The landing-gear representation utilizes linear springs and dampers. Effects of engine transients, i.e., spinup and spindown, engine failure, reverse thrust, friction variation with velocity (wet runway), pitch dynamics and associated load transfer between gears, and flap-spoiler settings have been accounted for. The program is called LANRTO and is capable of computing maximum potential brake energies (100% braking efficiency) and stopping distances under landing and refused takeoff conditions for jet transport airplanes.

80-486

Treatment of the Control Mechanisms of Light Airplanes in the Flutter Clearance Process

E J. Breitbach

NASA Langley Research Ctr., Hampton, VA, In: Its Sci. & Tech. of Low Speed and Motorless Flight, pp 437-466 (June 1979)

N79-27078

Key Words: Aircraft, Control equipment, Flutter, Mathematical models

Many difficulties encountered in the course of aircraft flutter analyses can be traced to strong localized nonlinearities in the control mechanisms. More reliable mathematical models to control system nonlinearities are established by means of modified ground vibration test procedures in combination with suitably adapted modal synthesis approaches. Three different concepts are presented.

80-487

Combined Vibration/Temperature/Sideload Environmental Testing of UHF Blade Antennas

R. Volker

McDonnell Douglas Corp., McDonnell Aircraft Co., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 79-84 (Sept 1979) 9 figs, 3 tables

Key Words: Aircraft equipment, Antennas, Blades, Testing techniques

Service problems encountered on the F-4 aircraft showed that the environmental qualification requirements for the UHF blade antenna are not adequate. Techniques for applying static side load simultaneously with vibration and temperature are developed. The combined environment testing is instrumental in the rapid assessment of antenna modifications and results in a final configuration which proves satisfactory in service. A need to include combined environmental testing for qualification of blade antennas is established.

MISSILES AND SPACECRAFT

80-488

An Impedance Technique for Determining Low Frequency Payload Environments

K.R. Payne

Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 1-14 (Sept 1979) 16 figs, 7 refs

Key Words: Spacecraft, Space shuttles, Spacecraft launching, Impedance technique

An approximation method for determining low frequency payload environments is developed and compared to state of the art coupling/response routines. Problems in signal conditioning techniques and frequency domain analysis are discussed. Results from analytical simulations with a spring mass system and a math model of the Space Transportation System and Long Duration Facility are presented.

80-489

The Development of a Method for Predicting the Noise Exposure of Payloads in the Space Shuttle Orbiter Vehicle

J.F. Wilby and L.D. Pope

Bolt Beranek and Newman, Inc., Canoga Park, CA 91303, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 5-30 (Sept 1979) 27 figs, 20 refs

Key Words: Spacecraft, Space shuttles, Launching response, Noise excitation

A program was initiated by NASA Headquarters with the objectives of obtaining reliable estimates of the sound levels and designing noise control approaches. NASA Goddard Space Flight Center served as contracting center and technical monitor for the program. The purpose of this paper is to review the tasks undertaken by Bolt Beranek and Newman Inc. (BBN) during the program and to outline future efforts required to complete the construction of an analytical model for the prediction of sound levels in the payload bay of the space shuttle orbiter vehicle at lift-off. The program provides an example of the development of an analytical acoustic model, through the various stages of formulation and validation.

80-490

Space Shuttle Solid Rocket Booster Aft Skirt Reentry Noise Induced by an Aerodynamic Cavity-Flow Interaction

L.A. Schutzenhofer, P.W. Howard, W.W. Clever, and S.H. Guest

Structural Dynamics Div., Systems Dynamics Lab., George C. Marshall Space Flight Ctr., Marshall Space Flight Ctr., AL 35812, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 67-82 (Sept 1979) 18 figs, 15 refs

Key Words: Booster rockets, Spacecraft, Space shuttles, Reentry, Simulation, Wind tunnel tests, Noise generation

High amplitude discrete frequency cavity induced noise is observed during wind tunnel testing of the reentry flight phase conditions of the Solid Rocket Booster (SRB) of the Space Shuttle vehicle system. These wind tunnel tests are designed to acquire aerodynamic noise data for the development of vibroacoustic design and qualification test criteria for the SRB.

80-491

Application of Random Time Domain Analysis to Dynamic Flight Measurements

S.R. Ibrahim

Dept. of Mech. Engrg. & Mechanics, Old Dominion Univ., Norfolk, VA 23508, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 165-170 (Sept 1979) 4 figs, 6 refs

Key Words: Spacecraft, Aircraft, Modal analysis, Time domain method, Random decrement technique

In this paper, an approach is presented for modal identification of aerospace structures from flight measurements. This approach is the result of combining the "time domain" modal identification technique and the multiple channel random decrement technique. Also, a new technique is presented to determine relative levels of excitation for identified modes. These techniques are applied to flight data taken from the B-1 bomber.

80-492

On the Use of Coherence Functions to Evaluate Sources of Dynamic Excitation

S. Barrett

Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 43-58 (Sept 1979) 19 figs, 3 tables, 9 refs

Key Words: Spacecraft components, Noise source identification, Vibration source identification, Coherence function technique

The objective of the study is to investigate the use of coherence functions for identifying the relative contirbutions of multiple dynamic inputs to the measured vibration response of spacecraft components on a practical, complex structure. Data for the study are generated by applying simultaneous vibratory and acoustic excitation to a test model (a modified Titan instrumentation truss). Up to three inputs are used and in some cases mutually coherent inputs are generated. A digital computer program is written to analyze the test data.

BIOLOGICAL SYSTEMS

HUMAN

(Also see Nos. 439, 440, 441, 442, 443, 444, 445, 446, 454, 472, 586, 624, 625, 655)

80-493

Whole-Body Vibration of Heavy Equipment Operators

D.E. Wasserman, W.C. Asburry, and T.E. Doyle

National Inst. for Occupational Safety and Health, Cincinnati, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 47-68 (Sept 1979) 10 figs, 6 tables, 13 refs

Key Words: Vibration excitation, Human response

A vibration field study is made of one of the groups of workers exposed to whole-body vibration (heavy equipment operators). Several types of machines (track-type tractors, scrapers, motor graders, loaders, backhoes, compactors, skidders, and dump trucks) are operated by one or two of four operators with differing degrees of experience. Vibration data are obtained from the following locations: vehicle floor, manseat interface, as well as from the operator's knee, shoulder, and head.

80-494
Research Related to the Expansion and Improvement of Human Vibration Exposure Criteria
R.W. Shoenberger
Aerospace Medical Research Lab., Aerospace Medical Div., Wright-Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 69-79 (Sept 1979) 2 figs, 6 tables, 8 refs

Key Words: Vibration excitation, Human response

A program of research directed toward improvement of the validity and generality of human vibration exposure criteria is described. A psychophysical matching technique is used to investigate the perceived intensity of various types of vibration environments. Experiments conducted to date are of two types: comparisons of sinusoidal and non-sinusoidal vibrations, and comparison of translational and angular vibrations.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

(Also see Nos. 432, 507, 595)

80-495
An Optimal Suspension for an Automobile on a Random Road
A.G. Thompson and C.E.M. Pearce
Dept. of Mech. Engrg., Univ. of Adelaide, South Australia, SAE Paper No. 790478, 12 pp, 3 figs, 5 refs

Key Words: Isolators, Active isolation, Suspension systems (vehicles), Random excitation, Optimum control theory

Optimal control theory is applied to the design of an active suspension system for a car on a random road. The performance index employed is a weighted sum of mean-squared values for the body forces, tire dynamic deflections and relative wheel travels. An explicit expression is obtained for the performance index. The practical realization of the optimal system is discussed and its characteristics compared with those of a conventional passive type suspension system.

80-496
A Method for Obtaining Practical Flutter-Suppression Control Laws Using Results of Optimal Control Theory
J.R. Newson
NASA Langley Research Ctr., Hampton, VA, Rept. No. NASA-TP-1471; L-12728, 34 pp (Aug 1979) N79-28614

Key Words: Flutter, Active control, Optimum control theory

The results of optimal control theory are used to synthesize a feedback filter. The feedback filter is used to force the output of the filtered frequency response to match that of a desired optimal frequency response over a finite frequency range. This matching is accomplished by employing a non-linear programming algorithm to search for the coefficients of the feedback filter that minimize the error between the optimal frequency response and the filtered frequency response. The method is applied to the synthesis of an active flutter-suppression control law for an aeroelastic wind-tunnel model.

80-497
Liquid Spring Shock Isolator Modeling by System Identification
P.N. Sonnenburg, B.H. Wendler, and W.E. Fisher
The U.S. Army Corps of Engineers, Construction Engrg. Research Lab., Champaign, IL, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 119-134 (Sept 1979) 16 figs, 1 table, 7 refs

Key Words: Isolators, Shock isolators, Springs, Liquid springs, Mathematical models, System identification technique

A feasibility study was undertaken to determine if a reasonably accurate model of an off-the-shelf liquid-spring isolator could be found, using data from a few simple and inexpensive tests. A liquid spring was selected for its design versatility and potential use in high-performance shock isolation systems. General acceptance of a system identification approach ultimately will depend on the simplicity and cost of testing and the ability to represent installed operating conditions by the mathematical formulation.

80-498
Suspension Parameter Prediction Using Finite Element Analysis
W.A. Cobb

General Motors Engrg. Staff, General Motors Corp., SAE Paper No. 790376, 12 pp, 11 figs, 8 refs

Key Words: Suspension systems (vehicles), Ride dynamics, Computer programs, Finite element technique

A technique is developed for applying finite element computer models, assembled for vibration work, to analysis and prediction of vehicle handling performance. The method facilitates the prediction of chassis stiffnesses important to handling before a vehicle is built and available for laboratory testing by more traditional methods. The technique incorporates the *general purpose finite element computer program* (NASTRAN), total vehicle system models developed for structural analysis, and applied loads intended to simulate an existing laboratory test. A post-processor program summarizes chassis parameters related to handling from the general NASTRAN displacements in familiar units. Example *results from actual and simulated testing are compared.*

80-499

Kenworth Airglide 100 Rear Suspension

J.K. Winslow

Kenworth Truck Co., SAE Paper No. 790768, 12 pp, 13 figs

Key Words: Suspension systems (vehicles), Trucks, Motor vehicles

An air suspension is developed to meet the needs of the Class 8 truck market of the 1980's. This design is developed to satisfy a list of objectives that conform to present and future requirements for a tandem axle rear suspension. Throughout the development program, exhaustive tests are conducted to assure successful performance and minimize the possibility of last minute tooling changes. Dual anti-sway *bars contribute significantly to the dynamic performance* characteristics of this suspension and, along with the full *air springing, represent its most significant performance* features.

80-500

Computer Aided Design of Passive Vibration Isolators for Airborne Electro-Optical Systems

P.W. Whaley and J. Pearson

Air Force Inst. of Tech., Wright-Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 81-86 (Sept 1979) 4 figs, 2 tables, 10 refs

Key Words: Isolators, Vibration isolators, Electronic instrumentation, Aircraft equipment response

The concept of nodalization for jet-powered, winged aircraft is examined at the Flight Dynamics Laboratory using a simply supported beam loaded with a lumped mass at each end and supported by two passive isolators located arbitrarily along the beam. The Fibonacci numerical search routine is *used to minimize the sum of the mean squared angular vibra-*tion responses of the two ends.

80-501

Shock Isolation Platform for SEASPARROW Launcher

P.V. Roberts

Missile Systems Div., Raytheon Co., Bedford, MA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 85-95 (Sept 1979) 17 figs, 7 refs

Key Words: Shock isolators, Shipboard equipment response, Launching response, Missile launchers

A unique low frequency shock isolation platform is used to mount the NATO SEASPARROW Launcher aboard U.S. shock-hardened ships. The platform attenuates shock response to less than structural design loads which were used to minimize weight on smaller NATO ships and for compatibility with airborne missiles. The platform also isolates shipboard vibration in the most critical range of launch cell and *missile resonances between 14 and 30 Hz, and furnishes a* lightweight convenient means of installing the launcher aboard ship.

80-502

Hydragas Suspension

A.E. Moulton and A. Best

Moulton Developments Ltd., SAE Paper No. 790374, 24 pp, 32 figs, 7 refs

Key Words: Suspension systems (vehicles)

This paper describes the principles of the unique Hydragas fluid interconnection suspension system. Comparisons with conventional suspensions are given in terms of performance, weight, cost and packaging.

80-503

Design and Development of an Independent Rear Suspension for the 1979 Cadillac Eldorado

J.T. Hoban, C.J. Cislo, and R.H. Triemstra

Cadillac Motor Car Div., General Motors Corp., SAE Paper No. 790375, 16 pp, 31 figs, 3 refs

Key Words: Suspension systems (vehicles)

This two-part paper describes the rear suspension design and the vehicle development methodology for the 1979 Cadillac Eldorado.

80-504
1979 Firebird - An Advanced (Part 581) Soft Bumper System
J.V. Scrivo
Davidson Rubber Co., Inc., SAE Paper No. 790335, 12 pp, 13 figs, 6 tables, 5 refs

Key Words: Bumpers, Elastomers

Weight and performance characteristics of the 1979 Pontiac Firebird soft bumper system are compared to those for a typical new (1979) metal/hydraulic design to evaluate the effects of the new standard. This study demonstrates the changing competitive environment in the automotive bumper market due to the introduction of the Part 581 Standard. The deep soft bumper concept is also discussed including its potential for achieving weight reductions in future elastomeric bumper systems.

80-505
Bumper Energy Attenuators Made from Fiber Reinforced Plastic
M.K. McDougall, J.N. Epel, and R.E. Wilkinson
The Plastic Res. and Dev. Center, The Budd Co., Troy, MI, SAE Paper No. 790334, 13 pp, 23 figs, 1 table

Key Words: Bumpers, Energy absorption, Fiber composites

The objective of this paper is to describe the development of a new family of continuous fiber reinforced energy attenuators which meet FMVSS 581 and offer substantial weight reductions over conventional energy attenuator systems.

80-506
Dual Phase Steel Production Bumpers
H.H.L. Mantey and F.T. Burton
Cadillac Motor Car Div., General Motors Corp., SAE Paper No. 790281, 16 pp, 25 figs, 8 refs

Key Words: Bumpers, Steel, Automobiles

The use of HSLA dual phase steel is an effective method of reducing bumper weight while meeting government performance requirements. A paper analysis, followed by a hardware evaluation, successfully substituted "dual phase" for conventional HSLA steel at a reduced thickness. Bumpers for the all-new 1979 Cadillac Eldorado were designed and released using dual phase steel with yield strengths of 70-80 ksi for the face bars.

80-507
Evaluation of Optimized Multisectioned Acoustic Liners
K.J. Baumeister
NASA Lewis Research Ctr., Cleveland, OH, AIAA J., 17 (11), pp 1185-1192 (Nov 1979) 15 figs, 24 refs

Key Words: Ducts, Acoustic linings, Acoustic attenuation

A critical examination is presented of the use of optimized axially segmented acoustic liners to increase the attenuation of a liner. In house (finite difference) and contractor (mode matching) programs are used to generate theoretical attenuations for a number of liner configurations for liners in a rectangular duct with no mean flow.

SPRINGS

80-508
Coil Spring Design, An Analytical View
A.R. Solomon
Chevrolet Div., General Motors Corp., SAE Paper No. 790410, 12 pp, 11 figs, 3 refs

Key Words: Springs, Suspension systems (vehicles), Design techniques, Computer programs

Variable rate coil springs will improve the overall ride of light vehicles. A new computer program, developed by Chevrolet to simulate the operational characteristics of tapered wire and/or noncylindrical variable rate coil springs, has become an integral part of the design process.

