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SVIC NOTES

One of the more rewarding aspects of my job is the opportunity to visit with colleagues in government and industry who, although they have different responsibilities, have common interests in the solution of shock and vibration problems. Through discussions during these visits I learn about new developments which contribute to the advancement of our technology and, equally important, about problems in search of a solution. On occasion, my host for a visit takes the trouble to send a letter summarizing his views on the technical issues discussed. This is most helpful in either confirming or clarifying my own notes on the discussion.

The information obtained during such visits contributes to the SVIC mission in two ways. It helps to keep us aware of ongoing work and advancements in our technology and it provides a basis for the planning of our annual symposium. Over the years these symposia have been planned, insofar as possible, to address the most critical technical issues of the year. Ideally, the technical program planning should be based on an input from all concerned members of the technical community. Since it is not possible to meet personally with everyone, we have had to find other ways to obtain these inputs.

The 53rd Shock and Vibration Symposium will be held in Danvers, Massachusetts, on 26-28 October 1982. The Army Materials and Mechanics Research Center is the host. The preliminary announcement for the 53rd Symposium, among other things, offers addressees an opportunity to suggest topics for discussion. I hope the response will be even greater than last year when suggestions in response to a similar request contributed to an outstanding symposium. Our aim is to serve you. So, keep those cards and letters coming so that we will know how we can serve you best.

H.C.P.

EDITORS RATTLE SPACE

INNOVATION IN TESTING

Innovation, whether it is involved in the design, analysis, testing, or production of a product, is the essence of engineering. Innovation often goes unnoticed when a technique or procedure, developed by an engineer to do a job, is not documented and published. This is particularly true in the testing field. Owing to the potential gains in hardware innovations, the patent process has been overworked. This trend will certainly be followed in the computer software field. The lack of potential financial gain has curbed the publication and promotion of measurement and testing techniques. Perhaps the nature of these developments makes it impossible to protect them with a patent or a copyright.

One form of testing is an extension of the mathematical "testing" process whereby full or subscale models, prototypes or in-situ equipment are evaluated in the real world for their ability to realize performance, integrity, and life specifications. The simulation of environments which have the potential to degrade the product in performance or life usually requires innovative work -- whether it involves a test machine, a fixture, instrumentation, or the model itself. This effort usually goes unnoticed because it is accomplished with apparent ease. Therefore, to date much good information on product and design testing, because of being undocumented, is lost.

Testing for condition, fault diagnosis, and parameter identification requires skill in use of instrumentation and knowledge of the equipment under test. While more documentation has been forthcoming in these areas, much good information still does not appear in the open literature. The experience is not transferred to others and valuable time is consumed in repetition of technique development.

In previous years test oriented papers were not as readily accepted for publication as those containing extensive mathematical analyses. I believe these publication policies no longer exist for most technical journals. In fact there are many quality journals seeking good nonmathematical technical material. Therefore I would encourage engineers who deal with and develop testing, measurement, and evaluation techniques to offer them for publication in the open literature.

R.L.E.

THE CHANGING DIMENSIONS OF QUALIFICATION TESTING*

H.N. Abramson**

Abstract. The purpose of this paper is to demonstrate the changing dimensions of qualification testing in the interests of both the DOD and the nuclear power industry. In the one case the objective is mission integrity. It is achieved principally through generic testing; that is, the environment is a stable one. In the other case, the objective is operational reliability. It is achieved mostly through custom testing; that is, the environment is an unstable one.

INTRODUCTION

Qualification testing is often considered a routine endeavor that requires only the application of well established procedures and techniques. In actuality, however, qualification testing is dynamic and represents an interface for various groups -- from vendors, customers, and testing facilities to regulatory agencies -- each of which is striving in different ways to deliver an acceptable product at minimal incremental cost.

In the DOD field specifications are essentially determined by the federal government, as are testing methods; thus a stable situation can be disturbed by technical considerations that arise during qualification testing itself as a consequence of new design features of the product. Vendors account for the resulting additional development costs of product prices.

In the nuclear power field the situation is quite different: the government establishes guidelines or intentions only and leaves the development of actual specifications to interested professional organizations. The testing agencies (private laboratories) then develop relevant test procedures and techniques and provide a service to vendors (whose equipment is being purchased by the A/E contractor responsible for designing and building a plant for operation by a utility company). The government is required to make final judgments as to the validity of the qualification testing that has been conducted. Unfortunately, these decisions are not made until many months after completion of a project and thus create unstable situations. The vendors consider their products mature and of proven reliability (under normal conditions) and have accordingly priced them to be as competitive as possible; expenses incurred subsequently for qualification for seismic environments are therefore minimized. However, vendors and even plant designers sometimes have limited knowledge of dynamic environments and responses.

QUALIFICATION TESTING FOR THE DOD

Background. The need for a test demonstration of the capability of military hardware to meet the demands of field environments has been given serious engineering attention since World War II [1]. Even at that time it was realized that various environmental parameters -- including temperature, humidity, shock, and vibration -- can influence this capability; as a result an almost continuous program of research and development has been aimed at establishing guidelines for conducting appropriate qualification tests and specifying them for equipment manufacturers. These efforts have culminated in an extensive series of Military Standards (MIL-STDS) that have been updated periodically. Two of the most important concepts regarding test demonstrations that have evolved are qualification, or proof, tests and reliability tests.

MIL-STD 810 [2] has long been an important source of guidelines for environmental test specifications. A single failure during a qualification test usually constitutes grounds for rejection and subsequent redesign or other modification of the equipment. Such tests often require time-accelerated procedures in which environmental stress levels may be increased to compensate for reduced test durations. On the

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other hand, data given in MIL-STD 810 are generally recognized as conservative and could therefore lead to unnecessary rejection of equipment that is intended to be lightweight in design. Qualification tests for such equipment should thus be developed by some procedure that includes more relevant data.

MIL-STD 781C [3] also provides standard guidelines for vibration and other environmental testing when long-term reliability is a primary concern.

Unfortunately, it has become evident over the years that generic test procedures based on MIL-SPECS, and having the purpose of providing operational reliability or mission integrity, have often led to high rejection rates and higher cost through overdesign. The result has been custom testing to assure better products at lower cost. Custom testing involves alternate methods for developing test specifications. The application of such methods, however, means that vendors must be well aware of the requirements and be able to employ to full advantage the advanced analysis/measurement techniques required.

Methods for the development of DOD test specifications. Over the years, qualification and reliability tests have been conducted in both field and laboratory simulations in an attempt to duplicate anticipated operational environments. Field simulations alone can sometimes give a reasonable representation, especially when there is substantial lack of information about significant environmental parameters. Such field simulations are usually quite expensive, however; the trend has therefore been more and more toward developing improved laboratory simulations. Simulations that include test procedures more representative of anticipated operational requirements than those of, say MIL-STD 810, depend upon an improved data base. This in turn requires careful acquisition and analysis of field data under representative operational procedures and development of new laboratory test criteria from those data. This step is complex and requires considerable engineering judgment. The following examples are intended to demonstrate the evolutionary nature of improved MIL-STDS and customized qualification testing.

Early vibration qualification tests for most hardware were based on swept sine and sine dwell tests the specifications of which could be developed from MIL-STD-810. However, this type of test was particularly severe for systems with significant resonances, and failures occurred. If it was suspected that the true environment was less severe than the one specified (as was often the case), acquisition of field data and development of a suitable alternate test were necessary. Such was the case during qualification of the M200 rocket launcher for service on helicopter airframes [4]. It was first necessary to acquire flight vibration data for these units, which also required the development of a mission profile. Analog taped flight vibration data at anticipated critical locations were then acquired for various maneuvers of this profile. Analysis of these data led to two important conclusions:

- data for some maneuvers were quite stationary -- i.e., levels and frequency content were constant with time -- but for others, such as turns and dives, data were nonstationary, as shown in Figure 1
- time-averaged power spectra were a useful way of analyzing the data, as shown in Figure 2

These data showed that vibrational energy was dominant at the rotor passage frequency (11 Hz in this case) and several of its harmonics. Thus, sine dwell tests were applied only at these frequencies, rather than at resonances of the specimen, and time duration for the dwells was made commensurate with the mission profile and a specified number of missions. This work ultimately led to changes in recommended procedures for qualification testing of heli-

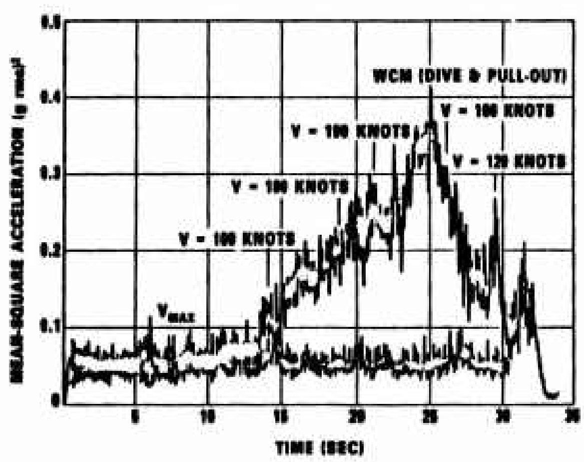


Figure 1. Mean-Square Accelerations from AH-1G Flight Tests, Vertical Axis

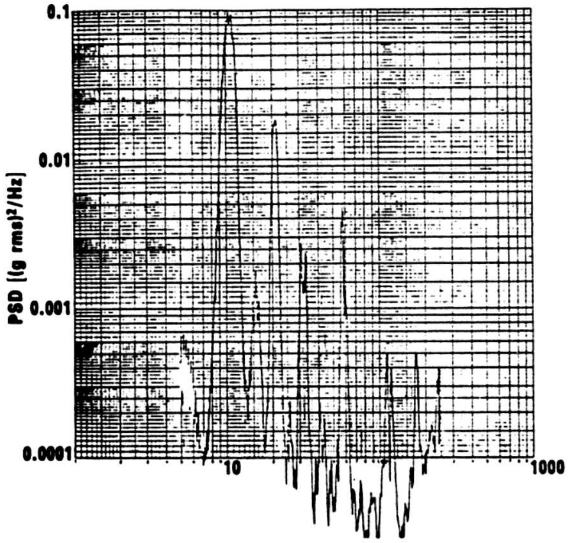


Figure 2. PSD Plot of Data from Accelerometer No. 5, Instrumentation (Code A)

copter external stores when MIL-STD-810B was revised to MIL-STD-810C. However, even these new procedures appear to be too conservative for more recent lightweight store designs, and so the program is still being actively developed.

A similar example is a ground vehicle vibration test specification developed for the LANCE missile [5, 6]. This specification included heating and cooling as well as vibration tests. A swept sine test was originally developed to represent the typical lifetime operational environment, but the vibration levels were complicated by the different environments caused by such factors as mode of transportation, terrain, and speed (Figure 3). Early failures were the result.