80-509
Material and Processing Effects on Fatigue Performance of Leaf Springs
R.W. Landgraf and R.C. Francis
Ford Motor Co., SAE Paper No. 790407, 12 pp, 18 figs, 8 refs

Key Words: Springs, Leaf springs, Fatigue life

Procedures are developed for assessing the influence of various material and processing factors on the fatigue performance of leaf springs. Cyclic material properties, determined from smooth axial specimens of spring steel, are used to determine the level and cyclic stability of residual stresses resulting from mechanical processing as well as the amount of permanent deformation associated with presetting operations. A damage parameter, incorporating material properties, residual stress effects and applied stressing conditions, is used to predict failure location, i.e. surface or subsurface, and lifetime as a function of processing sequence. Predictions are found to be in good agreement with experimental bending results.

TIRES AND WHEELS

(Also see Nos. 459, 462, 587)

80-510
Influence of Antiskid Systems on Vehicle Directional Dynamics
E. Bisimis
Alfred Teves GmbH, Frankfurt, Germany, SAE Paper No. 790455, 12 pp, 9 figs, 6 refs

Key Words: Ground vehicles, Tires, Braking effects, Skid resistance

The results presented demonstrate the influence of longitudinal tire slip and load transfer during braking on steering behavior of cars in terms of parameters which have been found to be important for the function of the driver/vehicle control loop. A description of an antiskid system and a comparison of directional properties during braking with conventional brake system and with antiskid are illustrated. The importance of appropriate selection of slip levels during adaptation of antiskid systems to a given vehicle is pointed out.

80-511
Development of the N-Type Runflat Tire and Its Evaluation in Vehicle Dynamics
K. Yabuta and H. Nishimura
Nissan Motor Co., Ltd., SAE Paper No. 790668, 12 pp, 15 figs, 10 tables, 8 refs

Key Words: Tires, Automobile tires, Dynamic tests

The "N" type run-flat tire, described in this paper, has a simple structure with reinforced side walls and additional beads to fit the rim flanges.

80-512
Proper Aircraft Tire Size Selection - Optimum Performance with Minimum Maintenance
L.J. Gehrett
The Goodyear Tire & Rubber Co., SAE Paper No. 790598, 8 pp, 4 figs, 3 tables, 2 refs

Key Words: Tires, Aircraft tires

High speeds with heavy loads represent the type of operating condition to which the aircraft tire is subjected during its utilization on business aircraft. This type of operation produces severe dynamic forces that challenge the tire design engineer.

BLADES

(Also see No. 487)

80-513
Design of Turbine Blades for Effective Slip Damping at High Rotational Speeds
D.I.G. Jones and A. Muszynska
Air Force Materials Lab., Wright-Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 87-96 (Sept 1979) 13 figs, 2 tables, 14 refs

Key Words: Blades, Turbine blades, Compressor blades, Damping effects, Design techniques

This paper examines the dynamic behavior of a blade having a root geometry compatible with low frictional forces at high rotational speeds, somewhat like a "Christmas Tree" root, but with a gap introduced which will close up only at high speed. Approximate non-linear equations of motion are derived and solved using a method of harmonic balance. Numerical examples are discussed.

80-514

Structural Analysis of a Gas Turbine Impeller Using Finite-Element and Holographic Techniques

P.S. Kuo and K.S. Collinge

Avco Lycoming Div., Stratford, CT, In: AGARD Stresses, Vibrations, Struc. Integration & Eng. Integrity (including Aeroelasticity & Flutter), 15 pp (Apr 1979)

N79-27149

Key Words: Blades, Gas turbine blades, Finite element techniques, Holographic techniques

A rigorous finite element structural analysis method is presented which, combined with the holographic technique, deals with the highly stressed, curved vanes and the vibration of the flexible circular backplate so that the magnitude and the pattern of static, dynamic, and thermal loadings can be improved. The method demonstrates a computerized procedure for the design of a modern centrifugal impeller. Comparison between the theoretical and the experimental results is made.

80-515

Design of Quiet Efficient Propellers

G.P. Succi

Massachusetts Inst. of Tech., Cambridge, MA, SAE Paper No. 790584, 16 pp, 19 figs, 2 tables, 13 refs

Key Words: Blades, Aircraft noise, Propeller noise, Noise reduction, Design techniques

A numerical computation scheme is developed to determine the sound generated by propellers. A comparison of these calculations to the noise data taken in the flight test of a propeller driven aircraft shows good agreement. The method is applied in a parametric study of fixed pitch propellers designed to reduce noise.

BEARINGS

(Also see Nos. 528, 598)

80-516

New Bearing Selection Concepts and Mounting Guidelines for Off-Highway Wheels

B.J. Cave and R.R. Bhatia

The Timken Co., SAE Paper No. 790525, 24 pp, 28 figs, 15 refs

Key Words: Bearings, Off-highway vehicles, Fatigue life

This paper discusses the role of new anti-friction roller bearing technology in avoiding problems created by changing design considerations and the performance/cost/EPA triad currently squeezing designers and manufacturers of rubber tired earthmoving machinery. A comparison is made of bearing fatigue life determined by several methods including those derived from vehicle instrumentation and purely empirical criteria. Some common problems relating to the mounting and set up of large wheel bearings are also reviewed together with corresponding remedies.

80-517

Nonlinear Vibrations of Large Rotors with Vertical Shaft Guided in Radial Tilting-pad Bearings (Nichtlineare Schwingungen schwerer Rotoren mit vertikaler Welle und Kippsegmentradiallagern)

H. Springer

Institut f. Maschinendynamik und Messtechnik an der Technischen Universität Wien, Wien, Austria, Forsch. Ingenieurw., 45 (4), pp 119-132 (1979) 13 figs, 12 refs

(In German)

Key Words: Bearings, Hydrodynamic bearings, Tilting pad bearings, Rotor-bearing systems, Finite element technique

In this paper an approximation method to calculate the pressure in hydrodynamic bearings is used to investigate nonlinear transient vibrations of a vertically suspended rotor system in the presence of large amplitudes of vibrations in the guide bearings of the shaft. The rotor system is modeled using finite beam elements. Static and dynamic unbalances as well as gyroscopic forces caused by rotating disc-shaped masses, magnetic pull, external damping forces etc. can be calculated applying the theory.

80-518

Some Studies on the Influence of Housing Stiffness on Bearing Reliability

C. Robinson and M.J. Hartnett

The Torrington Co., Torrington, CT, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 25-28, 6 figs, 13 refs

Key Words: *Bearings, Roller bearings, Housings, Reliability*

This paper describes how the analysis of bearings can be expanded to include the influence of structural deflections on performance. The results of several studies are presented.

80-519

UNIPAC - An Independently Sprung Driving Wheel Bearing

G.G. Gilbert and W.E. Harbottle

The Timken Co., Canton, OH, SAE Paper No. 790-714, 16 pp, 21 figs, 1 table, 7 refs

Key Words: Bearings, Roller bearings, Automobiles

UNIPAC is a new two row tapered roller bearing assembly that has been developed for smaller automobiles that use an independent suspension, and front wheel drive. The new two row assembly offers a complete tapered roller bearing package that is pregreased, preadjusted and sealed. These unique functional characteristics are required of this bearing assembly for the independently sprung driving wheel position. Each functional bearing requirement is studied and tested to assure satisfactory bearing performance at the most economical bearing price.

80-520

Pseudo-Random Binary Sequence Forcing in Journal and Squeeze-Film Bearings

R. Stanway, C.R. Burrows, and R. Holmes

Univ. of Sussex, Falmer, Brighton, UK, ASLE Trans., 22 (4), pp 315-322 (Oct 1979) 8 figs, 26 refs

Key Words: Bearings, Journal bearings, Squeeze-film bearings, Dynamic tests, Lubrication

The need is established for the experimental determination of linearized bearing oil-film coefficients. General methods of dynamic testing are discussed and previous attempts to measure bearing coefficients are reviewed. Three criteria for assessing the suitability of any test procedure for estimating linear bearing coefficients are formulated and used to show that improved techniques are still required. A new test procedure using pseudo-random binary sequence forcing is described. The method is applied to determine the linear characteristics of a prototype squeeze-film bearing and some experimental results are presented.

80-521

Analysis of Step Journal Bearings - Infinite Length, Inertia Effects

P.E. Allaire, J.C. Nicholas, and L.E. Barrett

Univ. of Virginia, Charlottesville, VA 22901, ASLE Trans., 22 (4), pp 333-341 (Oct 1979) 13 figs, 17 refs

Key Words: Bearings, Journal bearings, Finite element technique

This paper analyzes infinitely long centered and eccentric step journal bearings using finite elements. Step inertia and turbulence effects are included. The analysis is verified by comparison with other theoretical and experimental results for centered step bearings.

GEARS

80-522

An Introduction to Gear Failure Analysis

P.M. Dean

Mechanical Technology Inc., 968 Albany-Shaker Rd., Latham, NY 12110, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 67-85, 44 figs, 3 tables

Key Words: *Gears, Failure analysis*

Gear failure analysis is a procedure in which evidence is achieved not only from visual inspection but from metallurgical analysis, lubrication technology, system dynamic analysis, a review of the design of the casings, bearings, shafts and seals, and a detailed analysis of the individual gears is utilized to determine the cause of the gear failure. The aspects of the overall investigation pertaining primarily to the gears are the focus of this presentation.

80-523

Torsionally Resilient Couplings in Diesel Engine Drives

A.S. Herman

Koppers, P.O. Box 1696, Baltimore, MD 21203, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 275-279, 1 fig, 6 refs

Key Words: Couplings, Flexible couplings, Diesel engines

Some of the reasons for specifying torsionally resilient couplings in certain types of diesel drive trains are discussed. Examples where a coupling utilizing rubber blocks in compression provides a versatile design tool to avoid serious vibration problems are given.

80-524

Torsionally Soft Flexible Couplings

M.D. Wright

American Vulkan Corp., 2525 Dundee Rd., Winter Haven, FL 33880, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 263-265, 6 figs

Key Words: Couplings, Flexible couplings, Torsional response

The author describes a torsionally soft coupling and discusses the measurement of torsional rigidity and damping, torsional vibration calculation, and coupling design and construction.

80-525

The Use of Diaphragm Couplings in Turbomachinery

C.B. Gibbons

The Bendix Corp., Utica, NY, 47 figs

Key Words: Couplings, Turbomachinery

The use of diaphragm couplings in turbomachinery is discussed in detail.

80-526

An Analytical Investigation of Three-Dimensional Vibration in Gear-Coupled Rotor Systems

J.W. Daws

Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 423 pp (1979)

UM 7924099

Key Words: Couplings, Gear couplings, Rotors, Forced vibration

This paper presents a comprehensive analysis of three-dimensional forced vibration response of gear-coupled rotor systems. Gear coupling is studied and the time-varying nature of the gear mesh stiffness is developed and compared to other published results. To produce three-dimensional coupling, Hibner's branching technique is applied to the gear mesh. A multi-frequency transfer matrix formulation is developed from the method of harmonic balance which allows the transfer matrix approach to handle differential equations with periodic coefficients. The proposed analysis technique is used to predict the forced response of a set of high-speed gear-coupled turborotors for sixteen discrete frequencies. Bearing force level data obtained from the manufacturer is presented.

80-527

Elliptical Scotch-Yoke Coupling and a General Case of Kinetic Energy Harmonics (Die Kopplung elliptischer Schleifen mit der Kreuzschleife und die Harmonischen der Bewegungsenergie für den allgemeinen Fall)

W. Meyer zur Capellen and F. Meyer zur Capellen

Technische Hochschule Aachen, Aachen, Germany, Forsch. Ingenieurw., 45 (4), pp 105-110 (1979) 3 figs, 4 refs

(In German)

Key Words: Couplings, Mathematical models

In the coupling of an elliptic slide with a scotch-yoke chain, the Fourier coefficients of the kinetic energy can be represented by relatively simple closed expressions. The problem is treated by use of the principle of superposition for elliptic slides and by the method of partial fractions.

FASTENERS

80-528

Method of Designing Bolted Joints for Mounting Large-Diameter Bearings

E. Gusovius

Rotek, Inc., Aurora, OH, SAE Paper No. 790906, 16 pp, 24 figs, 6 refs

Key Words: Fasteners, Bearings, Antifriction bearings, Design techniques

A method is presented for calculating fastener requirements for use in mounting large diameter anti-friction bearings. Procedures for calculating static and dynamic fastener loading and capacity are presented, taking into account fastener diameter and length, resilience of the fastener and the clamped parts, fastener grade, number of interfaces, preload scatter, tightening method, etc.

80-529

Measurements of Hysteresis in Bolted Joints Loaded by a Bending Moment (Hysteresemessungen an einer biegebeanspruchten Klemmverbindung)

D. Ottl and R. Ritter

Forsch. Ingenieurw., 45 (4), pp 133-136 (1979) 8 figs, 5 refs

(In German)

Key Words: Joints (junctions), Hysteretic damping, Experimental results

Hysteresis of a bolted joint loaded by a bending moment, is measured. The experiments are performed with slowly varying bending moments in order to investigate the influence of the following parameter: frequency, amplitude and mean value of the loading, surface pressure.

STRUCTURAL COMPONENTS

STRINGS AND ROPES

80-530

Random Vibrations of Strings under Transverse Loads (Zufallsschwingungen von querangeströmten Saiten)

W. Wedig

Institut f. Technische Mechanik, Universität Karlsruhe, Kaiserstrasse 12, D-7500 Karlsruhe 1, Bundesrepublik Deutschland, Ing. Arch., 48 (5), pp 325-335 (1979) 5 figs, 13 refs

(In German)

Key Words: Strings, Random excitation, Random vibration

The example of a preloaded string under random excitation uncorrelated in time and in space is used in order to present a new method to calculate the associated covariance functions. By use of a Green's function this covariance analysis leads to integral equations, the solution of which can be given in a closed form in case of the stated problems.

80-531

Snaps in Structures

M. Zak

Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 83-87 (Sept 1979) 11 figs, 4 refs

Key Words: Strings, Mathematical models

Snaps as a type of shock phenomena which arise in structures employing films, or strings are studied. The sources and the variety of such snaps are defined and a new mathematical model for their investigation is presented.

80-532

Self-Sustained Oscillations of the Bowed String

R.T. Schumacher

Dept. of Physics, Carnegie-Mellon Univ., Pittsburgh, PA 15213, Acustica, 43 (2), pp 109-120 (Sept 1979) 7 figs, 16 refs

Key Words: Strings, Musical instruments, Periodic response

The Hammerstein integral equation, previously applied to study the oscillations of the organ pipe and the clarinet, is used here to calculate the velocity of a bowed string at the bowing point, and the force between the string and the bow, in the limit of steady state periodic motion. A derivation of the integral equation is given.

80-533

On the Fundamentals of Bowed-String Dynamics

M.E. McIntyre and J. Woodhouse

Dept. of Appl. Mathematics & Theoretical Physics, Univ. of Cambridge, MA, Acustica, 43 (2), pp 93-108 (Sept 1979) 13 figs, 28 refs

Key Words: Strings, Musical instruments, Dynamic structural analysis

A general class of models of the bowed string is considered. The effect of the bow is idealized in the usual way as a nonlinear friction force whose ratio to normal bow force depends only on relative velocity at a single point of contact with the string, while the string and its terminations are represented as a linear system with an impulse response at the bowing point.

CABLES

80-534

Program Development to Study Faired Towlines

J.B. Eades, Jr. and V. Majer

Business and Technological Systems, Inc., Seabrook, MD, Rept. No. BTS-TR-79-74, ONR-CR298-003-1, 121 pp (Jan 1979)

AD-A071 202/6GA

Key Words: Towing cables, Cables (ropes), Hydrodynamic excitation, Computer programs

A computer program is developed to study the interactions between hydrodynamic loading and structural response of flexible, faired, underwater towing cables. The equilibrium shape of the cable's cross-section when it is moving at an angle of attack in a steady two-dimensional viscous flow field is computed.

80-535

Investigation of the Shock Wave Sensitivity of Coaxial Cable in Water, 1975 (Undersoekning av Koaxialkabels Kaenslighet foer Stoetvaagor I Vatten 1975)

P. Stroem

Research Inst. of National Defence, Stockholm, Sweden, Rept. No. FOA-C-20233-D4, 12 pp (Apr 1978) (In Swedish)

N79-28443

Key Words: Cables, Shock waves, Underwater explosions

A previously unused antimicrophonic cable is compared with two other known types of cable. The new cable satisfies the necessary requirements for a cable which is exposed to shock waves in water during its use.

80-536

Comparison of Wire Rope Life Using Nylon and Steel Sheaves - Part 1: Test Methodology and Comparison of Wire Rope Endurance Life

J.H. Chen and C.R. Ursell

The Polymer Corp., Reading, PA, SAE Paper No. 790904, 12 pp, 7 figs, 6 refs

Key Words: Cables (ropes), Wire, Testing techniques, Cyclic loading, Fatigue life

A methodology is developed to test wire rope endurance characteristics to ANSI B30.5 removal criteria.

80-537

Comparison of Wire Rope Life Using Nylon and Steel Sheaves - Part II: New Concept to Improved Predictability of Wire Rope Remaining Strength After Cycling

J.H. Chen and P.E. Gage

The Polymer Corp., Reading, PA, SAE Paper No. 790905, 8 pp, 3 figs, 3 refs

Key Words: Cables (ropes), Wire, Fatigue life, Failure analysis

An analysis is made of the modes of failure of cycled rope. The linear relation, and deviations from it, can be used to evaluate reliability of wire rope/sheave systems. This relationship can also be used to predict the remaining strength of a wire rope after failure criteria is reached.

BARS AND RODS

80-538

Forced Torsional Vibrations of a Cylindrical Rod Connected to an Elastic Half-Space

H. Wada

Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan, J. Sound Vib., 66 (2), pp 265-275 (Sept 22, 1979) 5 figs, 19 refs

Key Words: Rods, Cylindrical bodies, Rotors (machine elements), Forced vibration, Torsional vibration

An analysis is presented of the forced torsional vibrations of a cylindrical rod connected to an elastic half-space under the condition that the circumferential displacement at the free end of the rod, where the disturbing moment is applied, varies proportionally with the distance from the rod axis. Both the Pochhammer-Chree and elementary theory are utilized.

80-539

Natural Oscillations of Kinked Rods (Berechnung der Eigenschwingungen geknickter Stabe)

P. Pfundner

Institut f. Allgemeine Elektrotechnik der Technischen Universität Wien, Vienna, Austria, Acustica, 43 (2), pp 156-161 (Sept 1979) 5 figs, 4 refs
(In German)

Key Words: Rods, Natural frequencies

The resonant frequencies of thin, free oscillating rods with a single sharp bend (kink) of different angles are found by setting up the vibration equation. Longitudinal as well as flexural waves have to be considered due to the coupling properties of the kink. A special form of the vibration equation is developed to find the resonant frequencies of a rod, in which no longitudinal waves exist in the bent part and no movement occurs at the kink itself.

80-540

On the Lateral Stability of a Bar with a Circular Axis Subjected to a Non-Conservative Load

Z. Celep

Faculty of Engrg. and Architecture, Technical Univ., Istanbul, Turkey, J. Sound Vib., 66 (2), pp 219-225 (Sept 22, 1979) 4 figs, 9 refs

Key Words: Bars, Flutter, Flexural vibration, Torsional vibration, Stability

This paper presents an investigation of the bending and torsional vibration and of the divergence and flutter stability of a simply supported bar with a circular axis subjected to conservative and follower loads which are distributed along a line parallel to the center line of the cross section and directed radially. The stability loads are illustrated in detail for various values of the distance of the point of application and those of the non-conservativeness parameter of the applied load.

BEAMS

(Also see No. 650)

80-541

Dynamic Buckling of a Nonlinear Timoshenko Beam

M.H. Sapir and E.L. Reiss

Dept. of Mathematics, Univ. of Miami, Coral Gables, FL 33124, SIAM J. Appl. Math., 37 (2), pp 290-301 (Oct 1979) 2 figs, 7 refs

Key Words: Beams, Timoshenko theory, Dynamic buckling

The transient motion that results when an ended-loaded column buckles is studied using a nonlinear Timoshenko beam theory. The two-time method is used to construct an asymptotic expansion of the solution. The results are then compared with those of a previous analysis of the same problem that employed the Euler-Bernoulli beam theory. Thus, the effects of shear deformations and rotary inertia on the dynamics of the column are explicitly demonstrated.

80-542

Free Vibration of Rectangular Beams of Arbitrary Depth

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

Dept. of Civil Engrg., Indian Inst. of Science, Bangalore, India, Acta Mech., 32 (4), pp 249-259 (1979) 1 fig, 5 tables, 8 refs

Key Words: Beams, Rectangular beams, Free vibration

The state space approach is extended to the two dimensional elastodynamic problems. The formulation is in a form amenable to consistent reduction to obtain approximate theories of any desired order. Free vibration of rectangular beams of arbitrary depth is investigated using this approach. It takes into account the vertical normal stress and the transverse shear stress. The frequency values are calculated using the Timoshenko beam theory and the present analysis for different values of Poisson's ratio and they are in good agreement. Four cases of beams with different end conditions are considered.

CYLINDERS

(See No. 414)

COLUMNS

80-543

Cyclid Inelastic Buckling of Thin Tubular Columns

E.P. Popov, V.A. Zayas, and S.A. Mahin

Univ. of California, Berkeley, CA, ASCE J. Struc. Div., 105 (ST11), pp 2261-2277 (Nov 1979) 11 figs, 1 table, 14 refs

Key Words: Columns (supports), Cyclic loading, Offshore structures, Towers, Seismic response

Experimental results on cyclic inelastic buckling of one-sixth scale thin tubular steel columns typical of braces employed in fixed offshore platforms are described. Tube diameter to wall thickness and slenderness ratios considered are typical of those used in practice.

FRAMES AND ARCHES

80-544

In-Plane Vibration of Timoshenko Arcs with Variable Cross-Section

T. Irie, G. Yamada, and I. Takahashi

Dept. of Mech. Engrg., Hokkaido Univ., North-13, West-8, 060 Sapporo, Japan, Ing. Arch., 48 (5), pp 337-346 (1979) 8 figs, 12 refs

Key Words: Arches, Variable cross section, Timoshenko theory, Transfer matrix method

This paper studies in-plane vibrations of Timoshenko arcs with variable cross-section by the transfer matrix approach. For this purpose, the equations governing the in-plane vibration of the arcs are written in a coupled set of first-order differential equations by use of the transfer matrix. Once the transfer matrix has been determined by numerical integration of the equations, the natural frequencies (the eigenvalues) and the mode shapes are calculated in terms of the elements of the matrix for a given set of boundary conditions. This method is applied to arcs with linearly, parabolically and exponentially varying cross section, and the effects of the varying cross-section and slenderness on the free vibrations of the arcs are studied.

80-545

Inelastic Behavior of Steel Structures Subjected to Earthquake-Induced Ground Motion

A.M. Kabe

Ph.D. Thesis, Univ. of California, Los Angeles, 207 pp (1979)

UM 7921423

Key Words: Framed structures, Steel, Earthquake response, Simulation

The large amplitude inelastic response of steel structures to earthquake type motions is investigated experimentally. Twenty moment resistant, steel frame structures are subjected to simulated earthquake motions by means of a high performance shaking table. The data obtained from the twenty structures is used to identify functional relationships between response quantities and the intensity of the table motion. The story drift index, permanent deformation drift index, and acceleration amplification factor are related to a dimensionless parameter which involves the mass of the structure, peak table acceleration and the plastic limit load for the structural columns.

MEMBRANES, FILMS, AND WEBS

(See No. 531)

PANELS

80-546

The Effect of Oblique Angle of Sound Incidence, Realistic Edge Conditions, Curvature and In-Plane Panel Stresses on the Noise Reduction Characteristics of General Aviation Type Panels

F. Grosveld, J. Lameris, and D. Dunn

Kansas Univ, Center for Research, Inc., Lawrence, KS, Rept. No. NASA-CR-157452, KU-FRL-417-10, 134 pp (July 1979)

N79-29958

Key Words: Panels, Aircraft, Noise reduction

Experiments and a theoretical analysis are conducted to predict the noise reduction of inclined and curved panels. These predictions are compared to the experimental results with reasonable agreement between theory and experiment for panels under an oblique angle of sound incidence. Experimentally measured noise reduction characteristics of flat aluminum panels with uniaxial in-plane stresses are presented.

80-547

Non-Linear Forces on Oscillating Plates: Review and Analysis of the Literature

J.F. Dalzell
Davidson Lab., Stevens Inst. of Tech., Hoboken, NJ, Rept. No. SIT-DL-78-9-2031, 118 pp (Dec 1978) AD-A071 146/5GA

Key Words: Plates, Ships, Oscillation

The general objective of the present work is to look for alternatives to the conventional time domain model for the oscillatory forces on plates, using what data could be found in the literature.

80-548

Solutions of the Lévy Type for the Free Vibration Analysis of Diagonally Supported Rectangular Plates

D.J. Gorman
Dept. of Mech. Engrg., Univ. of Ottawa, Ottawa, Canada, J. Sound Vib., 66 (2), pp 239-246 (Sept 22, 1979) 5 figs, 2 tables, 4 refs

Key Words: Plates, Rectangular plates, Free vibration, Harmonic excitation

A Lévy type solution is developed for the vibratory response of a simply supported rectangular plate subjected to a harmonic force distributed along the diagonal. The solution is then extended to determine the free vibration response of the same rectangular plate with inelastic lateral support on the diagonal. The significant advantages inherent in the present Lévy type solution are discussed.

80-549

Free Vibration of a Mindlin Annular Plate of Varying Thickness

T. Irie, G. Yamada, and S. Aomura
Dept. of Mech. Engrg., Hokkaido Univ., Sapporo, Japan, J. Sound Vib., 66 (2), pp 187-197 (Sept 22, 1979) 5 figs, 1 table, 15 refs

Key Words: Plates, Variable cross section, Transfer matrix method

The free vibration of a Mindlin annular plate of radially varying thickness is analyzed by use of the transfer matrix approach. For this purpose, the Mindlin equations of flexural vibration of an annular plate are written as a coupled set of first-order differential equations by using the transfer matrix of the plate. Once the matrix has been determined by the numerical integration of the equations, the natural frequencies and the mode shapes of the vibration are calculated numerically in terms of the elements of the matrix for a given set of boundary conditions at the edges of the plate. This method is applied to annular plates of linearly, parabolically and exponentially varying thickness, and the effects of the varying thickness are studied.

80-550

Calculation of Eigenvalues for Kirchhoff's Plate with Nonlinear Splines (Eigenwertberechnung für die Kirchhoff-Platte mit nichtlinearen Splinefunktionen)

P. Ruge
Lehrstuhl f. Mechanik und Festigkeitslehre im Mechanikzentrum der TU Braunschweig, Pockelsstrasse 4, D-3300 Braunschweig, Bundesrepublik Deutschland, Ing. Arch., 48 (5), pp 313-323 (1979) 2 figs, 4 tables (In German)

Key Words: Plates, Eigenvalue problems

The calculation of eigenvalues for Kirchhoff's plate by means of the matrix displacement method leads to the minimization of Rayleigh's quotient. The resulting nonlinear equations are solved in two steps: first by treating the usual algebraic eigenvalue problem for the nodal quantities and then by a stepwise consecutive iteration between Rayleigh's quotient and the additional parameters.

80-551

A Penalty Plate-Bending Element for the Analysis of Laminated Anisotropic Composite Plates

J.N. Reddy
School of Aerospace, Mechanical and Nuclear Engrg., Univ. of Oklahoma, Norman, OK 73019, Rept. No. OU-AMNE-79-14, 34 pp (Aug 1979) 10 figs, 45 refs

Key Words: Plates, Finite element technique, Transverse shear deformation effects, Rotatory inertia effects

A penalty plate-bending element for the analysis of laminated anisotropic composite plates is discussed. The YNS theory is a generalization of Mindlin's theory for homogeneous, iso-

tropic plates to arbitrarily laminated anisotropic plates and includes shear deformation and rotary inertia effects. The present element can also be used in the analysis of thin plates by appropriately specifying the penalty parameter. A variety of problems are solved, including those for which solutions are not available in the literature, to show the material effects and the parametric effects of plate aspect ratio, length-to-thickness ratio, lamination scheme, number of layers and lamination angle on the deflections, stresses, and vibration frequencies.

80-552

Finite-Element Analysis of Laminated Bimodulus Composite-Material Plates

J.N. Reddy and W.C. Chao
School of Aerospace, Mechanical and Nuclear Engrg., Univ. of Oklahoma, Norman, OK 73019, Rept. No. OU-AMNE-79-18, 26 pp (Aug 1979) 4 figs, 15 refs

Key Words: Plates, Anisotropy, Layered materials, Impact response (mechanical), Finite element technique

Finite-element analysis of the equations governing the small-deflection elastic behavior of thin plates laminated of anisotropic bimodulus materials (which have different elastic stiffnesses depending upon the sign of the fiber-direction strain) is presented. Single-layer and two-layer cross-ply, simply-supported rectangular plates subjected to sinusoidally distributed normal pressure and uniformly distributed normal pressure are analyzed.

80-553

Classical Analyses of Laminated Bimodulus Composite-Material Plates

C.W. Bert
School of Aerospace, Mechanical and Nuclear Engrg., Univ. of Oklahoma, Norman, OK 73019, Rept. No. OU-AMNE-79-10A, 40 pp (Aug 1979) 4 tables, 24 refs

Key Words: Plates, Anisotropy, Layered materials, Impact response (mechanical)

A differential-equation formulation is presented for the equations governing the small-deflection elastic behavior of thin plates laminated of anisotropic bimodulus materials (which have different elastic stiffnesses depending upon the sign of the fiber-direction strains). Exact closed-form solutions are presented for two cross-ply-laminated plate problems: a freely supported rectangular plate subjected to a sinusoidally distributed normal pressure and a fully clamped elliptic plate subjected to uniform normal pressure.

80-554

Impact Induced Stress Waves in an Anisotropic Plate

S.S. Kim and F. Moon
Cornell Univ., Ithaca, NY, AIAA J., 17 (10), pp 1126-1133 (Oct 1979) 7 figs, 19 refs

Key Words: Plates, Anisotropy, Layered materials, Impact response (mechanical)

Stress wave propagation in an anisotropic plate due to impact forces is examined. The plate is modeled as a number of identical anisotropic layers. Mindlin's approximate theory of plates is applied to each layer to obtain a set of difference-differential equations of motion with use of the interlaminar stresses and displacements as explicit variables. The difference-differential equations are reduced to difference equations via integral transforms. With given impact boundary conditions, these equations are solved for an arbitrary number of layers in the plate and the transient propagation of stress waves is calculated by means of a Fast Fourier Transform algorithm.