The test was modified several times until a swept narrow-band random test was developed that was more representative of the field environment. Based on additional field test data, a completely different

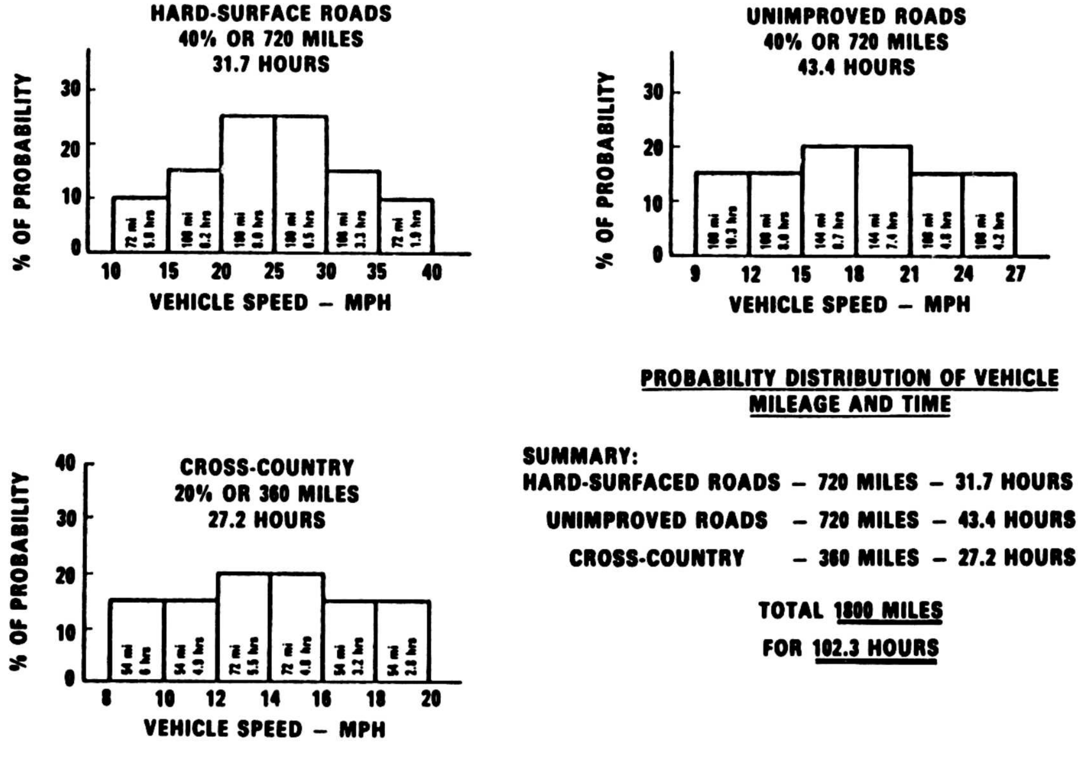


Figure 3. Probability Distribution of Vehicle Speeds

test was developed that included broad band random and a swept sine applied simultaneously. The swept sine component represented energy input from the vehicle track and varied with speed. Examples of power spectra from two different carrier modes on a gravel road are shown in Figure 4 for a given part of the service life. Similar data were acquired for truck and aircraft environments. These spectra were then used as a criterion for a laboratory time-accelerated test. An example of a comparison of scaled field spectrum and laboratory spectrum for one axis and terrain condition is shown in Figure 5. Test durations were again tailored to the corresponding operational service life.

These two examples show that development of environmental tests can be complex but can also provide representative simulations. Such programs are costly but can be justified for widely used systems.

In order to develop additional information on vibration environments, other fundamental studies have been performed [7]. A model hardware specimen (MHS) was instrumented to measure vibration and was tested in several helicopter and ground vehicle environments. The specimen represented an arbitrary hardware item (an assemblage of beams) with natural vibrational modes randomly oriented in space and frequency.

Figure 6 shows some typical results of vibration levels felt by each beam with the MHS secured in an M35 Truck that has run over a ground vehicle course; the strong nonstationarity of the data is evident. A vibration test representing this environment was developed by matching power spectra for individual parts of the course, as shown in Figure 7. The additional complexity of the tests is again evident; however, a more exact simulation has been achieved.

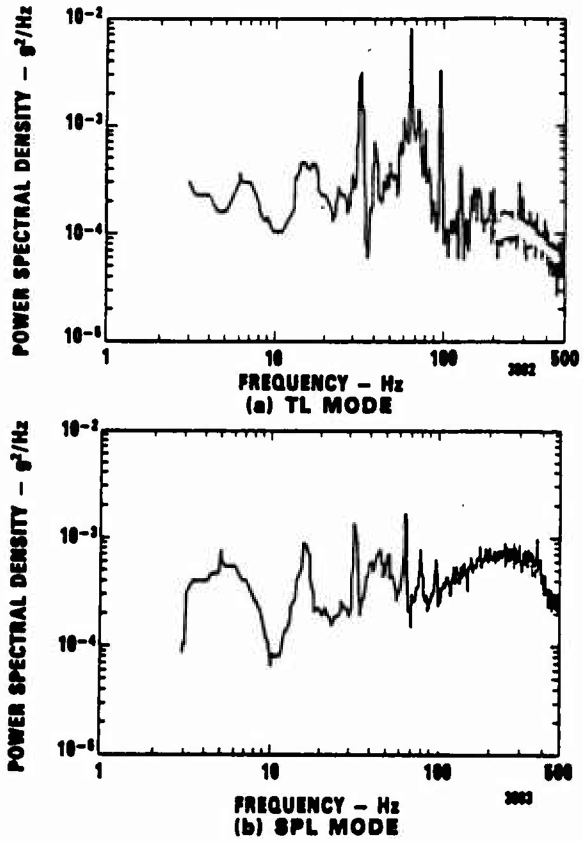


Figure 4. Power Spectral Density of Yuma Field Test Data - Gravel Terrain, 10 MPH, Aft Bulkhead, Vertical Axis

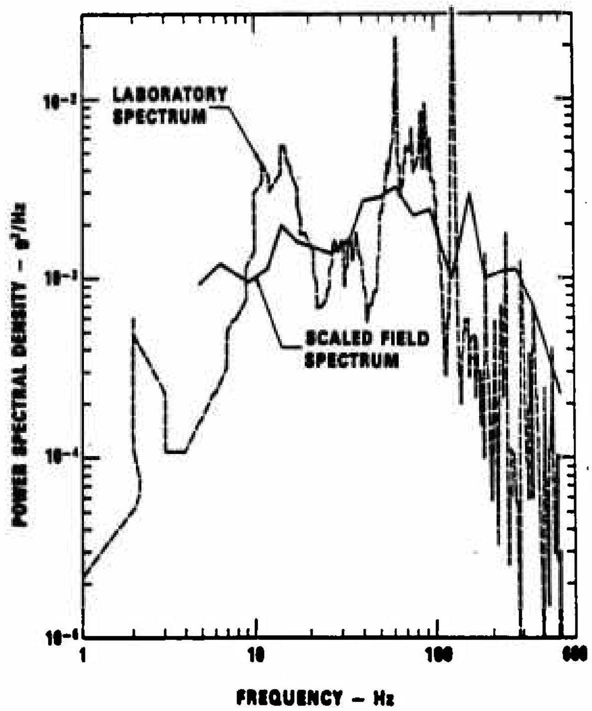


Figure 5. Comparison of Scaled Field Spectrum with Laboratory Duplicate for VSL Testing - Gravel Terrain, AFT Bulkhead, Vertical Axis

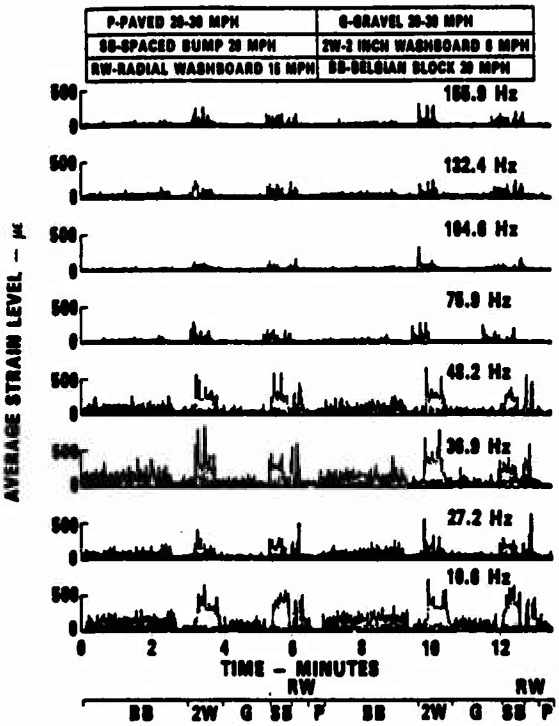


Figure 6. Average Strain Level Variation with Time Run No. 2A MHS Secured in Aft Cargo Area M35 Truck - Field Data

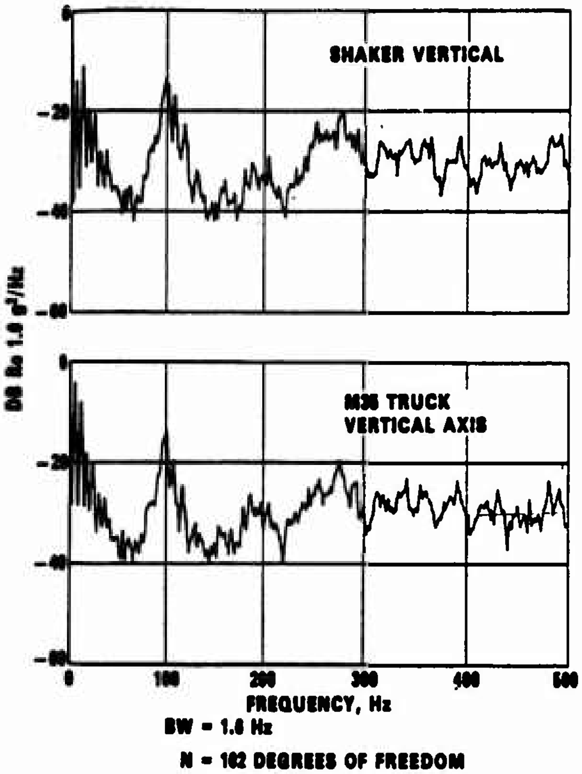


Figure 7. PSD of M35 Truck on 2-Inch Washboard

Considerable attention has also been given to the development of better laboratory systems for producing reliability tests. For some time there has been interest in the Army Test Methodology program for developing a vibration system capable of producing vibration along several axes simultaneously, as is actually experienced by field ha·dware. Because the exact nature of the requiremen(for the multi-axis shaker was unknown, a typical radio specimen was instrumented and flown in a helicopter under an appropriate operational plan [8]. Throughout these flights, excitation vibration analog tape data were acquired at three points on the radio face (where it was attached to the instrument panel), and response data were acquired at one point on the back of the radio.

The input-output data were used to develop a mathematical model of the radio using power spectra and cross spectra. The mathematical model was then used to predict radio responses for several different types of physical representation of the excitation. An example of comparisons of some results is shown in Figure 8. It was found that a triaxial system (three simultaneous independent orthogonal axes) for the shaker was the most feasible [9].

This development of a triaxial shaker system led to a concurrent program aimed at requiring reliability data for the purpose of comparing the effectiveness of several different types of reliability environments [10, 11]. Five different types of reliability tests were applied to five different sets of five radios. Each test included operation of the radios and some form of simulated environment. Vibration data were acquired during flight; this sequence was repeated many times for flight tests on the sample set V radios. These data were also used to develop tests for the uniaxial (set II) and triaxial (set IV) radios.

Figures 9 and 10 show samples of field and laboratory triaxial data. Time-averaged power spectra for different parts of the operational sequence were matched and used as the vibration test criteria. In addition, one group of five radios (set III) was subject to the AGREE test specified in the B-version of MIL-STD-781, and one group (set I) was subjected to bench tests in which only electrical operation was simulated.

It was found that humidity and nonuniformity of personnel operations had a large influence on the results; results for the vibration tests were inconclusive. The prohibitive cost and time for field testing are the driving forces for continuing efforts along the lines of laboratory simulation just described.