80-555

Analysis of Lower Modes of Vibration of Rectangular Plates of Linearly Varying Thickness

P.A. Laura and L.E. Luisoni
Inst. of Applied Mechanics, Base Naval Puerto Belgrano, Argentina, Appl. Acoust., 12 (5), pp 333-347 (Sept 1979) 4 figs, 9 tables, 6 refs

Key Words: Plates, Rectangular plates, Variable cross section, Natural frequencies, Forced vibration

The title problem is solved assuming that the thickness varies symmetrically with respect to the x-axis. The edges are elastically restrained against rotation while the remaining edges are clamped or simply supported. Approximate expressions for four of the lower natural frequencies of vibration (including the fundamental) are given. A forced vibrations situation is also dealt with.

SHELLS

80-556

A Numerical Comparison with an Exact Solution for the Transient Response of a Cylinder Immersed in a Fluid

M.E. Giltrud and D.S. Lucas

Naval Surface Weapons Ctr., White Oak, Silver Spring, MD 20910, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 23-28 (Sept 1979) 5 figs, 12 refs

Key Words: Interaction: structure-fluid, Cylindrical shells, Shells, Submerged structures, Transient response

The transient response of an elastic cylindrical shell immersed in an acoustic media that is engulfed by a plane wave is determined numerically. The method applies to the USA-STAGS code which utilizes the finite element method for the structural analysis and the Doubly Asymptotic Approximation (DAA) for the fluid-structure interaction. The calculations are compared to an exact analysis for two separate loading cases: a plane step wave and an exponentially decaying plane wave.

80-557

Vibration Damping Characteristics of a Thin Cylindrical Shell Stiffened with Viscoelastic Rings

H. Saito and H. Yamaguchi

Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan, Ing. Arch., 48 (5), pp 301-311 (1979) 6 figs, 14 refs

Key Words: Shells, Cylindrical shells, Stiffened shells, Vibration damping

The vibrations of a circular cylindrical shell reinforced with viscoelastic rings are theoretically treated. The frequency equation is derived using the transfer matrix together with the stiffness matrix. The numerical example surveys the damping effect of viscoelastic rings upon the dynamic behavior of the system.

PIPES AND TUBES

(Also see No. 650)

80-558

Acoustic Pulsations and Vibratory Stresses in Heat Exchangers

A. Jaudet and D. Huetzler

British Library Lending Div., Boston Spa, UK, Rept. No. BLL-Windscale-657-(9091.9F), 27 pp (1978) N79-29455

Key Words: Heat exchangers, Acoustic excitation, Resonant response

The flow of a heat-bearing fluid in a heat exchanger causes the loosening of nonstreamlined obstacles which it encounters. The effect is simultaneous production of a mechanical excitation of these obstacles and generation of fluctuations of pressure downstream from them.

DUCTS

(Also see No. 507)

80-559

Three-Dimensional Acoustic Waves Propagating in Acoustically Lined Cylindrically Curved Ducts without Fluid Flow

S.-H. Ko

New London Lab., Naval Underwater Systems Ctr., New London, CT 06320, J. Sound Vib., 66 (2), pp 165-179 (Sept 22, 1979) 10 figs, 2 tables, 8 refs

Key Words: Ducts, Acoustic linings, Sound waves, Wave propagation, Sound attenuation, Computer programs

A theoretical study is made of three-dimensional waves propagating in acoustically lined curved ducts in the absence of fluid flow. The acoustic lining considered here is a fibrous sheet mounted on a locally reacting core with impervious backing. The eigenvalue equations in both radial and axial directions are derived by matching the normal component of the particle displacement and the acoustic pressure on the acoustic lining surface. For a given duct geometry and known acoustic lining admittance, a computer program is developed to solve for the eigenvalues and to obtain the sound attenuation of the propagating waves in the lined curved duct. The sound attenuation is calculated by using the acoustic energy expression for the waves propagating in a curved duct with rectangular cross-section.

BUILDING COMPONENTS

80-560

Wind Loading Failures of Corrugated Roof Cladding

V.R. Beck and L.K. Stevens

Experimental Bldg. Station, Dept. of Housing and

Construction, Sydney, Australia, Instn. Engr., Austral., C.E. Trans., CE21 (1), pp 45-56 (1979) 6 figs, 6 tables, 24 refs

Key Words: Roofs, Wind-induced excitation, Fatigue life

A variable-amplitude loading distribution is developed and applied to a two-span laboratory model of screw-fixed corrugated roof-cladding to investigate possible fatigue damage caused by wind loading.

ELECTRIC COMPONENTS

CONTROLS (SWITCHES, CIRCUIT BREAKERS)

80-561
Shock Performance of a Shipboard Electrical Switchgear
E.W. Clements
Towson Labs., Inc., Baltimore, MD, Rept. No. NRL-MR-4003, 112 pp (June 15, 1979)
AD-A070 785/1GA

Key Words: Shipboard equipment response, Shock tests

In the study described here, a total of 27 AQB circuit breakers were tested on the LWSM (Lightweight Shock Machine), their performance notes and the shock environments to which they were exposed measured. The same breakers were then installed in a typical shipboard switchgear which was tested on the MWSM (Mediumweight Shock Machine), and again the performance of the breakers noted and their shock environments measured.

TRANSFORMERS
(See No. 658)

ELECTRONIC COMPONENTS
(Also see No. 500)

80-562
Predicting Dynamic Performance Limits for Servosystems with Saturating Nonlinearities
J.A. Webb, Jr. and R.A. Blech
NASA Lewis Research Ctr., Cleveland, OH, Rept. No. NASA-TP-1488; E-9903, 52 pp (July 1979)
N79-28186

Key Words: Servomechanisms, Dynamic properties

A generalized treatment for a system with a single saturating nonlinearity is presented and compared with frequency response plots obtained from an analog model of the system. Once the amplitude dynamics are predicted with the limit lines, an iterative technique is employed to determine the system phase response. The saturation limit line technique is used in conjunction with velocity and acceleration limits to predict the performance of an electro-hydraulic servosystem containing a single-stage servovalve. Good agreement was obtained between predicted performance and experimental data.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION
(Also see Nos. 420, 425, 456, 457, 464, 474, 478, 479, 480, 481, 482, 483, 489, 490, 558, 559, 575, 610, 611, 612, 616, 618, 619, 620, 621, 627, 628, 659)

80-563
Experimental Superposition of Acoustic Fields for Detection Performance Studies
J.A. Shooter and M.L. Gentry, Jr.
Applied Research Labs., Texas Univ. at Austin, TX, Rept. No. ARL-TM-79-3, 34 pp (Mar 15, 1979)
AD-A070 963/4GA

Key Words: Acoustic detection

The concept of superimposing a target acoustic field onto an independent noise acoustic field is discussed and sample results are presented using data from the deep Atlantic Ocean. The purpose is to explore the principles and methods of how this concept can be implemented for assessing signal detection in the presence of noise as applied to particular systems.

80-564

Reflection of a Plane Impulsive Acoustic Pressure Wave by a Rigid Sphere

M. Auphan and J. Matthys

Laboratoire d'Electronique et de Physique Appliquee, 3, Avenue Descartes BP 15, F-94450 Limeil-Brevannes, France, J. Sound Vib., 66 (2), pp 227-237 (Sept 22, 1979) 3 tables, 12 refs

Key Words: Elastic waves, Wave reflection, Spheres

The reflection of a plane impulsive acoustic pressure wave by a rigid sphere is studied in terms of distributions. The result is a formulation ideally suited for practical applications involving convolutions with arbitrary wave shapes.

80-565

The Matched Asymptotic Expansion (MAE) Technique Applied to Acoustic Radiation From Vibrating Surfaces

M. Pierucci

Electric Boat Div., General Dynamics, Groton, CT 06340, J. Sound Vib., 66 (2), pp 199-217 (Sept 22, 1979) 14 figs, 12 refs

Key Words: Elastic waves, Vibrating structures, Matched Asymptotic Expansion Technique, Underwater sound

The purpose of this paper is to very briefly review the MAE technique as applied to low frequency acoustics in general, and then apply the resulting approach to a series of progressively more difficult problems which are of interest to many underwater acousticians. The analysis is applied to two problems with single degrees of freedom for structural vibrations: a sphere, both velocity and force driven; and a circular piston in infinite rigid baffle. These are classical problems and the solutions as obtained by the MAE technique are then compared to the exact classical solutions.

80-566

An Approach to Controlling Noise of Production Machinery Developed from Noise Control of Products

M.F. Russell

Lucas Industries Noise Centre, Lucas CAV Ltd., P.O. Box 36, Warple Way, London WE 7SS, UK, Noise Control Engrg., 13 (2), pp 53-62 (Sept/Oct 1979) 13 figs, 8 refs

Key Words: Noise reduction, Machinery noise, Industrial facilities

How technology developed for controlling noise from products is being applied to production machinery is demonstrated.

80-567

Prediction Versus Reality: A Preliminary Evaluation of the NRC Traffic Noise Model

R.E. Halliwell and J.D. Quirt

Div. of Bldg. Res., National Research Council of Canada, Ottawa, Ontario K1A OR6, Canada, Noise Control Engrg., 13 (2), pp 76-82 (Sept/Oct 1979) 12 figs, 6 refs

Key Words: Traffic noise, Noise measurement, Measurement techniques, Noise barriers

A program of field measurements that has been initiated to evaluate the validity of the road noise prediction model developed by the National Research Council of Canada is discussed.

80-568

The Effect of Skewness and Standard Deviation on Sampling Errors for Traffic Noise

J.S. Bradley, J.G. Vaskor, and S.M. Dickinson

Faculty of Engrg. Science, The Univ. of Western Ontario, London, Ontario, Canada, Appl. Acoust., 12 (5), pp 397-409 (Sept 1979) 8 figs, 7 refs

Key Words: Traffic noise, Statistical analysis, Digital techniques, Error analysis

An empirical investigation of the influence of standard deviation and skewness of traffic noise climates upon the errors introduced into seven statistical noise descriptors by different digital sampling rates is reported. A total of 432 hours of digitally recorded traffic noise, representing a wide range of traffic flow conditions, is used in the study, the digital sampling being simulated by appropriate deletion of data during the computation of the statistical descriptors.

80-569
Unstable Resonators with Slightly Misaligned Mirrors
C. Santana and L.B. Felsen
Instituto de Pesquisas Espaciais, Sao Jose dos Campos, Brazil, Rept. No. INPE-1414-RPE/002, 11 pp (Jan 1979)
N79-28384

Key Words: Resonators, Alignment

Very small misalignments in unstable strip resonators may cause detachment of the low-loss eigenmode at lower equivalent Fresnel number, and introduce different periodicities into the eigenvalue curves. Using the resonance equation derived previously from the waveguide mode theory, this behavior is explained in physical terms. A simplified explicit equation for the eigenvalue of the detached mode is derived.

80-570
Levels of Structure-Borne and Air-Borne Sound and Sound Insulation of Technical Appliances in Buildings (Korperschallpegel, Luftschallpegel und Schalldammung haustechnischer Anlagen)
W. Kuhl
Am Reisenbrook 7a, D-2000, Hamburg 67, Germany, Acustica, 43 (1), pp 32-44 (Aug 1979) 24 figs, 1 table, 21 refs
(In German)

Key Words: Buildings, Acoustic absorption, Acoustic insulation

The preparation in planning, especially that of the single or double grade of structure-borne sound insulation is illustrated by means of practical examples. Structure- and air-borne sound from ten kinds of technical appliances in buildings are considered.

SHOCK EXCITATION

(Also see Nos. 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 454, 465, 468, 469, 470, 471, 472, 473, 492, 535, 545, 552, 553, 554, 622, 623, 625, 646)

80-571
Development of Random Choice Numerical Methods for Blast Wave Problems
H.M. Glaz
Naval Surface Weapons Ctr., White Oak Lab., Silver Spring, MD, Rept. No. NSWC/WOL/TR-78-211, 45 pp (Mar 7, 1979)
AD-A071 156/4GA

Key Words: Shock wave propagation, Numerical analysis

This report contains an outline of Glimm's method for solving hyperbolic systems of conservation laws, a discussion of the published numerical tests of the method, and some new numerical test results. The latter are one-dimensional models of the effects seen in blast wave propagation. The application of Glimm's method to explosion problems is studied. An appendix is included to indicate how the method can be applied to problems involving a nonideal equation of state.

80-572
Dynamic Modeling of Post Failure Conditions of Reinforced Concrete Subjected to Blast
M.F. Leondi
Large Caliber Weapon Systems Lab., Army Armament Res. & Dev. Command, Dover, NJ, Rept. No. ARLCD-MR-78007, AD-E400 305, 18 pp (Mar 1979)
AD-A070 734/9GA

Key Words: Reinforced concrete, Blast loads, Mathematical models

A dynamic modeling analysis of post-failure fragments of reinforced concrete subjected to blast overpressures is performed. The analysis relates the physical (constitutive) properties as well as the geometric relationships of the model and the prototype.

80-573
Failure Criteria for Reinforced Concrete Structures. Volume II. Analytical Model and Response Data
R.W. Litton and J.M. Gidwani
PMB Systems Engrg., Inc., San Francisco, CA, Rept. No. AFWL-TR-77-239-VOL-2, 267 pp (May 1979)
AD-A070 644/0GA

Key Words: Structural components, Reinforced concrete, Blast loads, Failure analysis, Finite element technique, Mathematical models

Failure criteria defining complete loss of section strength for reinforced concrete sections are defined in this Volume II of the report. Failure envelopes obtained from a three-dimensional finite element analysis with a three dimensional nonlinear constitutive material model are presented in terms of deformations for various rectangular and cylindrical sections. Applications and examples of the use of these failure envelopes are also presented.

80-574

On the Growth and Decay of Acceleration Waves in Transient Gas Flows with Vibrational Relaxation

R. Ram and B.D. Pandey

Applied Math. Section, Inst. of Tech., Banaras Hindu Univ., Varanasi, India, Acta Mech., 33 (3), pp 171-178 (1979) 4 figs, 8 refs

Key Words: Shock wave propagation

The problem of breakdown of acceleration waves in the neighborhood of the leading frozen characteristics in transient gas flows with vibrational relaxation is studied. The critical time is determined when the breakdown of the wave will occur at the cusp of the envelope of the intersecting forward characteristics.

80-575

The Region of Nonlinear Effects for Intensive Sound Pulses in the Ocean

V.E. Fridman

Radiophysical Research Inst., Gorky, USSR, Wave Motion, 1 (4), pp 271-277 (Oct 1979) 4 figs, 16 refs

Key Words: Shock waves, Underwater sound

The formation of a stationary shock wave is studied in media with an arbitrary power dependence of the damping coefficient on the frequency. The conditions for existence of a stationary shock wave are defined. For acoustic waves generated by explosive sources a calculation is given of the location of the transition point of the nonlinear wave into a linear one, and the dependence of this point on the charge weight is defined.