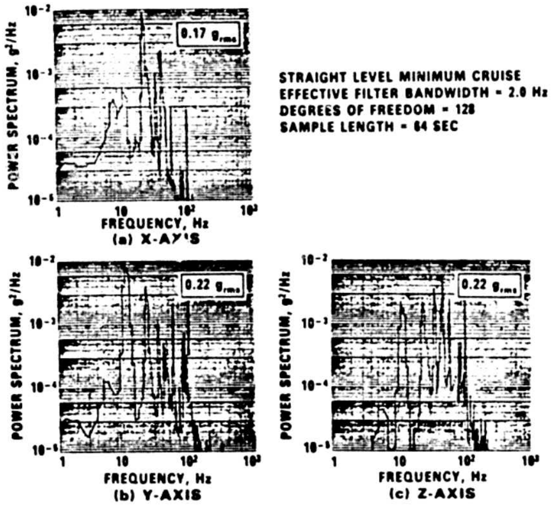


Figure 9. Acceleration Power Spectra from Flight Triaxial Data

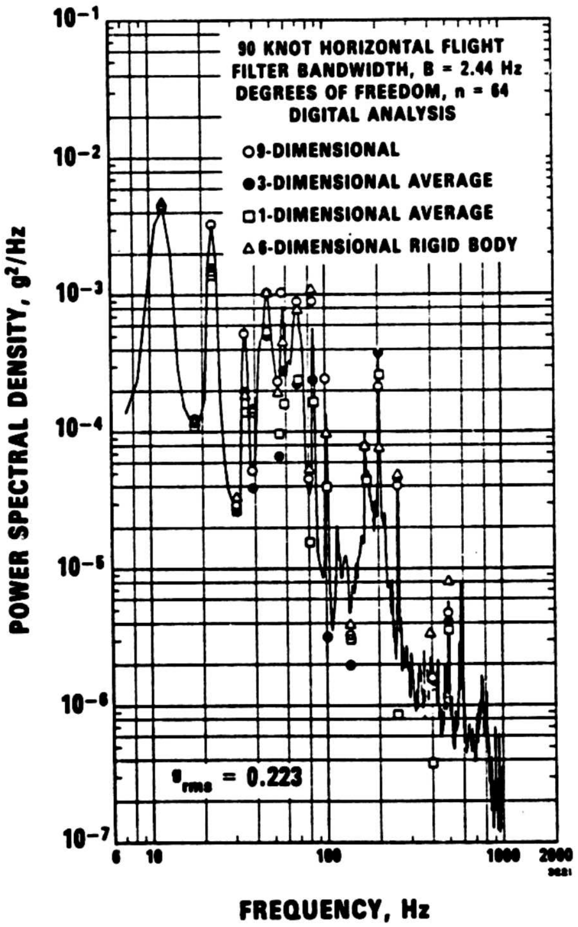


Figure 8. Longitudinal Response Amplitude (Y_{41}) and Simulations for OH 58A Helicopter

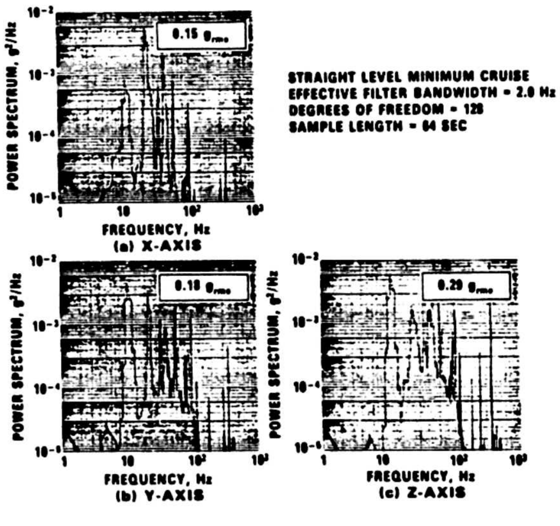


Figure 10. Acceleration Power Spectra from Laboratory Triaxial Data

QUALIFICATION TESTING FOR THE NUCLEAR POWER INDUSTRY

Background. Recommended procedures for seismic qualification of nuclear plant equipment and components have undergone rapid development over the last several years. The general guidelines are relatively intact, but detailed procedures have changed significantly. These changes result largely from reactions to individual problems that have arisen spontaneously in various test laboratories during actual qualification tests. Unfortunately, details are often buried in company proprietary test reports and have rarely been published for general evaluation.

A major problem for seismic qualification testing is that there is no operational data base! This lack of data base information further aggravates difficulties arising from the fact that many organizations are involved in the total qualification process [12]. The vendor issues a contract to a test laboratory for testing a specific hardware item with certain test specifications. The specifications are written by the A/E firm to whom the vendor is a supplier. In turn, the A/E firm must satisfy its contractual requirements with the utility company whose plant it is constructing. Finally the utility must satisfy licensing requirements of the NRC.

One of the few unifying aspects of this qualification process has been that interested members of the various organizations have served on IEEE committees that have actively developed qualification guidelines. The NRC has, in turn, published standards that either approve or supplement these guidelines. Unfortunately, the result of this somewhat convoluted process is very little published research evidence to support the test procedures that have evolved.

General guidelines for the conduct of seismic qualification tests are specified by the NRC in Standard Review Plans [13, 14]. These guidelines require considerable supplemental explanation and, therefore, rely on standards written by committees of the IEEE. For example, IEEE 323 [15] is a standard* that addresses general environmental requirements. IEEE 344 [16] is a more detailed guideline for seismic qualification of electrical equipment; it has been supplemented by NRC Reg. Guide 1.100 [17], which recognizes the use of IEEE 344 for qualification of both electrical and mechanical components. Such documents are further supplemented by other standards that apply to specific equipment such as valve operators [18].

Although little hard data has been published on developments in seismic qualification, several review papers have appeared [19, 20]. They were followed by a review [21] of research needs based on observations during various seismic qualification tests. One research program was based on experimental data throughout and identified specific problem areas; approaches were recommended to solve the problems, and new concepts were developed to handle the qualification process [22].

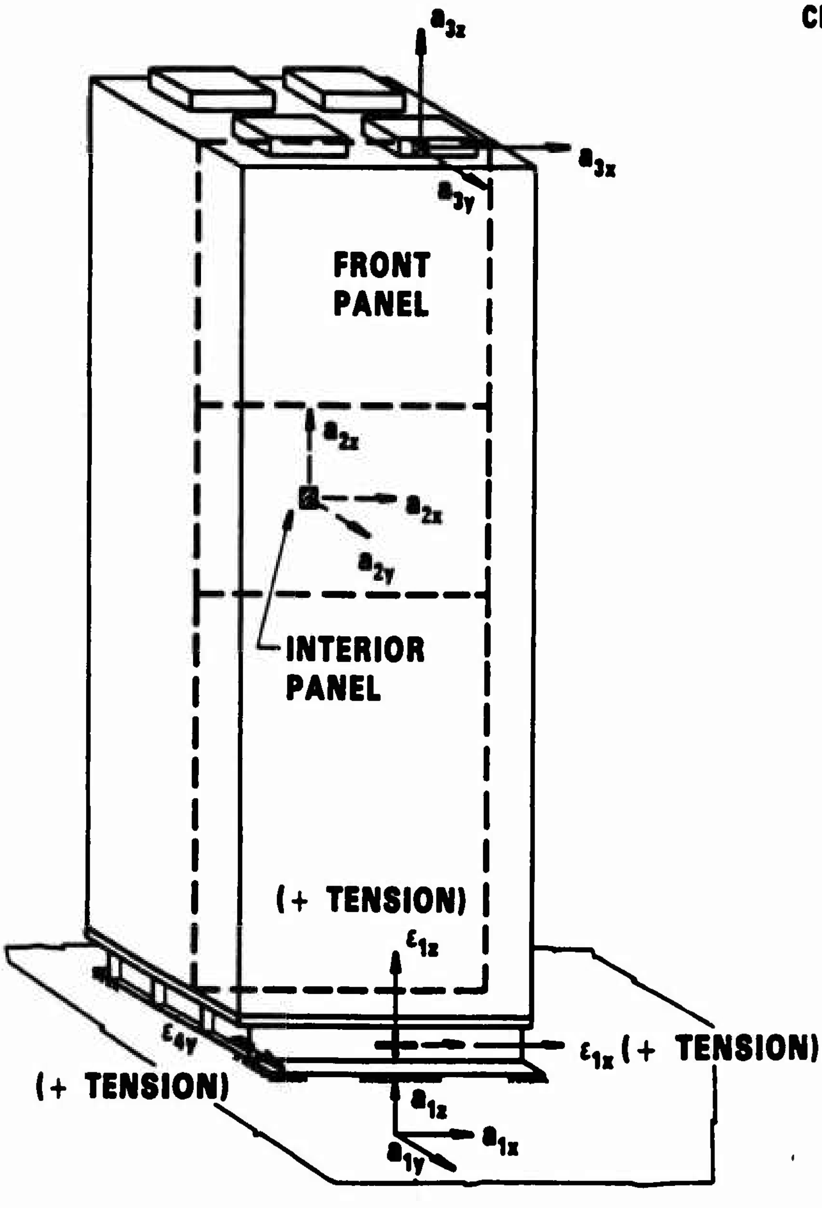
Test methods and the response spectrum anomaly. The following discussion identifies some of the current problem areas is seismic qualification testing. The case that is reviewed involves an electrical network control cabinet [22], but the results are applicable in general to both electrical and mechanical equipment and to qualification by analysis as well as by test.

A typical electrical cabinet was subjected to a variety of seismic tests that are currently recognized by IEEE 344-1975 and Reg. Guide 1.100. The objective was to develop data from which the responses to various tests could be compared. Figure 11 illustrates the cabinet and instrumentation locations; the latter involved three triaxial accelerometers and three strain gage channels to measure excitation and response data for the various tests.

In preliminary tests, natural modes of the cabinet were determined by resonance searches when mounted to the floor and when mounted on a biaxial seismic simulator. Figure 12 shows several of the prominent floor-mounted modes below 35 Hz. Typical transfer functions for the simulator-mounted searches are shown in Figure 13. It can be seen that some differences in frequencies occurred for the two different mounting methods. Procedures for handling these differences during qualification tests have evolved as a consequence of these data.

The cabinet was subjected to a series of qualification tests, including biaxial independent and biaxial dependent tests for typical ground level specifications. Both random and earthquake signal sources were used to develop drive signals for the simulator.

An updated version of this standard is NUREG 0588.



TAPE RECORDER CHANNEL ASSIGNMENT

CHANNEL	OSCILLO-GRAPH	TAPE
1	a_{3x}	a_{3x}
2	a_{3y}	a_{1H}
3	a_{3z}	a_{3y}
4	a_{2x}	a_{1T}
5	a_{2y}	a_{3z}
6	a_{2z}	a_{1z}
7	ε_{1x}	a_{2x}
8	ε_{4y}	ε_{1x}
9	ε_{1z}	a_{2y}
10	a_{1x}	ε_{1z}
11	a_{1y}	a_{2z}
12	a_{1z}	ε_{4y}
13	–	X_{CH}
14	–	X_{CZ}

CONTROL ACCELERATION, a_{1x}, a_{1y}, a_{1z}

COMMAND DISPLACEMENT, x_{cH}, x_{cz}

Figure 11. Positions for Instrumentation

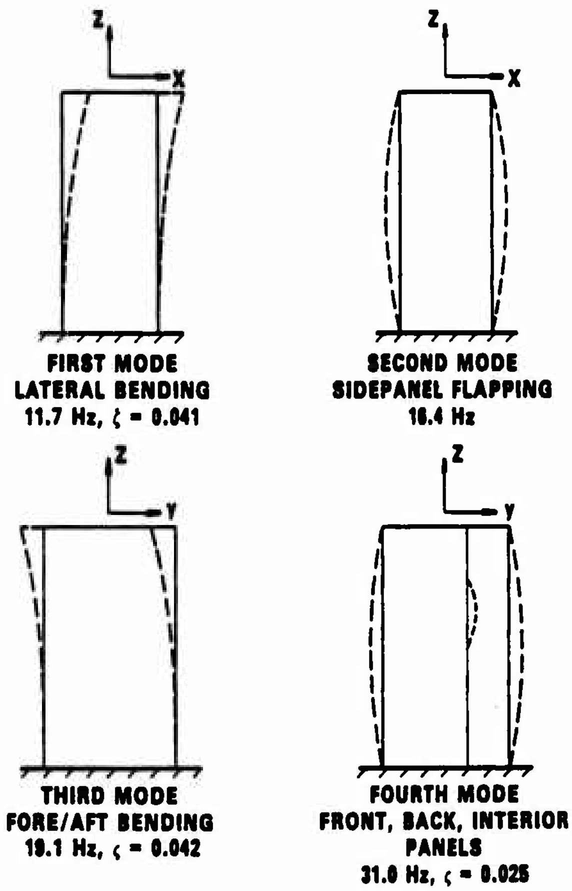


Figure 12. Cabinet Natural Modes Below 35 Hz

Another series of tests for floor level specifications included biaxial independent, uniaxial, sine beat, and sine dwell excitations. Both random and earthquake signal sources were again utilized to produce a typical floor level test.