80-576

Shockwave and Boundary Layer Interaction in the Presence of an Expansion Corner

Y.T. Chew

Univ. of Singapore, Singapore, Aeronaut. Quart., 30 (3), pp 506-527 (Aug 1979) 9 figs, 10 refs

Key Words: Shock wave propagation, Jet engines, Intake systems

An investigation is carried out to examine one aspect of supersonic jet-engine inlet flow, namely shock-wave and boundary-layer interaction in the presence of an expansion corner. The experiment is undertaken at Mach numbers of 1.8 and 2.5.

80-577

Shock-Wave Oscillations in a Transonic Diffuser Flow

C.P. Chen, M. Sajben, and J.C. Kroutil

McDonnell Douglas Corp., St. Louis, MO, AIAA J., 17 (10), pp 1076-1083 (Oct 1979) 14 figs, 1 table, 10 refs

Key Words: Shock wave propagation, Oscillation

Low-frequency, self-excited oscillations involving a normal shock wave and the subsonic flow behind it are investigated experimentally in a two-dimensional diffuser. The preshock supersonic flow is uniform and steady, and the exit pressure is constant. Static wall pressure fluctuations at numerous streamwise locations are recorded and analyzed statistically for flow conditions ranging from subsonic to a shock Mach number of 1.38. Root-mean-square fluctuation intensities, power spectra, and space-time correlation maps are computed.

80-578

Attitude of a Straight Shock Impinging on a Slightly Wavy Contact Surface (Das Verhalten eines geraden Verdichtungsstosses beim Auftreffen auf eine leicht gewellte Kontaktunstetigkeit)

H. Schilling

Institut f. Mechanik der Technischen Hochschule, Hochschulstrasse 1, 6100 Darmstadt, Z. Flugwiss, 3 (4), pp 234-240 (1979) 9 figs, 8 refs

(In German)

Key Words: Shock wave propagation, Wave propagation

The question of what happens when a straight, plane shock wave impinges normally on the slightly wavy contact surface between two perfect gases is discussed. Expressions are derived for the resulting pressure disturbances, for the decay

of the disturbances at the shock fronts (i.e. the deviations from the straight shock forms), and for the movement of the contact surface. The case of very weak shocks and the case of no shock reflection are treated.

80-579

Shock Spectra Design Methods for Equipment-Structure Systems

J.M. Kelly and J.L. Sackman
Dept. of Civil Engrg., Div. of Structural Engrg. & Structural Mechanics, Univ. of California, Berkeley, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 171-176 (Sept 1979) 2 figs, 2 refs

Key Words: Equipment response, Ground motion, Shock response spectra

An analytical method is developed whereby a simple estimate can be obtained of the maximum dynamic response of light equipment attached to a structure subjected to ground motion. The approach is based on the transient analysis of tuned or slightly detuned equipment-structure systems in which the mass of the equipment is much smaller than that of the structure. The results obtained are simple estimates of the maximum acceleration and displacement of the equipment. The method can also be used to treat closely spaced modes in structural systems, where the square root of the sum of the squares is known to be invalid.

80-580

Failure of Underground Concrete Structures Subjected to Blast Loadings

C.A. Ross, P.T. Nash, and G.R. Griner
USAF Armament Lab., Eglin AFB, FL 32542, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 1-9 (Sept 1979) 13 figs, 1 table, 6 refs

Key Words: Blast resistant construction, Reinforced concrete, Failure analysis

[illegible] study presents the results of analytical predictions of [illegible] and failure of two-edges-free reinforced concrete [illegible] intermediate blast loadings. Approximate [illegible] stationary and moving plastic [illegible] varying and time dependent [illegible] agreement between [illegible]

80-581

Optimization of Reinforced Concrete Slabs

J.M. Ferritto
Civil Engrg. Lab., Naval Construction Battalion Ctr., Port Hueneme, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 3, pp 11-22 (Sept 1979) 7 figs, 1 table, 8 refs

Key Words: Containment structures, Reinforced concrete, Blast resistant construction, Design techniques

An automated design procedure is discussed which considers the dynamic nonlinear behavior of the reinforced concrete of arbitrary geometrical and structural configuration subjected to dynamic pressure loading. Optimum design of the slab is accomplished by use of an interior penalty function. The paper discusses the optimization procedure and a discussion of the results is given. The results are compared with finite element analysis.

80-582

Engine Rotor Burst Containment/Control Studies

E.A. Witmer, T.R. Stagliano, and J.J.A. Rodal
Dept. of Aeronautics & Astronautics, Massachusetts Inst. of Tech., Cambridge, MA, In: AGARD Stresses, Vibrations, Struc. Integration and Eng. Integrity (including Aeroelasticity & Flutter), 30 pp (Apr 1979)
N79-27162

Key Words: Engine rotors, Containment structures

Investigations on the impact-interaction of both complex engine rotor fragments and simple fragments with various types of single-layer and multilayer containment structures are reviewed. The resulting data are used to develop empirical design rules and to evaluate proposed theoretical methods for predicting the impact induced responses of containment structures. Examples of typical numerical methods for predicting the large deflection, elastic-plastic transient structural responses of simple two dimensional and three dimensional containment shields are illustrated.

80-583

Effects of Soil-Structure Interaction on Seismic Response of a Steel Gravity Platform

A.S. Veletsos and I.B. Boaz
Dept. of Civil Engrg., Rice Univ., Houston, TX 77001

J. Energy Resources Tech., Trans. ASME, 101 (3), pp 171-181 (Sept 1979) 12 figs, 6 tables, 13 refs

Key Words: Interaction: soil-structure, Seismic response, Elastic foundations, Structural response

After a brief review of the principal effects of soil-structure interaction on the response of structures subjected to earthquakes, a simple practical procedure is presented for evaluating these effects. The procedure is next applied to a study of the response of a proposed 400-ft steel gravity platform in 300-ft water depth, and the results of the study are discussed. The structure investigated consists of three large-diameter legs of tubular construction interconnected by a truss-type bracing system and supported on three circular pads.

80-584

Dynamic Stiffness Matrices for Viscoelastic Half Planes

G. Dasgupta and A.K. Chopra

Dept. of Civil Engrg. & Engrg. Mech., Columbia Univ., New York, NY, ASCE J. Engr. Mech. Div., 105 (EM5), pp 729-745 (Oct 1979) 13 figs, 15 refs

Key Words: Interaction: soil-structure, Seismic response

Analytical expressions and numerical results are presented for the complex-valued, dynamic (frequency dependent), flexibility influence coefficients for a homogeneous, isotropic, linearly viscoelastic half space in plane strain or generalized plane stress. These influence coefficients, defined for uniformly spaced nodal points at the surface of the half plane, are obtained from solutions of two boundary value problems, associated with harmonically time-varying stresses uniformly distributed between two adjacent nodal points. Numerical values for these coefficients are presented for a viscoelastic half plane of constant hysteretic material. A method is developed to determine from these results the dynamic stiffness matrix, associated with the nodal points at the base of a surface supported structure, for the half plane.

80-585

Empirical Procedures for Estimating Recoilless Rifle Breech Blast Overpressures

P.S. Westine and R.E. Ricker

Southwest Research Inst., San Antonio, TX, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 109-125 (Sept 1979) 10 figs, 4 tables, 17 refs

Key Words: Gunfire effects

This paper presents an empirical equation for predicting breech blast overpressures aft of any recoilless rifle. Model theory and past scaling efforts for closed breech guns form a basis upon which this new solution is founded. The solution can also be extended for predicting blast pressure fields behind rocket motors.

80-586

High and Low Rate Force - Deformation Characteristics of Motorcycle Helmets

H.B. Kingsbury, W.C. Herrick, and D. Mohan

Dept. of Mech. and Aerospace Engrg., Univ. of Delaware, Newmark, DE, SAE Paper No. 790324, 16 pp, 25 figs, 2 tables, 9 refs

Key Words: Helmets, Dynamic tests

The load-displacement characteristics of fifteen motorcycle helmets were determined at displacement rates from quasi-static to 5M/S. Seven of these helmets had polycarbonate outer shells while the remaining shells were of fiberglass construction. Use of these data to predict helmeted head force and acceleration after impact with a rigid surface is illustrated using a mathematical model.

80-587

An Experimental Design for Total Container Impact Response Modeling at Extreme Temperatures

V.P. Kobler, R.M. Wyskida, and J.D. Johannes

U.S. Army Missile Res. & Dev. Command, Huntsville, AL 35809, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 101-107 (Sept 1979) 7 figs, 7 refs

Key Words: Packaging materials, Impact response (mechanical), Thermal excitation

An experimental design is developed to identify the actual effect of the outside container upon shock attenuation involving the protected item.

80-588

A Simplified Method of Evaluating the Stress Wave Environment of Internal Equipment

J.D. Colton and T.P. Desmond

SRI International, Menlo Park, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 89-96 (Sept 1979) 6 figs, 3 refs

Key Words: Equipment response, Stress waves, Impact response (mechanical)

A simplified method called the Transfer Function Technique (TFT) has been devised for evaluating the stress wave environment in a structure containing internal equipment. As a basis for evaluating the TFT, impact experiments and detailed stress wave analyses are performed for structures with two or three, or more members.

VIBRATION EXCITATION

80-589

On Determining the Number of Dominant Modes in Sinusoidal Structural Response

W.L. Hallauer, Jr. and A. Franck

Dept. of Aerospace & Ocean Engrg., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, Shock Vib. Bull., U.S. Naval Res. Lab., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 19-34 (Sept 1979) 12 figs, 2 tables, 10 refs

Key Words: Periodic response, Modal analysis

This paper addresses the problem of using structural dynamic transfer function data to determine the number of vibration modes dominant in response at a given frequency. Two relatively simple methods which have been used previously are reviewed, and a more effective new method, called the vector-fit method, is described in detail. Applications of these methods are given with the use of numerically simulated transfer function data.

80-590

Transition Through Resonance of a Duffing Oscillator

I.R. Collinge and J.R. Ockendon

Hunting Engrg. Ltd., Ampthill, Bedford, MK45 2HD, UK, SIAM J. Appl. Math., 37 (2), pp 350-357 (Oct 1979) 4 figs, 8 refs

Key Words: Resonance pass through, Oscillators

This note describes the transition through resonance of a weakly nonlinear oscillator. The oscillator is described by Duffing's equation and the forcing frequency varies very slowly in the neighborhood of the natural frequency of the linearized equation.

80-591

A Resonant Response to Random Excitation

H. Kurss and W. Vojir

Dept. of Mathematics, Adelphi Univ., Garden City, L.I., NY 11530, SIAM J. Appl. Math., 37 (2), pp 382-395 (Oct 1979) 8 refs

Key Words: Resonant response, Random excitation

This article discusses a resonant response to random excitation.

80-592

Development of Stability Methods for Application to Nonlinear Aeroelastic Optimization

R.F. Taylor

Ph.D. Thesis, Univ. of Dayton, 192 pp (1979)
UM 7925694

Key Words: Airfoils, Panels, Flutter, Stability methods, Aerodynamic loads

An approximate procedure is developed which determines efficiently and accurately the amplitude-dependent stability of nonlinear systems. This new procedure is referred to as the "method of imposed disturbances." Emphasis is placed on airfoil and panel flutter instabilities in aerodynamically nonlinear flow. To develop the theory, a modified form of the van der Pol oscillator equation and of the Lewis servomechanism equation are studied. Based on the principle of conservation of energy in a limit cycle, approximate closed-form expressions are developed which relate the loading and the limit amplitude to system design variables. Results are compared to solutions obtained by numerical integration.

80-593

Footfall-Induced Vibrations of Floors Supporting Sensitive Equipment

E.E. Ungar and R.W. White

Bolt Beranek and Newman, Inc., Cambridge, MA, S/V, Sound Vib., 13 (10), pp 10-13 (Oct 1979) 10 figs, 4 refs

Key Words: Floors, Vibration excitation, Equipment response

An approach is described for obtaining vibration criteria for sensitive equipment by observing its performance in the presence of floor vibrations due to intense footfall excitation. A method is presented for estimation of the salient parameters of footfall impacts and of the corresponding floor vibrations.

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 427, 513, 529, 617, 657)

80-594

A Stability Theorem for a Dynamically Loaded Linear Viscoelastic Structure

D.W. Nicholson

Naval Surface Weapons Ctr., White Oak, Silver Spring, MD 20910, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 203-208 (Sept 1979) 8 refs

Key Words: Stability, Damped structures, Viscoelastic damping

The response of a linear viscoelastic structure to a dynamic load is considered. For the finite element equation of dynamic equilibrium a representation of the solution is derived using the exponential matrix function, and this representation permits application of the highly efficient method of Gaussian quadrature.

80-595

The Effects of Frequency, Amplitude and Load on the Dynamic Properties of Elastomers

J.E. Cole, III

Cambridge Acoustical Associates, Inc., 1033 Massachusetts Ave., Cambridge, MA 02138, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49., Pt. 2, pp 105-118 (Sept 1979) 6 figs, 30 refs

Key Words: Elastomers, Vibration isolators, Dynamic properties

The dynamic-mechanical properties of elastomers depend upon the nature of the loading of the material. These properties vary significantly with other aspects of the loading such as strain amplitude and static load. To a fair degree of approximation the effects of frequency and strain amplitude are separable. The effects of hydrostatic loading are weakly coupled with frequency. The implications of these results on designs using elastomers are discussed.

80-596

The Analysis of Engine Vibrations (Analyse Des Vibrations De Moteur)

M. Lalanne, P. Trompette, R. Henry, and G. Ferraris

Lab. de Mechanique des Structures, Institut National des Sciences Appliquees de Lyon, Villeurbanne, France, In: AGARD Stresses, Vibrations, Struc. Integration & Eng. Integrity (including Aeroelasticity & Flutter), 13 pp (Apr 1979)

(In French)

N79-27150

Key Words: Engine vibrations, Vibration damping, Material damping, Finite element technique

The calculation of thick and thin blades, of axisymmetric systems in rotation, and of disk-blade assemblies is reviewed. The calculation of these types of damped structures is outlined; the finite element method is used. The diverse types of calculations performed in the study of frequencies and modes, and in predicting the damping introduced by the addition of materials, are illustrated by applications to the motor elements.

80-597

A Generalized Derivative Model for an Elastomer Damper

R.L. Bagley and P.J. Torvik

Air Force Inst. of Tech., Wright-Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 135-143 (Sept 1979) 4 figs, 19 refs

Key Words: Dampers, Elastomeric damping, Elastomers, Constitutive equations

A generalized derivative (fractional order) is used to construct a dynamic stress-strain constitutive relation for the elastomer 3M-467. The desirable features of this constitutive relation are demonstrated and the constitutive relation is used to determine vibration time histories of a single degree of freedom oscillator having an elastomer damper.

80-598

An Investigation of Vibration Dampers in Gas-Turbine Engines

R. Holmes and B. Humes

Sussex Univ., Brighton, UK, In: AGARD Stresses, Vibrations, Struc. Integration and Engr. Integrity (including Aeroelasticity & Flutter), 10 pp (Apr 1979) N79-27164

Key Words: Vibration dampers, Fluid-film bearings, Gas turbine engines

The feasibility of using the squeeze-film both as a damper and a load bearing member is investigated. Equations are presented for predicting the vibration amplitude and the force transmitted to the engine frame when the squeeze-film is used for damping.

80-599

Designing with Damping Materials to Reduce Noise and Structural Fatigue

E.J. O'Keefe

Specialty Composites Corp., Newark, DE, SAE Paper No. 790631, 16 pp, 12 figs, 9 refs

Key Words: Damping, Layered damping, Noise reduction, Vibration control, Aircraft

This paper describes some of the steps necessary in damping design for constrained layer dampers. Also presented are a few case histories where damping has been successfully used to minimize resonant noise and vibration problems.

80-600

Vibration Control Using Additive Damping and FFT Analysis

J.P. Henderson and M.L. Drake

Air Force Materials Lab., SAE Paper No. 790220, 16 pp, 22 figs, 14 refs

Key Words: Damping, Viscoelastic damping, Fast Fourier Transform

This paper discusses the use of FFT analysis in the design of damping applications for eliminating resonant high cycle fatigue in specific lightweight structural components.

80-601

Choice of Thickness Ratio of a Coated Beam Used for Investigating the Complex Modulus of Viscoelastic Materials

T. Pritz

Central Res. and Design Inst. for Silicate Industry, 1034 Budapest, Becsi ut 126/128, Hungary, J. Sound Vib., 66 (2), pp 155-164 (Sept 22, 1979) 5 figs, 1 table, 8 refs

Key Words: Viscoelastic damping, Coated beam method, Testing techniques

In this paper a procedure is described for finding the ratio of coating thickness to metal thickness required to obtain accurate results for the complex modulus in such investigations. The contradiction experienced earlier - that a relatively large thickness ratio is required for precision while the nature of the resonance method is such as to demand a small one - is analyzed mathematically. The relationships derived serve as a basis for optimizing the choice of the ratio. Diagrams and a procedure for this are worked out and presented. Finally, a few experimental results obtained with suitable and unsuitable thickness ratios are discussed.

FATIGUE

(Also see Nos. 431, 467, 475, 509, 516, 536, 537, 560)

80-602

Fatigue Strength in Heavy Machine Construction: Assumptions - Requirements - Objectives

D. Hanewinckel

Stahlwerke Peine - Salzgitter AG, Salzgitter, Germany, Intl. J. Fatigue, 1 (4), pp 191-194 (Oct 1979) 2 figs, 8 refs

Key Words: Fatigue life, Machinery

The fatigue strength in heavy machine construction is discussed and suggestions are made for future improvement.

80-603

Repeated Plastic Deformation as a Cause of Mechanical Surface Damage in Fatigue, Wear, Fretting-Fatigue and Rolling Fatigue

W. Barrois

Air Armament, French Air Force, 42 rue Larmeroux, 92170 Vanves, France, Intl. J. Fatigue, 1 (4), pp 167-189 (Oct 1979) 25 figs, 80 refs

Key Words: Fatigue life, Machinery, Crack propagation

This paper discusses repeated plastic deformation as a cause of mechanical surface damage in fatigue, wear, fretting-fatigue, and rolling fatigue.

80-604

Flight Simulation Fatigue Crack Propagation in 7010 and 7075 Aluminum Plate

R.J.H. Wanhill, W.G.J. 't Hart, and L. Schra
National Aerospace Lab., P.O. Box 90502, 1006 BM Amsterdam, The Netherlands, Intl. J. Fatigue, 1 (4), pp 205-209 (Oct 1979) 7 figs, 14 refs

Key Words: Fatigue life, Crack propagation

The fatigue crack propagation resistances of 7010-T7651, 7010-T73651, and 7075-T7351 thick plate are compared for flight simulation (gust spectrum) loading conditions.

80-605

Fatigue Crack Propagation in Aluminum Alloy NP8 Determined From Tests on 12.5 mm Nominal Thickness Specimens

A. Storey
Dept. of Mech. Engrg. & Materials Technology, Newcastle upon Tyne Polytechnic, UK, Intl. J. Fatigue, 1 (4), pp 195-204 (Oct 1979) 10 figs, 8 tables, 10 refs

Key Words: Fatigue life, Crack propagation

Fatigue crack growth tests are carried out on aluminium alloy BS1477 NP8 which has a 0.1% proof stress of 120 MN/m^2. The tests are performed in air at room temperature using center-crack fracture toughness specimens of 12.5 mm nominal thickness.

80-606

Reliability and Structural Fatigue in One-Crack Models

D.G. Ford
Aeronautical Research Labs., Melbourne, Australia, Rept. No. ARL/Struc Rept 369, AR 001 285 [illegible] (July 1978)
N79-29545

Key Words: Fatigue life, Reliability

A structural fatigue model that allows for attrition due to collapse, war damage, hijacking, etc. in one-crack structure is presented. Attrition adds a single term to the Fokker Planck equation.

80-607

Fretting Fatigue, with Reference to Aircraft Structures

J.A. Alic and A. Kantimathi
Office of Technology Assessment, Washington, D.C., SAE Paper No. 790612, 16 pp, 11 figs, 43 refs

Key Words: Fatigue life, Aircraft, Experimental data

Present knowledge concerning the mechanisms of fretting fatigue is reviewed, with particular attention to the following factors: stresses at and near the contracting surfaces; location of crack initiation sites with respect to regions of highest surface stress and the slip-nonslip boundary; contributions of surface damage to crack initiation; propagation of micro-cracks initiated by fretting; the effects of mean stress; and fretting fatigue under variable amplitude loading.

80-608

Computing the Fatigue Strength and Field Life of Shovel Loader Axle Shafts Using Finite Elements

N. Slack
SAE Paper No. 790854, 12 pp, 16 figs, 2 tables, 5 refs

Key Words: Fatigue life, Shafts, Finite element technique

Design analysis of earth moving equipment has been used extensively in recent years. This increased utilization has focused on finite element analysis methods. This paper presents a method for accumulating, analyzing, and interpreting data for effectively meeting design strength analysis needs. This method is used in an example involving a shovel loader axle. Internal stresses at weld interfaces and the stress concentration at notches are presented.

[illegible]
[illegible] Prediction for Step-Stress Fa-tigue [illegible] Random Stress

[illegible] Utica,
[illegible] Naval Res. Lab.
[illegible] 1979) 11 figs,

Key Words: Fatigue [illegible] Failure analysis

A previously proposed cumulative fatigue damage law is extended to predict the probability of failure or fatigue life for structural materials with S-N fatigue curves represented as a scatterband of failure points. The proposed law applies to structures subjected to sinusoidal or random stresses and includes the effect of initial crack (i.e., flaw) sizes.

ELASTICITY AND PLASTICITY

(See No. 629)

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see Nos. 483, 567, 601)

80-610
Sampling Errors in Near Field Measurements on Non-Planar Surfaces
M.J. Earwicker
Admiralty Underwater Weapons Establishment, HM Naval Base, Portland DT5 2JS, UK, J. Sound Vib., 66 (2), pp 255-264 (Sept 22, 1979) 10 figs, 5 refs

Key Words: Vibration measurement, Measurement techniques, Elastic waves, Vibrating structures

The effects of spatial sampling and measurement errors on the calculated radiated field have been investigated by several authors for planar measurement surfaces. In this paper an extension of these analyses to non-planar surfaces is presented. Examples of the application of the new sampling criteria and error calculations are shown for a cylindrical near field measurement surface.

80-611
Aircraft Noise Monitoring - Instrumentation Concepts
J.K. Nestun
Norwegian Electronics, Noise Control Vib. Isolation, 10 (7), pp 288-294 (Aug/Sept 1979) 14 figs

Key Words: Aircraft noise, Noise meters

The purpose of this article is to discuss various requirements to noise monitoring systems with respect to flexibility, reliability, and operation.

80-612
Low Cost Environmental Noise Monitoring Installation
I. Campbell
Computer Engineering Ltd., Noise Control Vib. Isolation, 10 (7), pp 275-277 (Aug/Sept 1979) 3 figs

Key Words: Noise measurement, Test facilities, Noise meters

This article discusses low cost environmental noise monitoring installation in detail.

80-613
Dynamic Photoelastic Studies of Fracture
J.W. Dally
College of Engrg., Univ. of Rhode Island, Kingston, RI 02851, Exptl. Mech., 19 (10), pp 349-370 (Oct 1979) 15 figs, 1 table, 9 refs

Key Words: Photoelastic analysis, Fracture properties, Crack propagation

Dynamic characterization of brittle fracture is possible by relating the instantaneous stress-intensity factor K(t) to the velocity of propagation of the crack. High-speed photographic systems are employed with photoelastic methods to obtain a sequence of isochromatic-fringe patterns representing the state of stress associated with the propagating crack. Methods for determining K(t) from these isochromatic patterns are reviewed.

80-614
Pulsed Holographic Analysis of Large Vibrating Vehicle Components
G.R. Gerhart and G. Arutunian

Tank-Automotive R&D Command, Warren, MI, SAE Paper No. 790413, 12 pp, 11 figs, 3 refs

Key Words: Testing techniques, Holographic techniques, Ground vehicles

The recent development of pulsed ruby lasers with large energy outputs and long temporal coherence lengths has made the holographic analysis of large vehicle structures feasible and within the state-of-the-art.

80-615

Computer Assisted Data Reduction System

R.F. Bosmans

Mechanical Engrg. Services, Bently Nevada Corp., Minden, NV 89423, Machinery Vibrations III, Proc., Boxborough, MA, Sept 18-20, 1979, 8 pp, 4 figs Sponsored by the Vibration Inst., Clarendon Hills, IL

Key Words: Computer-aided techniques, Data processing, Graphic methods

This paper addresses the utilization of advanced micro-processor based systems to provide rapid, accurate reduction of dynamic data to hard copy graphical presentations. Justification of micro-processor systems is discussed along with a detailed description of the types of programming and graphical formats available. Several examples of graphical presentations of dynamic data are included to illustrate the various measurements and presentation techniques.

80-616

The Application of the Acoustic Telescope to Transportation Noise Measurement

A D Broadhurst and A.H.M. Martin

Dept of Engrg., University of Cambridge, UK, Acustica, 43 (1), pp 45-53 (Aug 1979) 29 figs, 5 refs

Key Words: Measurement techniques, Measuring instruments, Noise measurement, Traffic noise, High speed transportation systems, Railroad trains

A system capable of determining the spectral and spatial distribution of noise generated by modern jet engines, known as the Acoustic Telescope, is modified to study the noise of high speed trains. The telescope consists of an array of 14 microphones situated a short distance from the track, a 14 channel tape recorder and a computer with associated disc storage.

80-617

A Simple Low-Cost Technique for Measuring Material Damping Behavior

D.I.G. Jones

Air Force Materials Lab., Wright-Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 97-103 (Sept 1979) 16 figs, 2 tables, 7 refs

Key Words: Measurement techniques, Testing techniques, Elastomers, Damping values

This paper describes a simple test procedure in which a cylindrical specimen of damping material supporting an added mass is impacted by a small "hammer". The force transmitted through the specimen is measured by a force gage and the acceleration experienced by the hammer is measured by an accelerometer. The transient signals so generated are displayed on a storage oscilloscope, and the modulus and loss factor of the material are derived from comparisons with a simple transient analysis of a single degree of freedom system having a complex stiffness for the spring element. Examples and test data are discussed and comparisons are made with results of other methods of measurement.

80-618

The Variance of Decay Rates in Reverberation Rooms

J.L. Davy, I.P. Dunn, and P. Dubout

Div. of Bldg Research, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, Acustica, 43 (1), pp 12-25 (Aug 1979) 6 figs, 9 refs

Key Words: Measurement techniques, Noise measurement

This paper reports theoretical and experimental investigations of the variance of decay rates of interrupted noise bands in reverberation rooms. Two types of variance are examined: the variance between decay rates measured at the same microphone position and the variance between decay rates measured at different microphone positions. Theoretical formulae are developed for both types of variance.

80-619

The Curvature of Decay Records Measured in Reverberation Rooms

J.L. Davy, I.P. Dunn, and P. Dubout

Div. of Bldg. Research, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, Acustica, 43 (1), pp 26-31 (Aug 1979) 4 figs, 3 refs

Key Words: Measurement techniques, Noise measurement

This paper presents a quantitative examination of the curvature of reverberant decay records.

80-620
Piezoelectric Ultrasonic Transducers with Non-Directional Sound Radiation (Piezoelektrische Ultraschallsender mit ungebundelter Schallabstrahlung)
H. Kuttruff and K.M. Sung
Institut f. Technische Akustik der Rheinisch-Westfalischen Technischen Hochschule, Aachen, Germany, Acustica, 43 (2), pp 162-166 (Sept 1979) 8 figs, 3 refs
(In German)

Key Words: Transducers, Measuring instruments, Piezoelectric transducers

In this paper ultrasonic transducers which are composed of parallel stripes of piezoelectric material are described. The measured directional diagrams are compared to theoretical results.

80-621
A Fourier Theory of the Nonlinear Interaction of Acoustical Beams in Absorbing Fluid. The Special Case of Parametric Emission (Etude par une methode de Fourier de l'interaction non lineaire de deux rayonnements acoustiques dans un fluide absorbant. Cas particulier de l'emission parametrique)
P. Alais and P.Y. Hennion
Equipe de recherche associee au C.N.R.S., Acoustique et Informatique, Laboratoire de Mecanique Physique Universite Pierre et Marie Curie, 78210 - Saint Cyr l'Ecole, France, Acustica, 43 (1), pp 1-11 (Aug 1979) 7 figs, 12 refs
(In French)

Key Words: Noise measurement, Measurement techniques

The nonlinear weak interaction of two acoustical beams is studied using a Fourier analysis in plane modes. A full treatment of the nonlinear interaction of two such inhomogeneous modes is given as well for the near field as for the far field, with very few approximations; the particular case of the paraxial approximation is specially developed. These results are extended to the case of any primary beams which have to be defined by their angular spectrum. Numerical results are given for the parametric far field radiation of a plane circular piston and are compared with previous results.

DYNAMIC TESTS

(Also see Nos. 487, 520, 536, 561, 643)

80-622
Test Evaluation of Shock Buffering Concept for Hydrodynamic Ram Induced by Yawing Projectile Impacting a Simulated Integral Fuel Tank
P.H. Zabel
Southwest Research Inst., San Antonio, TX, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 141-170 (Sept 1979) 33 figs, 4 tables, 6 refs

Key Words: Dynamic tests, Projectile, Fuel tanks, Foams, Insulation

A concept for containing the shock inputs due to hydrodynamic ram caused by an impacting projectile within a fuel cell is discussed. This concept is to provide a buffering layer of foam, flexible, rigid or a combination thereof, which is sealed from a liquid. A program is described in which this buffering concept was tested. The effectiveness of a novel muzzle-mounted, "tumble", test device is shown.

80-623
High g Pyrotechnic Shock Simulation Using Metal-to-Metal Impact
M. Bai and W. Thatcher
Motorola Government Electronics Div., Scottsdale, AZ, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 1, pp 97-100 (Sept 1979) 9 figs

Key Words: Testing techniques, Pyrotechnic shock environment, Shock tests

This report presents a technique for simulating high g level pyrotechnic shocks, and the results of applying the technique to obtain the MIL-STD-1540A shock spectrum with a maximum acceleration of 18,000g at 2,000 Hz. Designing the resonant beam and plate on which the test unit is mounted, and generating a proper impulsive load on them, are the essentials of the technique. One dimensional stress wave and Euler equations are employed in the design. A metal pendulum hammer is used to generate the impulsive load.