Figure 14 shows time histories for a typical biaxial independent random ground level test run. Corresponding required response spectra (RRS) and test response spectra (TRS) are shown in Figure 15. These response spectra demonstrate a typical and very important problem; both Figure 15a and 15b show an excessive test zero period acceleration (ZPA) compared with the required value.

This problem has been discussed at length [20-22] and appears to indicate over-conservatism in the test as a result of a mismatch of response spectra.

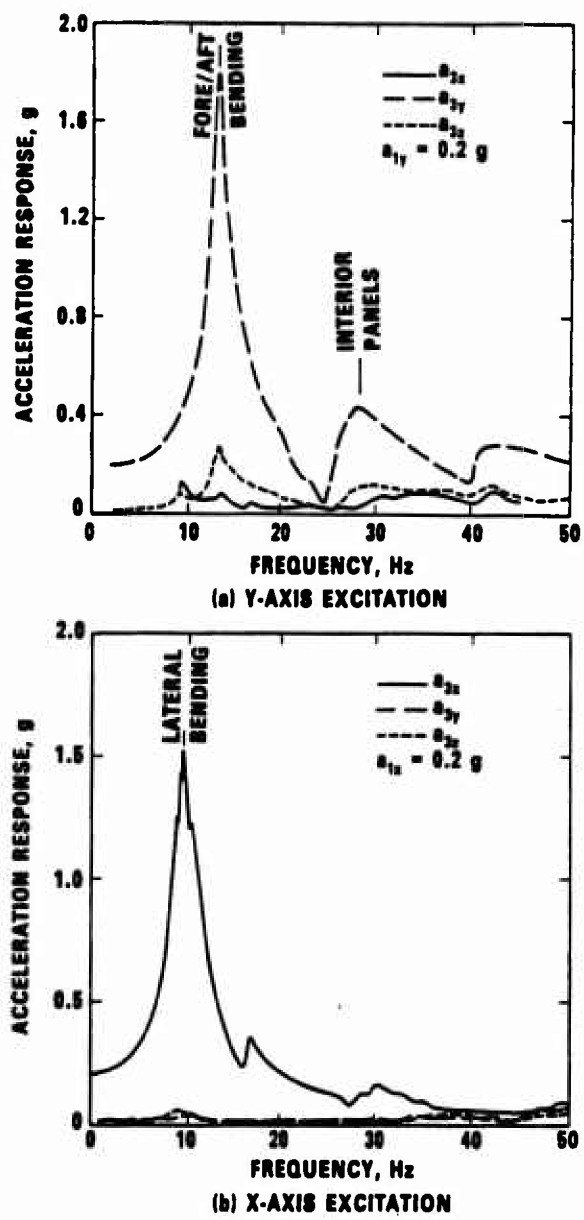


Figure 13. Top Acceleration Responses for Simulator-Mounted Sweep Test

This discrepancy may be a consequence of an insufficient designation of tolerances required to achieve the proper ZPA; or it might occur because no time history can be generated that will match the RRS entirely! In any event, the effects of this apparent overconservatism on test results need to be evaluated.

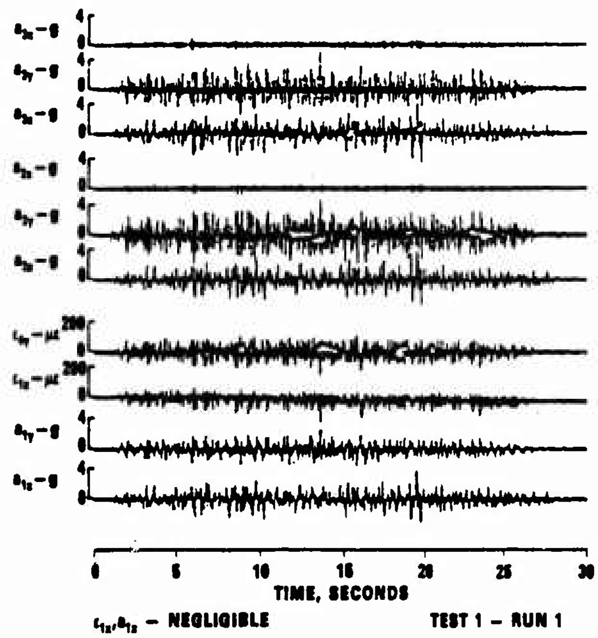


Figure 14. Responses for Biaxial Independent Random Ground Level Test, YZ-Excitation

Data from individual runs during the various tests were correlated in terms of peak measured response (a_3^*) as a function of peak response ($\hat{a}_1$) predicted from the response spectrum. That is,

$$a_3^* = 2\beta_r |H_{31}(\omega_r)| a_{1\,r}$$

H_{31} is a transfer function and β_r is modal damping. Examples of typical results are shown in Figure 16. This type of correlation indicates that reasonable agreement exists between measured responses and those predicted by shock spectrum analysis. The principal discrepancy seemed to result from nonlinearity of the transfer functions for the various modes.

A second type of correlation was developed in terms of average RMS response ($\bar{a}_3$) as a function of average RMS excitation ($\bar{a}_1$). That is,

$$\bar{a}_3 = A_{31}\bar{a}_1$$

A_{31} is a constant. Correlations of this type are applications of the equations developed for a general

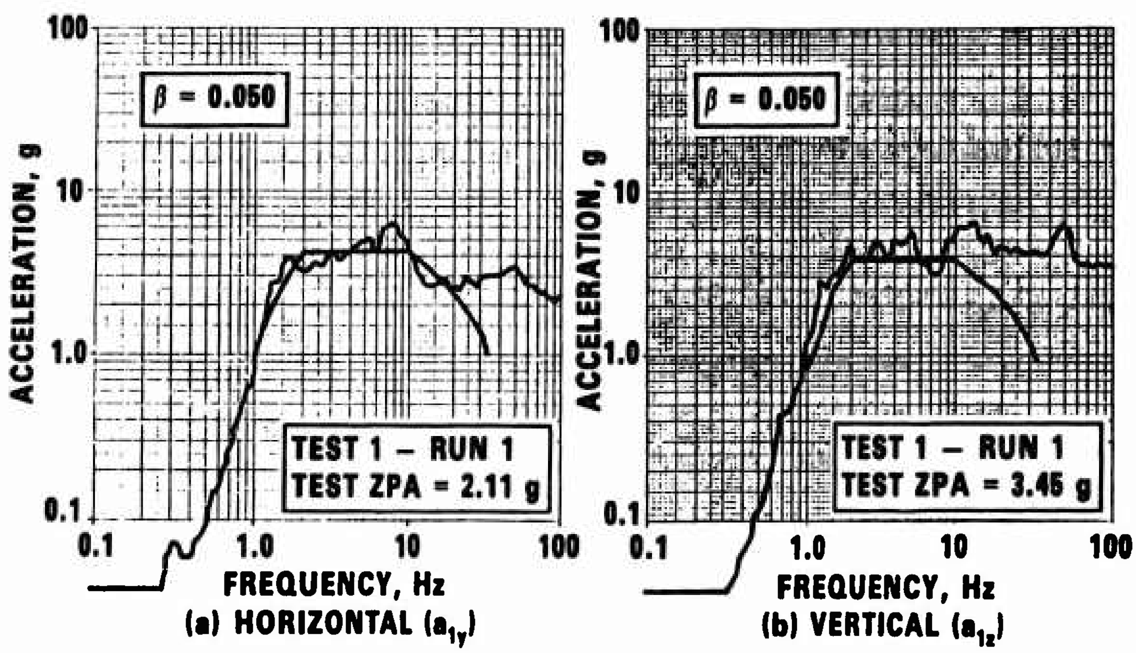


Figure 15. Response Spectra for Biaxial Independent Random Ground Level Test, YZ-Excitation