80-624

The Need for a Force Measuring Dummy in Side Impact Testing

R.W. Lowne, S.P.F. Petty, J. Harris, and C.A. Hobbs
Transport and Road Research Lab., Dept. of the Environment, Dept. of Transport, Berkshire, UK, SAE Paper No 790750, 16 pp, 7 figs, 8 tables, 7 refs

Key Words: Testing techniques, Anthropomorphic dummies, Collision research (automotive)

This paper illustrates, from crash-injury studies, the types of injury seen in side impacts. The development of a special dummy designed to measure these forces in side impacts is described. T is dummy is calibrated against accident data and tentative ' uman tolerance limits are proposed.

80-625

A New Concept in Anthropomorphic Test Dummies for Lateral Impact

S.W. Alderson
Humanoid Systems, SAE Paper No. 790748, 12 pp, 8 figs, 3 refs

Key Words: Testing techniques, Anthropomorphic dummies, Collision research (automotive)

A preliminary study is reported here of new design principles which might lead to dummies which would provide more humanlike data for lateral crashes, while, at the same time maintaining a capability for use in frontal crashes. This concept is based upon the substitution of rubber shoulders for the rigid, articulated mechanical linkages which constitute the skeletal structures of present dummies. This concept includes the use of plastic bones and energy-absorbing flesh sections in the upper arms.

SCALING AND MODELING

80-626

Modeling Large Deformations Using Polycarbonate Scale Models

W.A. Elliott, D.E. Malen, and D.R. Whittaker
General Motors Corp., SAE Paper No. 790701, 12 pp, 18 figs, 7 refs

Key Words: Collision research (automotive), Scaling, Test models

This paper presents a method for modeling large deformations of structures using scale plastic models. The method is used to predict the dynamic barrier crash performance of a proposed vehicle structure with the aid of a computer simulation of the collision. The use of the technique can provide design direction in the early stages of the vehicle design process.

DIAGNOSTICS

(Also see No. 633)

80-627

Optimization of Certain Parameters of an Acoustic Monitoring System for Structures

D.P. Krasilnikov and V.V. Shemyakin
Addis Translations Intl., Portola Valley, CA, Rept. No. UCRL-Trans-11441; IAE-2948, 35 pp (Dec 1978)
N79-29557

Key Words: Acoustic emission, Diagnostic instrumentation

Problems related to acoustic emission testing are examined. These include the optimization of the amplitude threshold; the operating frequency of the receiving circuit; the radius of coverage of the surface monitored by a group of four transducers; and the base distance of the group of transducers from the standpoint of maximizing the probability that acoustic emission signals will be passed into the measuring and analyzing section of the system in the presence of fluctuation noise.

80-628

Signature Response for Friction and Wear

O.P. Gandhi and J.P. Sharma
Indian Inst. of Tech., New Delhi-110029, India, ASLE Trans., 22 (4), pp 365-368 (Oct 1979) 5 figs, 1 table, 11 refs

Key Words: Diagnostic techniques, Acoustic signatures, Friction, Wear

An experimental study of signature response for friction and wear is carried out in a triplane ball-on-peg machine under varying load conditions. Photographs of worn roller test specimens at critical temperatures are taken to determine the nature of the wear surface under boundary lubricated conditions.

80-629

An Inversion Integral for Crack-Scattering Data

J.D. Achenbach, K. Viswanathan, and A. Norris

The Technological Inst., Northwestern Univ., Evanston, IL 60201, Wave Motion, 1 (4), pp 299-316 (Oct 1979) 8 figs, 2 tables, 18 refs

Key Words: Elastic waves, Wave diffraction, Cracked media, Crack detection

The inverse problem of determining the size, shape and orientation of a flat crack from high-frequency far-field elastic waves scattered by the crack is investigated. Two kinds of inversion integrals are examined. The inversion problem becomes relatively simple if some a-priori information is available, either on the orientation of the plane of the crack or on a plane of symmetry. The method of inversion is verified for a flat crack of elliptical shape. Some computational technicalities are discussed, and the method is also applied to experimental scattering data.

BALANCING

80-630

Development of Flexible Rotor Balancing Criteria

W.W. Walter and N.F. Rieger

Rochester Inst. of Tech., Rochester, NY 14623, Rept. No. NASA-CR-159506, 112 pp (Mar 1979)

Key Words: Balancing techniques, Rotors, Flexible rotors

This report describes several studies in which analytical procedures are used to obtain balancing criteria for flexible rotors. General response data for a uniform rotor in damped flexible supports are first obtained for plain cylindrical bearings, tilting-pad bearings, axial groove bearings, and partial arc bearings. This data is the basis for the flexible rotor balance criteria presented herein. A procedure by which a practical rotor in bearings could be reduced to an equivalent uniform rotor is next developed and tested. The equivalent rotor procedure is then tested against six practical rotor configurations.

80-631

Industrial Balancing Machines

J.F.G. Wort

Bruel & Kjaer, Naerum, Denmark, S/V, Sound Vib., 13 (10), pp 14-19 (Oct 1979) 7 figs

Key Words: Balancing machines

Dynamic unbalance in rotating machinery is defined and related to machinery vibration. The design of balancing machines and their operating functions for the balancing of various types of rotating components are reviewed. Typical balancing systems are reviewed as well.

ANALYSIS AND DESIGN

ANALOGS AND ANALOG COMPUTATION

80-632

Numerical Simulation of Three-Dimensional Fluid-Structure Response

W.C. Rivard and M.D. Torrey

Los Alamos Scientific Lab., NM, Rept. No. LA-UR-78-3271, 18 pp (1979)

N79-29484

Key Words: Nuclear reactor components, Interaction: structure-fluid, Simulation

Three-dimensional, coupled, fluid-structure calculations are performed for the dynamics of the core support barrel in an HDR reactor vessel during blowdown. For these calculations the three-dimensional, two-fluid code K-FIX is coupled to the three-dimensional elastic shell code FLX. The coupling procedure is described, and conditions derived from truncation error and Fourier analysis are given for numerical stability of the separate and coupled finite difference solution algorithms.

80-633

Analog Double Integration of Shock Pulses

K. Peleg and R.A. Lund

School of Packaging, Michigan State Univ., East

Lansing, MI, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 209-217 (Sept 1979) 5 figs, 5 refs

Key Words: Diagnostic techniques, Shock tests, Analog techniques

An approach to acceleration transient analysis is described whereby a real-time double integrator circuit provides analog readout of velocity and displacement as well as acceleration. Absolute and relative velocity changes and displacements are obtained by means of consecutive integration of signals from acceleration transducers. Although an analog double integration circuit is featured in this work, the applications also apply to digital double integration.

ANALYTICAL METHODS

(Also see Nos. 415, 485, 488, 565)

80-634

Simulation of a Non-Stationary Stochastic Process with Respect to Its Power Spectral Density

J. Čačko and M. Bílý
Inst. of Machine Mechanics of the Slovak Academy of Sciences, 809 31 Bratislava, Czechoslovakia, J. Sound Vib., 66 (2), pp 277-284 (Sept 22, 1979) 1 fig, 6 refs

Key Words: Simulation, Stochastic processes, Power spectra, Spectral energy distribution

The paper presents a method of simulation of non-stationary stochastic processes, which is based on modeling of their time-dependent power spectral densities. Filtering of a non-stationary white noise through a conveniently selected linear dynamic system is used.

80-635

On the Construction of a Dynamical System from a Preassigned Family of Solutions

R. Broucke
Dept. of Aerospace Engrg. and Engrg. Mechanics, The Univ. of Texas at Austin, TX 78712, Intl. J. Engr. Sci., 17 (11), pp 1151-1162 (1979) 13 figs, 8 refs

Key Words: Dynamic systems, Oscillation

This article deals with the determination of the forces in a dynamical system, when the general form of the solution is given. This makes it possible to construct a system with a predetermined type of behavior. The method of constraints and Lagrange multipliers is used to derive the equation. The relation with some older results (Dainelli's formulas) is shown. As an illustration of the application of the method, the partial differential equation is solved for a family of potentials that result in oscillatory motions on a parabolic curve.

80-636

Dynamic Analysis of Flexible Mechanisms

J. Song
Ph.D. Thesis, The Univ. of Iowa, 126 pp (1979)
UM 7924533

Key Words: Plane mechanisms, Dynamic structural analysis

A method for transient dynamic analysis of planar mechanisms consisting of flexible members is developed, accounting for coupled large displacements and small elastic deformations. A computer code that systematically constructs and solves the equations of motion of general planar flexible mechanisms is developed. Numerical results for four example problems are presented to demonstrate the effectiveness of the theory and numerical analysis methods. Agreement of results obtained by the present method and results available in the literature is good.

80-637

Multiple Scale Fourier Transformation: An Application to Nonlinear Dispersive Waves

A. Jeffrey and T. Kawahara
Dept. of Engrg. Mathematics, The University, Newcastle upon Tyne, UK, Wave Motion, 1 (4), pp 249-258 (Oct 1979) 7 refs

Key Words: Fourier transformation, Wave propagation, Nonlinear theories

A Fourier transformation involving multiple scales is applied to describe the far-field asymptotic behavior of nonlinear dispersive waves. Fourier transformed versions of the nonlinear Schrödinger and Korteweg-de Vries equations are derived explicitly.

80-638

Near Field of the Open-Ended Parallel-Plate Waveguide

R.C. Menendez and S.W. Lee
Dept. of Elec. Engrg., Univ. of Illinois, Urbana-Champaign, IL, Wave Motion, 1 (4), pp 239-248 (Oct 1979) 7 figs, 17 refs

Key Words: Waveguides, Asymptotic series

The near-field radiation of an open-ended parallel-plate waveguide is analyzed by the uniform asymptotic theory. The results are compared with those obtained by Keller's geometrical theory of diffraction.

80-639

Influence of a Strong Discontinuity on the Propagation of Second Order Discontinuities

A. Donato
Istituto Matematica, Universita di Messina, Italy, Wave Motion, 1 (4), pp 279-285 (Oct 1979) 1 fig, 7 refs

Key Words: Water waves, Wave propagation

The propagation of second order weak discontinuities in quasi-linear hyperbolic systems of equations with discontinuous coefficients is studied. The general theory is applied to shallow water waves.

80-640

Epstein Transition Zones in Nonhomogeneous Isotropic Elastic Media

C.R.A. Rao
School of Mathematical Sciences, The Flinders Univ. of South Australia, Bedford Park, Australia 5042, Wave Motion, 1 (4), pp 259-270 (Oct 1979) 7 figs, 2 tables, 7 refs

Key Words: Wave propagation, Transformation techniques

A simple transformation in the independent variable makes it possible to obtain power series solutions of the stress equations of motion of elasticity for inhomogeneous elastic media whose refractive indices are represented by the Epstein profiles. Graphs of reflection and transmission coefficients versus angles of incidence are presented for different frequencies in the case of incident P as well as incident SV waves for some profiles.

MODELING TECHNIQUES

(Also see Nos. 423, 455, 458, 460, 469, 486, 497, 498, 514, 521, 527, 551, 572, 573, 646, 653, 654)

80-641

Finite Dynamic Element Formulation for a Plane Triangular Element

K.K. Gupta
Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, Intl. J. Numer. Methods Engr., 14 (10), pp 1431-1448 (1979) 4 figs, 1 table, 6 refs

Key Words: Finite element technique, Computer programs

The higher order dynamic correction terms for the stiffness and inertia matrices associated with a triangular plane stress-strain finite dynamic element are developed in detail. Numerical results are presented. A FORTRAN IV computer program listing of the various relevant element matrices is also presented in the Appendix.

80-642

A Comparison of Algorithms for the Adjustment of a Computational Model of a Vibrating Elastomechanical Structure to Experimental Values (Vergleich von Algorithmen f. die Anpassung des Rechenmodells einer schwingungsfahigen elastomechanischen Struktur an Versuchswerte)

H.G. Natke
Univ. Hannover, Hannover, West Germany, Z. angew. Math. Mech., 59 (6), pp 257-268 (1979) 3 tables
(In German)

Key Words: Mathematical models, Stiffness methods

The system analysis of elastomechanical structures based on drafts gives the computational model as an approximation of the real structure. The improvement of the computational model by correcting the stiffness (flexibility) matrix which is divided in submatrices is treated for undamped structures by means of measured natural frequencies, natural frequencies and normal modes, harmonic forces and/or corresponding dynamic responses. These distinct adapting procedures are mutually compared in a global manner.

80-643

Using Bond Graphs in Simulating an Electro-Hydraulic System

P. Dransfield and M.K. Teo

Dept. of Mech. Engrg., Monash Univ., Australia, J. Franklin Inst., 307 (3), pp 173-184 (Mar 1979) 3 figs, 2 refs

Key Words: Mathematical models, Bond graph technique, Electrohydraulic systems, Vibrators (machinery)

The paper describes the preparation of a dynamic model required for simulation of a 30 kW electro-hydraulic system used to induce controlled vibration of a wide range of components, machines or structures. The vibrator system is associated with a 28 ton seismic block. The model is highly detailed to allow study of the system to its dynamic performance limits of around 300 Hz. The model consists of nearly eighty equations some of them nonlinear and discontinuous. The paper describes the orderly development of the model emanating from the bond graph approach. Some simulation results, with limited experimental correlation, are included.

80-644

A Two-Axis, Bond Graph Model of the Dynamics of Synchronous Electrical Machines

D. Sahm

Institut f. Leistungselektronik und Anlagentechnik der Universität Stuttgart, Postfach 560, D 7000 Stuttgart, West Germany, J. Franklin Inst., 307 (3), pp 205-218 (Mar 1979) 7 figs

Key Words: Mathematical models, Bond graph technique, Electrical machines

In this paper the two-axis-model-machine is described using a bond graph. An example is given in which state-space-equations and output-equations are derived from the bond graph. A power-conserving transformation between the electrical quantities of the armature windings of the model machine and those of the real three phase armature windings is developed.

80-645

Bond Graph Fluid Line Models for Inclusion with Dynamic Systems Simulations

D.L. Margolis

Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, J. Franklin Inst., 307 (4), pp 255-268 (Mar 1979) 11 figs, 9 refs

Key Words: Mathematical models, Bond graph technique, Digital simulation

A procedure is presented whereby the control volume equations for one-dimensional, compressible gas dynamics are cast into first-order, state variable form. These equations are interpreted using casual bond graphs.

NONLINEAR ANALYSIS

80-646

Shock Response of Non-Linear Systems

K. Peleg

School of Packaging, Michigan State Univ., East Lansing, MI, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 145-157 (Sept 1979) 6 figs, 7 refs

Key Words: Nonlinear response, Mathematical models, Shock response (mechanical), Shock isolation, Packaging

A realistic model consisting of a mass between two preloaded non-linear (cubic elasticity) springs and restrained by a Coulomb and viscous damper is proposed. An approximate quasi-harmonic solution of the non-linear differential equation of motion of the model whereby both amplitude and phase are time dependent, enables a study of the motion during the first half cycle (pulse) after collision. Formulae are developed for calculating peak acceleration, rise time, pulse duration and maximum deflection. These are compared with corresponding formulae of special cases for which exact solutions are known. Acceleration versus time pulses are classified in accordance to pulse shape, e.g. sawtooth, half-sine and trapezoidal, as a function of system damping.