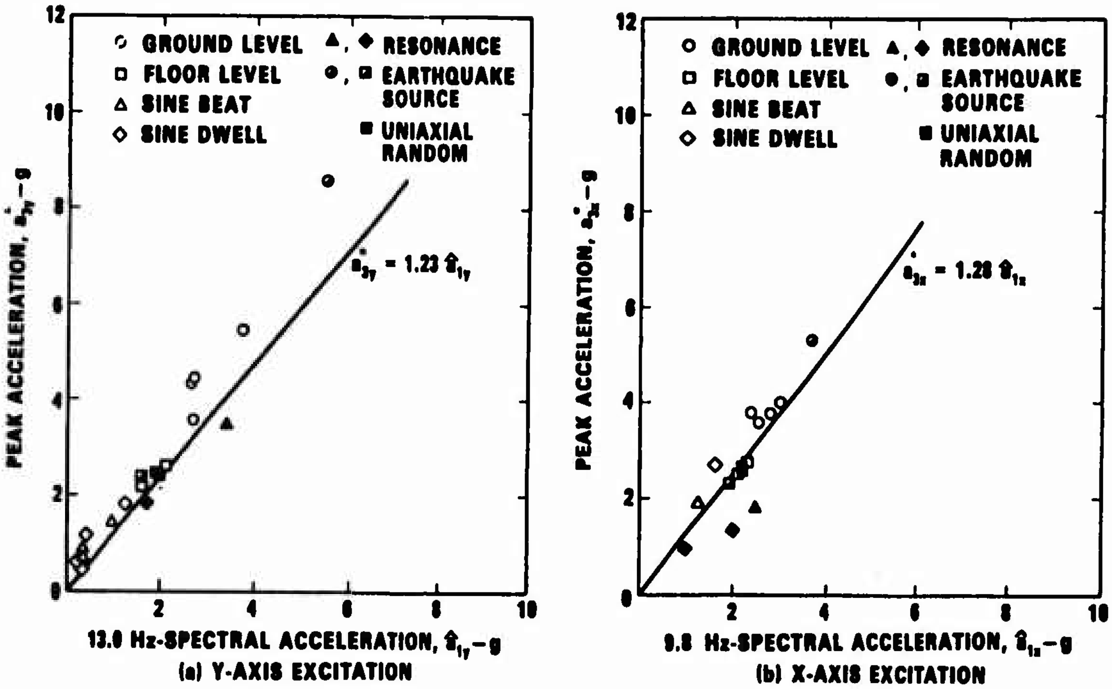


Figure 16. Peak Acceleration Responses at Cabinet Top

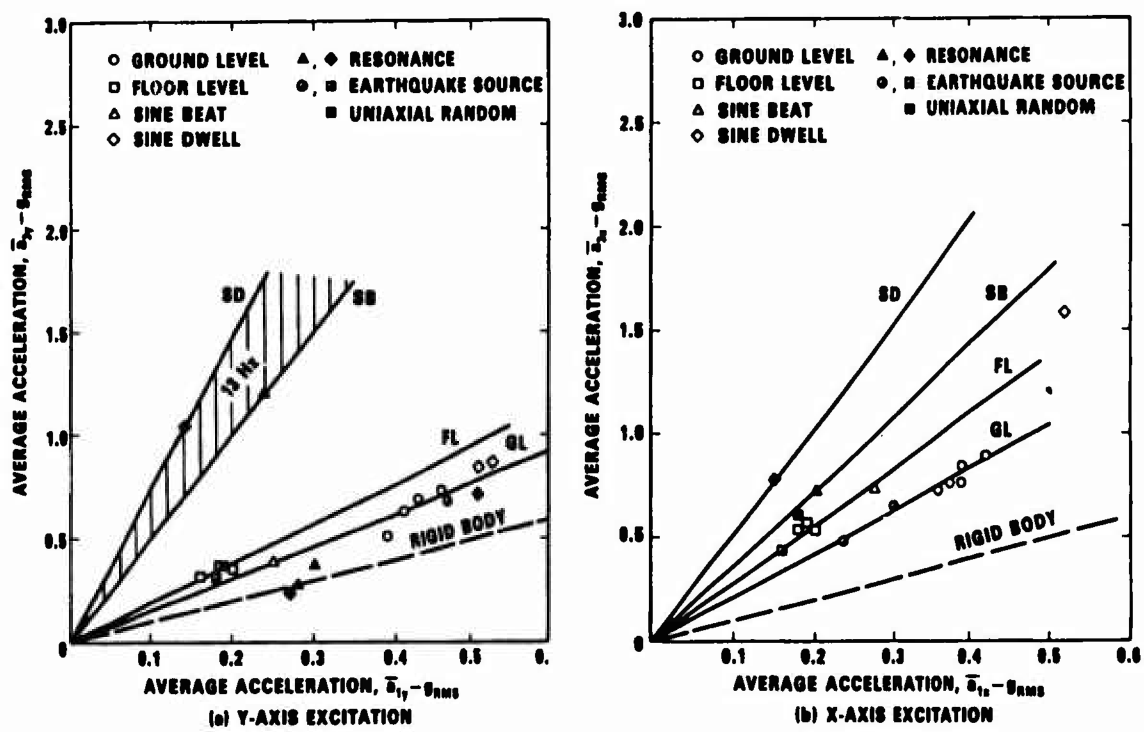


Figure 17. Time-Average Acceleration Responses at Cabinet Top

structural system [23]. The RMS value is a useful measure of intensity, as has been pointed out elsewhere [24]. Examples of results are presented in Figure 17. In general, it can be seen that less scatter of data occurs for data of a given type of test run. Further, each test run having similar sustained damage potential falls on a corresponding curve; thus, a parameter that describes an all-around damage severity of a given type of test can be developed [25].

An important anomaly that affects the criterion for matching or enveloping a response spectrum has recently been described [22]. It appears that enveloping a response spectrum does not guarantee that all modes of a structure will be excited properly during some tests.

Figure 18a shows the RRS and matching TRS used for one run on the electrical cabinet. This run involved a ground level test in which motion was developed from a random noise generator; a ±3 dB tolerance was allowed in the matching below 20 Hz. Note that this tolerance was slightly exceeded at about 7.5 Hz. Nevertheless, the TRS envelopes the RRS at all frequencies above 3.4 Hz. Note also that the test ZPA exceeds that required by a factor of 3 so that this would appear to have been a severe overtest; however, further investigation showed that it in fact represented an undertest.

The possibility of an undertest was suspected when a time-average power spectrum of the excitation was computed; the results are shown in Figure 18b. It is immediately apparent that there is essentially no energy in the input at 13 Hz. But from Figure 13a, it can be seen that the first fore/aft bending mode of the cabinet occurred at 13 Hz. On the other hand, the RRS indicates that energy input and amplification should occur at this frequency.

That a direct contradiction has occurred is shown by the data in Figure 19, which is based on the response acceleration at the cabinet top. Although the input energy peak at 7.5 Hz is amplified, again, there is no resonance at this frequency; in fact, there is no amplified peak in the response spectrum at 13 Hz, where a resonance is known to occur. Similarly in Figure 19b the response power spectrum shows no prominent energy in the response at 13 Hz.

In view of the excitation response spectrum data of Figure 18a it would appear that a proper test had been conducted and, in fact, that a severe overtest

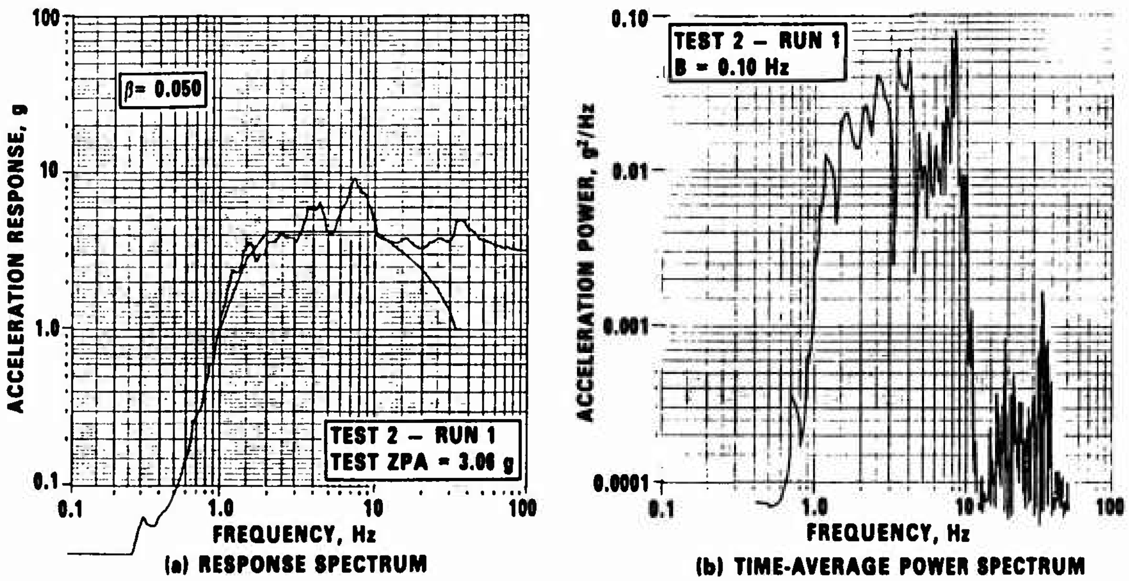


Figure 18. Parameters That Describe Ground Acceleration (a_{1y}), YZ-Excitation

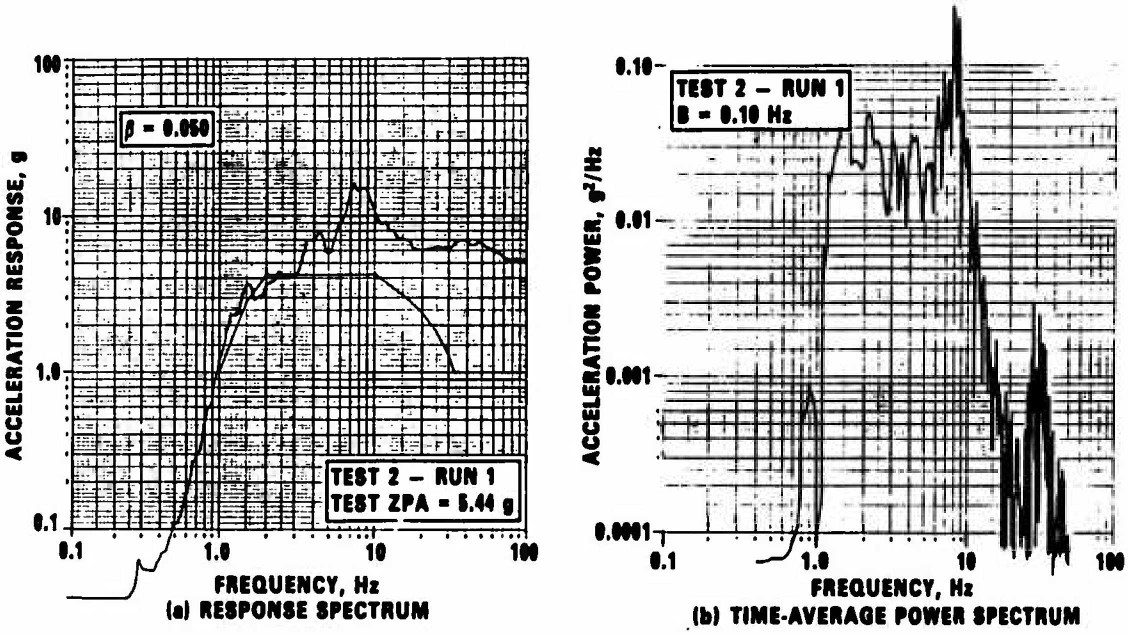


Figure 19. Parameters That Describe Cabinet Top Response Acceleration (a_{3y}), YZ-Excitation

was employed. On the other hand, the additional data and the power spectra in particular indicated that something was awry with the test and that an undertest had occurred. It must be emphasized that there is nothing special or peculiar about the time history for this test run. In fact, similar results were found for all ground level tests utilized for signals generated from both random and earthquake sources. It is immediately obvious that this type of anomaly can affect most qualification tests performed today.

Other questions and problems. It is important to mention the current revision efforts of the IEEE 344 Committee as a way of outlining other questions and problems. These generally deal with both the analytical and testing areas of qualification.

Several problems of basic accuracy arise in enveloping an RRS with a TRS. The matter of margin deals with how much conservatism is inherent in an RRS even before a TRS is attempted. There is also a move toward making spectral damping values more uniform. Tolerances associated with enveloping are also being considered because they have a pronounced effect on test costs.

Adequacy of simulated earthquake waveforms is of concern. In analysis by time history as well as in testing, some form of earthquake representation is generated; additional evaluation of the potential methods for generating appropriate time histories is needed. An associated problem is the addition of motion from other dynamic sources -- for example, valve closure. How can these effects be properly added to those of an earthquake?

Spectrum intensity or damage severity is an important concept, especially for comparing the effects of one type of test (or assumed analytical load) with another. It is also important for SQRT efforts in evaluating prior qualification of operating plants. This leads to the question of in situ testing.

Generic and type testing procedures should be clarified -- particularly the effectiveness of combining test and analysis for qualifying a series of valves of different sizes.

Several areas of qualification by analysis are being considered for revision. For example, should some form of partial experimental verification be included in all analyses? Is this appropriate for qualification of multiple cabinet combinations?

Various questions remain with regard to line-mounted equipment. Should torsional effects of valves on attached pipes be included? Are narrow-band random motion tests more representative than the large amplitude sine sweep tests now in use?

SOME ADDITIONAL DISTINCTIONS AND PROBLEMS

Interactive environmental testing. In general, environmental testing in the DOD area is performed prior to vibration, acoustic, and shock testing, which are usually done in that sequence. The purposes of the environmental tests are to age the test item prior to subjecting it to dynamic environments and to assure the ability of the test item to survive the specified environments. Environmental testing in the nuclear power plant area, however, involves subjecting the test item to the specified conditions both pre- and post-vibration testing. The purpose of pre-vibration exposure is again aging; that of post-vibration exposure is to demonstrate that the test item can remain functional under postulated abnormal plant operating conditions after a worst case seismic event.

The sequence and type of environmental tests performed under DOD philosophies vary with both the intended use and the location of the test item; i.e., sheltered or non-sheltered equipment; location within an aircraft, missile, or ground vehicle; and whether the equipment is classified as mechanical, electrical, or armament. In contrast, environmental tests for nuclear service have a fixed sequence regardless of the intended location of the test item. The test parameters are, however, a function of test item location and are specific as to both a given plant and the location within that plant.

The variety and sequence of environmental tests generally performed for DOD and nuclear service are shown in Figure 20. The DOD tests include a group of temperature and pressure extremes that can be said to be related to weathering or outdoor environments and a group of other specialized conditions; all precede the group of tests characterizing dynamic environments. Nuclear environmental tests are intended to produce long-term aging characteristic of a 40-year service life primarily in controlled indoor environments. Extreme condition testing is conducted after dynamic testing to simulate abnormal operating conditions in the plant.

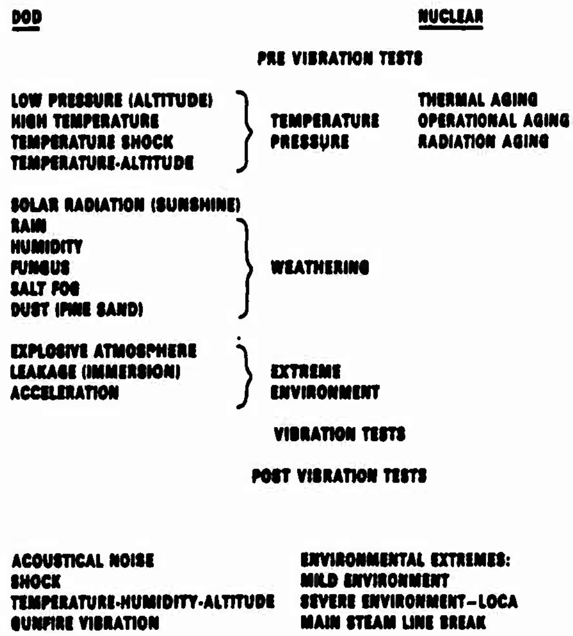


Figure 20. Comparison of Interactive Environmental Tests for DOD and Nuclear Related Component Qualification Tests

Frequency range. Vibration testing typical of DOD requirements involves frequency ranges representative of the environment produced by such vehicles as fixed and rotary wing aircraft, ground vehicles, and ships. The frequency ranges used in vibration testing are specified in a few standards (MIL-STD 810C, MIL-STD 167, Ships) and are of the order 10-10^3 Hz.

On the other hand, nuclear-related vibration testing is more complex because the frequencies depend to a great extent not only on the seismic event itself (1-35 Hz) but also on the attenuation or amplification of the dynamic environment provided by the response of the structure in which the equipment is located. Such dynamic events as the activation of steam relief valves and the response of pipelines to internal flow conditions can therefore extend the frequency range of interest up to the order of 10^2 Hz. There are no general standards available to provide guidance in nuclear qualification testing; test conditions are therefore defined by the many different A/E firms responsible for plant design. Wide differences result from site-specific considerations and even from differences in engineering judgment as to what constitutes conservatism. After-the-fact evaluation and judgment as to the adequacy of testing procedures aggravates the cost of component qualification.

Equalization and control in dynamic testing. Probably the oldest vibration test procedure adopted by either the DOD or the nuclear industry is the sinusoidal test. This general test method is useful for determining such system characteristics as resonant frequencies and damping. Its use as a generic qualification procedure is limited and often unsatisfactory, however, because the result generally is highly overdesigned equipment. A similar generic test developed specifically for the nuclear industry is called the RIM (Required Input Motion) test. This test specifies a dwell (or beat) at the equipment resonant frequency at a base g level equal to the maximum expected peak in the earthquake transient; i.e., a dwell at the ZPA level. Unfortunately, even for the lightest weight equipment, this test is so demanding of the test facilities that it is rarely attempted.

An alternative form of dynamic testing involves the application of a specified transient (shock) or continuous random waveform time histories (PSD) to linear systems. Stand-alone digital based equalization and control systems are readily available that can reproduce these inputs on electromagnetic exciters that are linear with respect to acceleration control. On the other hand, electrohydraulic actuators that are nonlinear with respect to acceleration control (linear with respect to displacement control) often require iterative procedures in addition to the FFT and inverse transform algorithms employed in linear control systems. Several digital control system techniques have been developed for shock spectrum enveloping [26].

Vibration test levels representative of operational DOD environments are now often specified in terms of an acceleration power spectrum (recall that the PSD spectrum is the time average rms acceleration levels taken from stationary random response time histories). The response spectrum for earthquake simulation, on the otner hand, is the peak response of a series of single degree-of-freedom oscillators to a nonstationary random time history input. During the strong portion of an earthquake event, a duration of approximately 15 seconds, the time history is for the most part stationary.

Efforts are underway in the nuclear industry to employ a mapping between the two spectrum representations [27]. This would allow methods for correcting an elevated spectrum for known levels of overtest and combining response spectrum on an energy basis. The nuclear industry is historically response-spectrum oriented; however, studies are now in progress to supplement the specifications with corresponding strong-motion PSD spectra.

It is interesting to consider where in the DOD and aerospace areas the power/response spectrum specification would be appropriate as well. One might consider those portions of a maneuver spectrum where a nonstationary vibration response would occur -- during a transition from one maneuver to another, for example, or during deployment of weaponry from a flight vehicle. The importance of such considerations stems from the fact that in a PSD spectrum the expected peak acceleration to overall rms level is usually about 3.0; values on the order of 5 to 7 can actually be experienced in a nonstationary input such as in the earthquake event.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

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

This issue of the DIGEST contains articles about analysis of measured structural frequency response data and recent developments in hygrothermoviscoelastic analysis of composites.

Dr. M. Radeş of Polytechnic Institute Bucharest, Romania has written an article concerned with computer-aided analysis of data obtained by single vibrator excitation and the development of multi-vibrator excitation techniques.

Dr. T.J. Chung of the Department of Mechanical Engineering, University of Alabama in Huntsville has written a paper reviewing some recent advances in constitutive theories of hygrothermomechanical behavior of viscoelastic composites.

ANALYSIS OF MEASURED STRUCTURAL FREQUENCY RESPONSE DATA

M. Radeş*

Abstract. ***This article is concerned with computer-aided analysis of data obtained by single vibrator excitation and to the development of multi-vibrator excitation techniques.***

Methods for analyzing experimental frequency response data have been presented in two previous review articles [1, 2]. Excellent up-dated surveys have appeared in recent years [3-9].

There has recently been a marked increase in the use of frequency response measurement techniques to support studies of structural vibration [10-12]. Current digital signal processing equipment and software permit measurement and analysis of frequency response functions in a fraction of the time required by previous techniques. Efficient and reliable software has been developed for real-time data manipulation, on-line estimation of modal parameters, and data presentation in animated and annotated form.

Most advanced applications are concerned with mathematical modeling of structures in order to provide descriptions of actual dynamic behavior and to investigate the effects of modifications or connecting substructures [13, 14]. Combined experimental and analytical modal analyses have become a powerful, cost-effective tool in product development based on computer-aided design [15, 16].

Testing techniques can be divided into single vibrator and multi-vibrator excitation tests. This article describes these techniques.

SINGLE VIBRATOR TECHNIQUES

Single vibrator excitation techniques use frequency response information measured either between one force input point and several response points on the structure or between several force input points and a single response point. For most structures it is necessary to measure just one row or column of the transfer function matrix of the system to completely define the mode shapes of that system [17, 18]. A row in the response matrix can be best filled using random excitation at a single point and a rowing response transducer. A column can be best filled by impact testing with a stationary response transducer and rowing impact excitation [19].

Broadband excitation is routinely used to speed up and simplify modal testing. Types of excitation include pure random, pseudorandom, periodic random, shaped pseudorandom, impact, swept sine, periodic chirps, and step sine have been described and compared [20-23]. Pure and periodic random and impact were considered the most useful at that time. Comprehensive references for this type of testing are available [18, 24-28].

Several modal analysis systems are commercially available. Gen Rad 2507, 2508, and the Micro Modal Analyzer and Hewlett Packard 5423A and 5451B plus Option 402 are dedicated, function-based instruments. Other minicomputer-based systems are Spectral Dynamics SD2001DM, Nicolet OF-400B plus Option MA, Nicolet 6601B, Solartron 1191 and the Time/Data TDA3 plus Modal Analysis Software. Many companies have designed computer configurations with a flexible operating system and dedicated software. METRAVIB is using the SYAME-02 system based on a Nova 4X or an Eclipse minicomputer and the SYSTEC software [29]. ANCO Engrs. has designed a field portable vibration analysis system [30].

Digital spectrum analyzers generate transfer functions from transient or random single-point excitation and FFT evaluation. They include GenRad 2512, Spectral

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Dynamics SD345, SD350 and SD360 DSP, Bruel & Kjaer 2031, EMR Schlumberger 1510, Hewlett Packard 3582A, Nicolet 444A, 446B and 660A-2D, Rockland 512/S. Their effectiveness and moderate price have made them popular. Using IEEE 488 or RS232 interfaces, these can be connected to calculators such as HP 9800 series, Tektronix 4051, DEC PDP-11 or Data General NOVA to build modal analysis computerized systems. The new range of processing digital oscilloscopes including Tektronix 7704A and Norland Instr. 2001A can be used as well.

The minicomputer can efficiently handle large quantities of data and increases flexibility of data manipulation and presentation. If a structure behaves linearly and has a not-too-high modal density, a modal analysis system produces parameters more quickly and accurately than any other system. Increased frequency resolution of structures with closely spaced modes is obtained by zoom measurements (band selectable Fourier analysis).

Alternatively, low cost time-sharing computer-based modal analysis systems include Zonic's DMS/TSA testing system [19, 28, 31] which uses the SDRC DAD II software. Experience with computerized systems has been reported [4, 30, 32, 33].

GenRad, Zonic Tech. Lab., MTS, and Spectral Dynamics systems are supported by SDRC (Structural Dynamics Research Corp.) software. The general structure of the SDRC MODAL PLUS software package has been described by Klosterman and Zimmerman [34] and is part of the SDRC Mechanical Testing Library. A simpler version (MODAL) is used with the GenRad 2507 and 2508 Structural Analysis Systems. Hewlett Packard's MAP is based on the theory presented by Richardson [35].

Modal parameters for detailed structural modeling studies are calculated by curve-fitting the transfer functions to analytical models [36, 37]. Multi-degree-of-freedom curve fitting is used to estimate parameters. An iterative weighted least squares method is employed in which the quadratic error between measured and analytically derived response functions is minimized. Single-degree-of-freedom curve fit is used to estimate mode shape coefficients. A least-squares error circle fit is done in the Argand plane. The mode shape magnitude is taken proportional to circle diameter; phase is defined either by the vector from the center of the circle to the resonance frequency or by the vector from the origin of the coordinates to the center of the circle. Both complex and real modes can be considered.

A peak picking method is used for simpler resonance search or troubleshooting cases. Corresponding co-quad values are extracted at operator entered resonance frequencies.

All curve-fit methods are based on specific analytical models and require an estimate of the number of composing modes (with the risk of eliminating in advance some modes). The iterative process is begun with estimated values of some modal parameters. Several methods have been proposed [38-42], but none has been completely satisfactory. Consideration of residual terms -- the contribution of modes with resonances outside the analyzed frequency band -- is of great importance.

Because DAD [43], DYNPAR [38], MIDAS [44], IDEPP [45], GMAP [46], and other computer programs have demonstrated poor convergence of iterative methods when the initial estimates of natural frequencies, damping, and number of dominant modes are far from the real values, an interactive use is recommended. Possible improvements might be simultaneous multi-curve multi-mode fit [45] and use of redundant sets of data from more than one row or column of the transfer matrix of the system [25].