80-647

Stability Analysis and Response Characteristics of Two-Degree of Freedom Nonlinear Systems

M. Subudhi and J.R. Curreri

Brookhaven National Lab., Upton, NY, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 159-163 (Sept 1979) 6 figs, 10 refs

Key Words: Periodic excitation, Mass-spring systems, Stability, Computer programs

AD-A082 399 NAVAL RESEARCH LAB WASHINGTON DC SHOCK AND VIBRATION--ETC F/6 20/11
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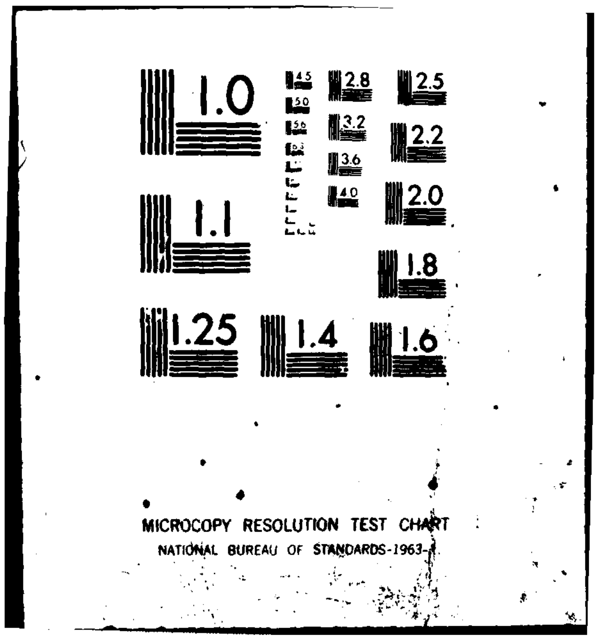
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-

The stability of a nonlinear two degree-of-freedom spring-mass system subjected to a sinusoidal exciting force is examined. The solution is perturbed to arrive at a set of coupled variational linear differential equations with periodic coefficients. Floquet theory is used to obtain a characteristic equation. The Routh-Hurwitz stability criterion is adopted to study the stable and unstable regions of the response curves. A computer program is developed to carry out the entire analysis. Extensive information regarding stable zones of the system response is described by means of nondimensional frequency-amplitude diagrams. The results are examined in terms of inferring dynamic response characteristics for sine sweep tests.

80-648

Decoupling of Nonlinear Vibrations (Entkopplung nichtlinearer Schwingungen)

H.D. Schrapel

Institut f. Mechanik (Bauwesen), Universität Stuttgart Pfaffenwaldring 7, D-7000 Stuttgart 80, Bundesrepublik Deutschland, Ing. Arch., 48 (5), pp 289-300 (1979) 2 figs, 11 refs

(In German)

Key Words: Nonlinear response, Transformation techniques

In this paper the decoupling of nonlinear vibration is investigated by means of canonical transformation. First the linear terms in the equations of motion are decoupled by use of the well-known linear transformation. Then the complete decoupling by means of canonical transformation is very simple.

NUMERICAL METHODS

(See No. 571)

STATISTICAL METHODS

(Also see No. 568)

80-649

A Statistical Look at Modal Displacement Response to Sequential Excitations

W.J. Kacena

Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 49, Pt. 2, pp 15-18 (Sept 1979) 4 figs, 2 refs

Key Words: Statistical analysis, Parametric response, Error analysis, Spacecraft

The residual displacement response to a sequence of simple excitations separated by nearly equal time intervals is evaluated on a statistical basis. Mean plus three-sigma responses are plotted as a function of the number of sequential excitations for a range of damping values. The curves are derived for parametric evaluation of the vibratory pointing error for a maneuvering spacecraft.

PARAMETER IDENTIFICATION

(Also see Nos. 437, 484, 497)

80-650

Analytical/Experimental Correlation of a Non-linear System Subjected to a Dynamic Load

J.C. Anderson and S.F. Masri

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, 57 pp (July 1979)

NUREG/CR-0949

Key Words: Dynamic structural analysis, Cantilever beams, Beams, Piping systems, Nuclear reactor components

Analytical and experimental studies of the dynamic response of a system with geometric and material nonlinearity are described. The dynamic excitation consists of sinusoidal and impulsive base acceleration. The dynamic system, which is representative of many practical cases involving mechanical equipment and piping systems, including nuclear steam piping systems, consists of a cantilever beam with a gapped support at the free end. The material nonlinearity considers both the effect of yielding and the effect of strain rate on the initial yield level. The analytical studies are performed by transforming the continuous system to an equivalent single-degree-of-freedom system and using numerical techniques to solve the resulting equation of motion. Experimental studies are conducted and responses are measured on the same dynamic systems. Critical comparisons are made between the calculated and measured responses.

80-651

Parameter Estimation Techniques for Modal Analysis

D.L. Brown, R.J. Allemang, R. Zimmerman, and M. Mergeay

Univ. of Cincinnati, OH, SAE Paper No. 790221, 24 pp, 13 figs, 14 refs

Key Words: Parameter identification technique, Modal analysis

Parameter estimation techniques that can be used to determine modal parameters (frequency, damping, and mode shape) from experimentally measured frequency response or unit impulse response are presented with respect to practical implementation and use. The methods are separated into two categories: a curve fit of only one degree of freedom with or without residuals, and a curve fit of multiple degrees of freedom with or without residuals. Particular details are given with respect to multiple degree of freedom techniques utilizing the Complex Exponential algorithm.

MOBILITY/IMPEDANCE METHODS

(See No. 488)

OPTIMIZATION TECHNIQUES

(See Nos. 495, 496)

COMPUTER PROGRAMS

(Also see Nos. 419, 466, 470, 498, 508, 534, 641, 647)

80-652

A Simplified Computer Program for the Prediction of the Linear Stability Behavior of Liquid Propellant Combustors

C.E. Mitchell and K. Eckert

Colorado State Univ., Fort Collins, Rept. No. NASA-CR-3169, 59 pp (Aug 1979)

N79-28226

Key Words: Computer programs, Liquid propellant rocket engines, Stability

A program for predicting the linear stability of liquid propellant rocket engines is presented. The underlying model assumptions and analytical steps necessary for understanding the program and its input and output are also given. The rocket engine is modeled as a right circular cylinder with an injector with a concentrated combustion zone, a nozzle, finite mean flow, and an acoustic admittance, or the sensitive time lag theory. Finally, a flow diagram, sample input and output for a typical application and a complete program listing for program MODULE are presented.

80-653

CELFE: Coupled Eulerian-Lagrangian Finite Element Program for High Velocity Impact. Part 2: Program User's Manual. Final Report, June 1975 - Sept 1977

C.H. Lee

Research and Engrg. Ctr., Lockheed Missiles and Space Co., Huntsville, AL, Rept. No. NASA-CR-159-396; LMSC-HREC-TR-D497204-Pt-2, 270 pp (Jan 1978)

N79-29833

Key Words: Computer programs, Finite element technique, Euler-Lagrange equation, Impact response (mechanical)

The CELFE computer program and user's manual, together with the execution of the CELFE/NASTRAN system, are described. The execution procedure and the transfer of data between the CELFE and NASTRAN programs are controlled through the use of DATA files in the Univac 1100 system. Five data files are used to control the runstream and data transfer, and three files are used to hold the programs. These files are contained on a single tape. Changes in NASTRAN routines required by the present analysis are also discussed in this report. All the program listings, except the last two files (where the absolute and relocatable elements are stored), are included in the appendixes.

80-654

CELFE: Coupled Eulerian-Lagrangian Finite Element Program for High Velocity Impact. Part 1: Theory and Formulation

C.H. Lee

Research and Engrg. Ctr., Lockheed Missiles and Space Co., Huntsville, AL, Rept. No. NASA-CR-159-395; LMSC-HREC-TR-D497204-Pt-1, 168 pp (Jan 1978)

N79-29832

Key Words: Computer programs, Finite element technique, Euler-Lagrange equation, Impact response (mechanical)

A 3-D finite element program capable of simulating the dynamic behavior in the vicinity of the impact point, together with predicting the dynamic response in the remaining part of the structural component subjected to high velocity impact is discussed. The finite algorithm is formulated in a general moving coordinate system. The dynamic behavior inside the region is described by Eulerian formulation based on a hydroelasto-viscoplastic model. The failure front which can be regarded as the boundary of the impact zone is described by a transition layer. The dynamic response in the remaining part of the structure described by the Lagrangian formulation is treated using advanced structural analysis.

CONFERENCE PROCEEDINGS AND GENERAL TOPICS

CONFERENCE PROCEEDINGS

80-655
The Effect of Noise and Vibration of Human Beings
M.J. Rycroft
Dept. of Physics, The University, Southampton, UK, Noise Control Vib. Isolation, 10 (7), pp 279-280 (Aug/Sept 1979)

Key Words: Human response, Noise tolerance, Vibration tolerance, Proceedings

The effect of noise and vibration on human beings was the subject of a one-day symposium, organized by the Wessex Branch of the Institute of Mathematics and its Applications, and held at Southampton University on 8 December 1978.

80-656
Zeitschrift für Angewandte Mathematic und Mechanik
Volume 59, Number 5 (May 1979)

Key Words: Vibration response, Stability, Proceedings

This issue contains summaries of lectures presented at the Annual Meeting of the Gesellschaft für Angewandte Mathematic und Mechanik (Society for the Applied Mathematics and Mechanics), 1978 in Brüssels, Belgium. The conference consisted of four sections: mechanics of rigid bodies; vibration and stability problems; elastic and plastic mechanics; and fluid mechanics.

TUTORIALS AND REVIEWS

80-657
Estimating Modal Damping: A Survey
D.E. Miller
Sandia Labs., Albuquerque, NM, Rept. No. SAND-79-0793C, 9 pp (1979)
N79-29555

Key Words: Modal damping, Reviews

A brief overview of some of the methods currently being utilized to estimate modal damping ratios is presented. Included are classic methods such as Nyquist plots, logarithmic decrement, and half-power frequency response methods. In addition, a few methods which were recently developed in an effort to overcome the limitations of the classic methods are presented.

80-658
Achieving a Quiet Lighting Transformer Installation
P.R. Neal
Specialty Transformer Business Dept., General Electric Co., Fort Wayne, IN, Plant Engr., 67 (11), p 131 (Nov 15, 1979) 1 fig

Key Words: Transformers, Noise reduction

This paper discusses several methods used to achieve a quiet lighting transformer installation.

CRITERIA, STANDARDS, AND SPECIFICATIONS
(Also see No. 425)

80-659
Residential Planning with Respect to Road and Rail Noise
T.D. Northwood, J.D. Quirt, and R.E. Halliwell
Div. of Bldg. Research, National Research Council of Canada, Ottawa, Ontario K1A OR6, Canada, Noise Control Engrg., 13 (2), pp 63-75 (Sept/Oct 1979) 14 figs, 6 tables, 29 refs

Key Words: Traffic noise, Noise reduction, Standards and codes

A procedure for providing adequate protection to housing from the noises of road and rail traffic is described. The method involves the establishment of criteria of acceptable noise, inside a building and in a sheltered outdoor space; prediction of the noise level at a proposed site, considering traffic flow parameters, barriers, topographical effects, and ground attenuation; and the design of a building to meet the noise criteria.

80-660

Vibration Standards for Power Transmission Equipment

R.L. Eshleman

The Vibration Inst., 101 W. 55th St., Clarendon Hills, IL 60514, National Conf. on Power Transmission, Proc., Sixth Annual Mtg., Nov 13-15, 1979, pp 99-109, 5 figs, 10 tables, 36 refs

Key Words: Standards and codes, Power transmission system

This paper describes the standards available for and standardization activity pertaining to the power transmission industry in the vibration area. National, international, and trade association standards are reviewed. Criteria, classification, measurement, and measures are discussed for specific and general machine standards.

80-661

SAE Vibration Test for Motor Vehicle Lighting Devices and Components

D.D. Walker

Body and Electrical Product Engrg., Ford Motor Co., SAE Paper No. 790747, 28 pp, 18 figs, 2 tables

Key Words: Lamps, Motor vehicles, Vibration measurement, Specifications

A new laboratory test specification is developed through vibration measurements at various locations on selected vehicles including trucks. Various alternatives for laboratory test equipment and test procedures are also studied.

80-662

Seat Belt Laws: Implications for Occupant Protection

A.F. Williams and B. O'Neill

Insurance Inst. for Highway Safety, SAE Paper No. 790683, 12 pp, 2 tables, 36 refs

Key Words: Rules and regulations, Collision research (automotive), Automobile seat belts, Human factors engineering

The implications for occupant protection regarding seat belt laws are discussed.

AUTHOR INDEX

CALENDAR

MARCH 1980

9-13 **25th Annual International Gas Turbine Conference and Exhibit** [ASME] New Orleans, LA ***(ASME Hq.)***

24-27 **Design Engineering Conference and Show** [ASME] McCormick Place, Chicago, IL ***(ASME Hq.)***

APRIL 1980

21-25 **Acoustical Society of America, Spring Meeting** [ASA] Atlanta, GA ***(ASA Hq.)***

28-May 1 **NOISEXPO '80** [S/V, Sound and Vibration] Hyatt Regency O'Hare, Chicago, IL ***(Acoustic Publications, Inc., 27101 E. Oviat Rd., Bay Village, OH 44140)***

MAY 1980

5-8 **Offshore Technology Conference**, Astrohall, Houston, TX ***(ASME Hq.)***

11-14 **1980 Annual Technical Meeting & Equipment Exposition** [IES] Philadelphia, PA ***(IES Hq.)***

19-23 **Fourth International Conference on Pressure Vessel Technology** [ASME] London, England ***(ASME Hq.)***

25-30 **Fourth SESA International Congress on Experimental Mechanics** [SESA] The Copley Plaza, Boston, MA ***(SESA Hq.)***

JUNE 1980

11 **Experimental Techniques for Fatigue Crack Growth Measurement** [SEE] British Rail Technical Centre ***(SEE Hq.)***

22-26 **Summer Annual Meeting** [ASME] Waldorf-Astoria, New York, NY ***(ASME Hq.)***

JULY 1980

7-11 **Recent Advances in Structural Dynamics Symp.**, [Institute of Sound and Vibration Research] University of Southampton, Southampton, S09 5NH, UK ***(Mrs. O.G. Hyde, ISVR Conference Secretary, The University, Southampton, S09 5NH, UK - Tel (0703) 559122, Ext. 2310)***

SEPTEMBER 1980

2-4 **International Conference on Vibrations in Rotating Machinery** [IMechE] Cambridge, England ***(Mr. A.J. Tugwell, Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1H 9JJ, UK)***

8-11 **Off-Highway Meeting and Exposition** [SAE] MECCA, Milwaukee, WI ***(SAE Hq.)***

OCTOBER 1980

Stapp Car Crash Conference [SAE] Detroit, MI ***(SAE Hq.)***

Joint Lubrication Conference [ASME] Washington, D.C. ***(ASME Hq.)***

6-8 **Computational Methods in Nonlinear Structural and Solid Mechanics** [George Washington University & NASA Langley Research Center] Washington, D.C. ***(Professor A.K. Noor, The George Washington University, NASA Langley Research Center, MS246, Hampton, VA 23665 - Tel (804)827-2897)***

21-23 **51st Shock and Vibration Symposium** [Shock and Vibration Information Center, Washington, D.C.] San Diego, CA ***(Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375)***

NOVEMBER 1980

18-21 **Acoustical Society of America, Fall Meeting** [ASA] Los Angeles, CA ***(ASA Hq.)***

DECEMBER 1980

Aerospace Meeting [SAE] San Diego, CA ***(SAE Hq.)***

8-10 **INTER-NOISE 80** [International Institute of Noise Control Engineering] Miami, FL ***(INTER-NOISE 80, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603)***