The problem of determining the number of dominant modes in a given frequency band has been considered [47]. Identification methods based on simplified expressions of the frequency response functions have been suggested [48-50]. Frequency domain procedures for estimating modal characteristics from response-only measurements have been discussed [51], as have approximate methods based on the relationship between the real and imaginary parts of a frequency response function [52].

Methods for improving an analytical model using results of vibration tests have been reported [4, 53-56]. Experimental problems raised by small-scale models [57], use of impedance heads [58], mass loading, and accelerometer loading errors [59] have been treated. An interesting survey [6] contains an assessment of current techniques for measuring structural mobility properties. Effects of Coulomb friction [60, 61], quadratic damping [62], nonlinear structural damping [63], cubic stiffness, and cubic damping [64] have been studied.

Comparisons of single-point random and multi-vibrator sine testing have been presented [65, 66]. Conclusions were contradictory with regard to accuracy, cost and time effectiveness, ease of implementation, and ability to isolate all significant modes.

A new method for parameter identification of linear systems has been suggested [67]. A modern approach to structural identification [68] consists of: formulation of a pretest analytical model; acquisition and reduction of experimental data taken from static and dynamic tests; eigenparameter identifiction; and post-test model refinement via Bayesian estimation techniques.

MULTI-VIBRATOR TECHNIQUES

Multi-vibrator excitation technqiues can be divided into appropriated excitation or non-appropriated excitation methods. The first category includes analytically aided tuning methods that use information from non-appropriated excitation, even from single-vibrator tests.

Appropriated Excitation Techniques

The main objective of appropriated excitation techniques is to excite (tune) a pure undamped natural mode of a system using a set of synchronous and coherently phased forces [9, 69, 70]. Mode shape vectors are determined by direct measurement of (total or quadrature) responses at phase resonances. Subsequent parameter identification is performed using either methods developed for single-degree-of-freedom systems [1] or specific methods. Tuning of undamped modes can be done by sinusoidal dwells or sweeps.

Tuned-dwell methods. Tuned-dwell methods [71-74] are experimental iterative processes that either minimize phase lags between discrete points or monitor the peaks and zeroes of real and imaginary components of response. Critical comments [69, 75, 76] reveal the complicated instrumentation required, the inadequate strategy of adjusting force ratios, the possibility of overlooking modes, and the limitation in some cases to nonproportionally damped structures. GRAMPA [77], MAMA [78], and other automatic techniques have been described [79].

Early parameter identification procedures based on either the method of displaced frequencies or the method of forces in quadrature have been reviewed [80-82]. Use of additional masses or stiffnesses and of additional reactive forces generally involves retuning or consideration of mode shape changes. Many features of classical methods have not yet been fully investigated because of equipment limitations at the time they were used. Further research is needed in this direction.

Sine-dwell methods are inadequate for analyzing systems with very close natural frequencies. Their results are dependent on operator skill and experience. Such modern computerized systems as MOD-APS [83] have servo lock systems and the capability to use analytically aided tuning.

Tuned-sweep methods. Tuned-sweep methods combine the advantages of multi-driver tuning and curve-fitting techniques. Narrow-band sine sweeps are done close to the undamped natural frequencies with fixed force-amplitude distribution. Analysis of co-quad plots of the complex response admittance provides good estimates of mode shapes and modal parameters for systems with proportional damping. Multi-vibrator frequency-response functions are used for nonproportionally damped systems.

The complex power method [84, 81] is a parametric identification technique that requires perfect modal tuning. The frequency dependence of the coincident and quadrature components of the applied complex power are plotted in the neighborhood of each resonance to establish a modal purity criterion. Generalized masses, stiffnesses, and diagonal damping ratios can then be determined. A computerized system for implementing the method has been set up [85]. A similar method, including a force-appropriation technique, has been suggested [86].

The complex energy admittance technique [87] eliminates the necessity for perfect tuning. It uses the co-quad plots of complex ratios of the total (or local) kinetic energy of the system to the applied power; the energy and applied power are analogous to the co-quad plots of the displacement admittance of single-degree-of-freedom systems. The MODALAB automated test system has been designed to apply this procedure [88].

None of the above methods can assure adequate tuning. Difficulties are encountered in maintaining fixed amplitudes and phases of applied forces due to the interaction between vibrators and tested structure. Limits imposed on the excitation level and inaccessibility of key points produce untunable modes that affect the accuracy of any multi-vibrator method.

Analytically-aided tuning methods. Analytically-aided tuning methods became effective after the development of powerful digital systems. They generally use experimental frequency response data generated by single-vibrator sweeps, but multi-vibrator excitation has been used as well [70, 89].

Early attempts for a systematic appropriation of excitation forces that would be valid for systems with nonproportional damping have been made by Asher [90], Traill-Nash [89], and Clerc [91]. The theory and practical application of Asher's method have been presented [69, 75, 76, 88, 92-94]. It has been proved analytically [93] and experimentally [88] that the method can separate closely spaced modes. Numerical simulation studies [69, 75, 94] have shown both success and failure of the method. A procedure for designing mathematical structural models having closely spaced modes has been used [95]. The case of incomplete excitation (fewer vibrators than degrees of freedom) has been analyzed [70, 75].

Undamped natural frequencies are determined at the steep zero crossings of the determinant of the coincident response matrix plotted versus frequency. Zero crossings that are not true natural frequencies can occur, mostly as a result of incomplete excitation. It has been shown [75] that modes corresponding to these spurious frequencies exhibit large phase errors at some of the non-excited stations and can thus be readily identified.

Two strategies have been suggested for positioning vibrators. One requires successive location of vibrators at points at which the largest error in the modal purity criterion is observed. In other methods vibrator displacement is based either on the operator's experience or on a pretest model [70]. Improvements of Asher's method include consideration of different numbers of sources than measurement points, use of transient or impulsive forces, and use of multiple exciter sweeps for data collection. The problem of determining the number of vibrators required to tune a mode has also been discussed [75, 69, 89, 96].

Another method [97] uses previously estimated natural frequencies and iterates directly with multiple vibrators. The objective is to minimize some global modal purity criterion functions. It is well suited to automation. Methods based on the calculation of tuning forces from responses to non-appropriated excitations have been proposed [45, 91, 98] and reviewed [9, 99].

Methods limited to systems having proportional damping have been suggested. One method is based on a modal elimination process [100]. The others use incomplete excitation [101] or even a very small number of vibrators [65]. In Morosow's method, the errors due to residual phase lags at the excitation points and to the interference of neighboring modes removed by using an iterative algorithm that suppresses responses in the undesired modes.

Use of incomplete excitation or supplementary measuring points requires manipulation of rectangular matrices. Good results for calculating the pseudo inverse have been obtained with a new algorithm [102]. Of particular interest for further research are the methods the objective of which is the excitation of the damped modes of a structure [103, 104].

Non-appropriated Excitation Methods

Non-appropriated excitation methods do not include experimental modal tuning. Techniques developed in Europe through 1976 have been reviewed [105]. A comparative study of some methods [106-108] has been done [109] and criticized [110]. Base excitation has also been considered [111]. Some methods reported [107, 108] are the first attempts to determine damped complex modes of vibration and corresponding complex eigenvalues using multi-point excitation. Natke's method uses a single non-appropriated harmonic excitation distribution.

Angelini [106] extended Traill-Nash's method of independent forces [89]. Testing begins with measurement at discrete frequencies of a complex square matrix of N response vectors due to N independent force vectors; these data are stored. A complex NxN matrix is formed; the response matrix is premultiplied by the transpose of the square matrix of the forcing vectors. The eigenvalues and eigenvectors of the real part of this matrix are calculated at discrete frequencies. The latent roots of this matrix are the undamped natural frequencies. The latent vectors are further used to determine mode shapes and modal parameters; the real and imaginary parts of the matrix evaluated at each natural frequency are used. Equipment used at ONERA to implement the method has been described [100]. An alternative method [112] has been suggested in which the eigenvalue problem of the real part of the matrix of complex responses is solved. It requires acquisition and manipulation of large quantities of data.

A general theory of the characteristic eigenvalues by the author [113] combines the advantages of the techniques developed by Asher and Angelini. The system transfer function matrix is used in one variant of the new method. The determinant of the real part of this matrix is plotted against frequency and used, as in Asher's method, to locate undamped natural frequencies. The slope is proportional to the modal mass at the points of zero crossing. The nonzero eigenvalues of the coincident response matrix must be calculated at the natural frequencies. The latent vectors are the forced modes of excitation. The quadrature response matrix, estimated at each natural frequency, is used to calculate mode shape vectors and modal damping coefficients.

A promising adaptation of Asher's method [94] is based on a modal analysis system. A three-step procedure is suggested: 1) generation of the transfer function matrix by broad-band single-point excitation, temporary storage of incremental frequency data, FFT evaluation, curve fitting, and final storage of parameters from the curve-fit equations; 2) use of Asher's method to determine undamped natural frequencies and corresponding tuning force-amplitude distributions; 3) generation of co-quad plots of the responses in each mode by numerically simulated narrow-band sweeps. The effectiveness of the method has been demonstrated numerically.

Another method [45] is based on measurements of responses produced at a single point by forces applied in turn at N points on the structure. The response that would be produced by simultaneous application of forces at all N points is calculated by superposition. Force amplitudes are determined by an iterative least squares fit to the response in a natural mode. Modal damping and natural frequencies as well as forced modes of excitation are obtained using the program AMSIC. The mode shapes are obtained afterward.

Of particular interest is the capability of the above methods to analyze systems having close natural frequencies. More work is needed to assess the influence of structural nonlinearities on their accuracy.

APPLICATIONS

Most applications of the above methods are from the aerospace and automotive industries. Others are described in two comprehensive surveys [4, 114] or have been reported in papers presented at three recent meetings held at Leuven [10], Besancon [11], and Udine [12].

A number of interesting studies have recently been made concerning machine tools [23], vehicles [15, 115, 116], helicopters [117], gas turbine buckets [18], compressor blades [118], gear units [119], cooling towers [120], gas diffusion columns [45], and off-shore platforms [29]. Other significant contributions include flutter testing [121], ship-hull vibration studies [122], and identification of stiffness and damping coefficients of journal bearings [123].

CONCLUSIONS

The past few years have been dominated by the development of dedicated computerized commercially-available modal analysis systems. In most practical applications, they give the best trade off between test cost and accuracy of results. Fewer novel methods than review papers have been published, and there is need of further experimentally-based comparative studies to assess the capabilities of existing methods.

New techniques have been suggested for analytically-aided and/or numerically simulated modal tuning.

More basic research is needed regarding the optimization of shaker locations and use of complex damped modes of vibration in multi-vibrator excitation techniques applied to large structures.

In cases of high modal density and coupling, many current methods fail to isolate all significant modes and cannot distinguish false modes introduced by test attachments. Research is required to develop combined part time-domain part frequency-domain modal analysis methods that utilize the capabilities of modern equipment to collect, transform, and analyze data in both time and frequency domains. Combined use of mobility-type and impedance-type data, including rotational mobilities, might improve the accuracy of existing curve-fitting methods.

Investigation of the capability of known techniques to provide nonlinear analyses, improvement of measurement techniques in order to obtain more consistent experimental data, and development of parameter estimation algorithms requiring less user interaction and based on simultaneous ensemble curve-fitting are also areas in need of further study.

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RECENT DEVELOPMENTS IN HYGROTHERMOVISCOELASTIC ANALYSIS OF COMPOSITES

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Abstract. The physical phenomena associated with moisture diffusion and heat transfer in composite materials under static or dynamic loadings have been studied extensively in recent years. Objects of study include aircraft subjected to hostile weather during prolonged periods of service, moisture infiltration in solid rocket propellants, and loss of load carrying capacity in aerospace vehicles and components during heating, cooling, and moisture changes. This article reviews some recent advances in constitutive theories of hygrothermomechanical behavior of viscoelastic composites.

Epoxy composite structures reinforced with glass, boron, or graphite fibers are widely used because of their superior performance characteristics. It is known that the adverse effects of moisture and heat on the strength of composites are significant and should be accounted for in design. Moisture absorption in a composite laminate dilates the matrix and reduces the resin softening temperature or glass transition temperature. Furthermore, it is possible that the concentration gradients of moisture diffusion could cause unequal swelling stresses and result in the formation of microcracks as well as predictable dimensional changes in both resin and lamina .

When a hygroscopic environment is coupled to high temperatures, test results of matrix-fiber composites show that significant degradation occurs [1-14]. If mechanical loading is combined with long-term hygrothermal environments, however, laboratory measurements are not possible. Thus, a customary procedure for determining degradation is to first subject a specimen to hygrothermal loadings and then independently subject it to mechanical load. Under service conditions, however, complete coupling of hygroscopic, thermal, and mechanical loadings would be necessary because their effects on each other must be recognized [15-17].

Suppose moisture is in contact with the surface of a matrix-laminate. It can be postulated that fluid particles wander in a random manner through the lattice but tend to get trapped or delayed at certain fixed sites. It can further be postulated that the probability that active traps capture a hydrogen atom is proportional to the concentration of diffusing hydrogen. An additional variable is the fraction of occupied traps that might release hydrogen atoms. Thus, on one hand, a free phase is associated with the diffusing fluid; on the other hand, a bound phase contains trapped fluid particles.

Under such conditions the conventional Fick's law is no longer valid, and an additional relationship is needed to describe the time rate of change of the trapped phase [18-21]. In addition, the mass flux for the free phase is assumed to be a function of the gradients of temperature and strain as well as moisture concentration; this can be called the modified Fick's law. The so-called Dutfour and Soret effects are included in the formulation.

The consistent governing equations for two-phase diffusion are derived in the context of chemical potential, which is the rate of change of free energy with respect to moisture concentration. The temperature distribution is governed by the modified Fourier law, in which heat flux is considered a function of both moisture and temperature gradients. The hygrothermal equations are shown to be a consequence of the second law of thermodynamics with modification for moisture diffusion.

The mechanics of deformation of the matrix-laminate system is described by the first law of thermodynamics coupled completely with hygrothermal behavior.

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The constitutive equation includes viscoelastic behavior and the irreversible process combined with the second law of thermodynamics. The resulting equations are rigorous in theory and convenient for numerical analysis.

This paper presents recent developments in theoretical formulations and predictions of responses of a matrix laminate subjected to hygrothermomechanical loadings. It is concluded that the approach can be used successfully to provide design criteria that will keep the material from failure.

BALANCE LAWS AND CONSTITUTIVE STRUCTURE

The most consistent approach for deriving a constitutive theory stems from adherence to balance laws -- conservation of mass, momentum, and energy. It is thus necessary to choose either a Lagrangian or Eulerian coordinate system. The conservation of mass requires

$$\rho_0 = \rho\sqrt{G} \qquad \text{for Lagrangian coordinates} \tag{1}$$

$$\frac{\partial\rho}{\partial t} + \underset{\sim}{\nabla} \cdot \rho\underset{\sim}{V} = 0 \qquad \text{for Eulerian coordinates} \tag{2}$$

where ρ is the density, $\underset{\sim}{V}$ is the velocity vector, and G is the determinant of the metric tensor. Because no solid or fluid particles are expected to undergo large motions, the Eulerian coordinate system is not needed, and the logical choice is Lagrangian coordinates. For small deformations the metric tensor G is unity; the density ρ is equal to the initial density ρ_0. The total mass consists of contributions from matrix, fibers, and the free and bound phases of moisture

$$\rho = \sum_k \rho_k \qquad (k=1,2,3,4)$$

Consider a motion governed by the following functions: body force f_i, stress σ_{ij}, thermal flux $q_i^{(T)}$, moisture flux $q_i^{(M)}$, heat supply $h^{(T)}$, moisture supply $h^{(M)}$, entropy due to temperaure $\eta^{(T)}$, and the chemical potential $\eta^{(M)}$ which may also be called the entropy due to moisture. The combined thermal and hygroscopic quantities are $q_i = q_i^{(T)} + q_i^{(M)}$, $h = h^{(T)} + h^{(M)}$.

The first law of thermodynamics is given by

$$\dot{K} + \dot{U} = R + Q \tag{3}$$

The kinetic energy K, internal energy U, mechanical power R, and heat sources Q are defined as

$$K = \frac{1}{2}\int_\Omega \rho V_i V_i d\Omega \tag{4}$$

$$U = \int_\Omega \rho\varepsilon d\Omega \tag{5}$$

$$R = \int_\Omega \rho f_i V_i d\Omega + \int_\Gamma \sigma_{ij} n_j V_i d\Gamma \tag{6}$$

$$Q = \int_\Omega \rho h d\Omega + \int_\Gamma q_i n_i d\Gamma \tag{7}$$

where Ω is the interior domain, Γ is the boundary surface, and n_i is the component of a vector normal to the boundary surface. It can be shown that the consequence of the first law of thermodynamics assumes the conservation of mass and the balance of momentum and energy such that

$$\rho\ddot{u}_i - \sigma_{ij,j} - \rho f_i = 0 \tag{8}$$

$$\rho\dot{\varepsilon} = \sigma_{ij}\dot{\gamma}_{ij} + q_{i,i} + \rho h \tag{9}$$

where u_i and γ_{ij} are the components of the displacement and strain tensor respectively.

ENTROPIES AND IRREVERSIBLE PROCESSES

The second law of thermodynamics in local form is given by

$$d\dot{\eta}^{(T)} - \frac{dQ^{(T)}}{\theta} \geq 0 \tag{10a}$$

where θ is the absolute temperature; $\theta = T_0 + T$, and T_0 and T are the initial temperature and the temperature change respectively. The global form of equation (10a) for an irreversible process is

$$\int_\Omega \rho\dot{\eta}^{(T)} d\Omega - \int_\Omega \frac{\rho h^{(T)}}{\theta} d\Omega - \int_\Gamma \frac{q_i^{(T)} n_i}{\theta} d\Gamma \geq 0 \tag{10b}$$

Use a similar argument to write $\mathcal{M} = M_0 + M$ where $\mathcal{M}$, M_0, and M are the total moisture content, initial moisture content, and change in moisture. The chemical potential $\eta^{(M)}$ has a unit of (lb-in.)/(unit mass) as compared with (lb-in.)/(unit mass-°C) for the entropy due to temperature. It is asserted [13] that irreversibility also arises from moisture infiltration and results in the condition

$$d\dot{\eta}^{(M)} - \frac{dQ^{(M)}}{\mathcal{M}} \geq 0 \quad (11a)$$

and

$$\int_\Omega \rho\dot{\eta}^{(M)} d\Omega - \int_\Omega \frac{\rho h^{(M)}}{\mathcal{M}} d\Omega - \int_\Gamma \frac{q_i^{(M)} n_i}{\mathcal{M}} d\Gamma \geq 0 \quad (11b)$$

The expressions (10b) and (11b) respectively are written using the Green-Gauss theorem

$$\int_\Omega \left(\rho\theta\dot{\eta}^{(T)} - q_{i,i}^{(T)} - \rho h^{(T)} + \frac{1}{\theta} q_i^{(T)} \theta_{,i}\right) d\Omega \geq 0 \quad (12a)$$

and

$$\int_\Omega \left(\rho\mathcal{M}\dot{\eta}^{(M)} - q_{i,i}^{(M)} - \rho h^{(M)} + \frac{1}{\mathcal{M}} q_i^{(M)} \mathcal{M}_{,i}\right) d\Omega \geq 0 \quad (12b)$$

For the above expressions to be valid for all arbitrary volumes the integrands must be of the form

$$D^{(T)} + \frac{1}{\theta} q_i^{(T)} \theta_{,i} \geq 0, \quad D^{(M)} + \frac{1}{\mathcal{M}} q_i^{(M)} \mathcal{M}_{,i} \geq 0 \quad (13)$$

The total internal dissipation D is given by

$$D = D^{(T)} + D^{(M)} \geq 0 \quad (14)$$

for an irreversible process. The internal dissipations due to temperature and moisture are respectively

$$D^{(T)} = \rho\theta\dot{\eta}^{(T)} - q_{i,i}^{(T)} - \rho h^{(T)} \quad (15a)$$

$$D^{(M)} = \rho\mathcal{M}\dot{\eta}^{(M)} - q_{i,i}^{(M)} - \rho h^{(M)} \quad (15b)$$

The expressions (15a) and (15b) are the equations of heat conduction and diffusion respectively. To satisfy equation (14), in which the total internal dissipation is the sum of the dissipation from both temperature and moisture, introduce a parameter such that

$$0 \leq \phi \leq 1$$

Write the internal dissipations due to temperature and moisture with respect to the total internal dissipation respectively

$$D^{(T)} = \phi D \quad (16)$$

$$D^{(M)} = (1-\phi)D \quad (17)$$

The parameter ϕ signifies the portion of dissipation arising only from temperature. Thus, for an irreversible process $D^{(T)} > 0$ and $D^{(M)} > 0$ is assured. If the process is reversible, then $D^{(T)} = 0$ and $D^{(M)} = 0$. The notion of dissipation due to moisture infiltration is important not only because the classical diffusion equation results as a special case but also because the reasonable assertion that moisture infiltration creates an irreversible state of stress and strain and consequently dissipative energy can be taken into account.

The governing equations for heat conduction and moisture diffusion completely coupled with deformation are, from (15a) and (15b) respectively

$$\rho\theta\dot{\eta}^{(T)} - q_{i,i}^{(T)} - \rho h^{(T)} - D^{(T)} = 0 \quad (18)$$

$$\rho\mathcal{M}\dot{\eta}^{(M)} - q_{i,i}^{(M)} - \rho h^{(M)} - D^{(M)} = 0 \quad (19)$$

Note that expressions (18) and (19) are the consequence of energy equation (9) and the second law of thermodynamics, equation (11).

Constitutive equations are required for the stress (σ_{ij}), entropies ($\eta^{(T)}$, $\eta^{(M)}$), fluxes ($q_i^{(T)}$, $q_i^{(M)}$), and internal dissipations ($D^{(T)}$, $D^{(M)}$). Begin [22] with the Helmholtz free energy, which is assumed to be dependent on the strain (γ_{ij}); absolute temperature (θ); moisture concentration ($\mathcal{M}$); and the internal state variables ($\alpha_{ij}^{(r)}$).

$$\Psi = \Psi(\gamma_{ij}, \theta, \mathcal{M}, \alpha_{ij}^{(r)}) = \varepsilon - \theta\eta^{(T)} - \mathcal{M}\eta^{(M)} \quad (20)$$

Here $\alpha_{ij}^{(r)}$ (r = 1, 2, . . .) implies a possible damping effect (viscoelastic) that could lead to an irreversible process; it can be given by a generalized Maxwell-type kernal [23]

$$\alpha_{ij}^{(r)} = \int_0^t \exp\left[-\frac{(t-\tau)}{T_{(r)}}\right] \frac{\partial\gamma_{ij}}{\partial\tau} d\tau \qquad (21)$$

$T_{(r)}$ is the relaxation time and τ is the time variable.

FREE AND BOUND PHASES

Moisture diffusion is considered to be associated with a free phase ($M^{(f)}$) subjected to diffusion through the matrix. It is possible that some of the moisture particles (hydrogen) are attracted to the surfaces of the solid material (matrix-laminate), thus forming a bound phase ($M^{(b)}$). Assume that $M^{(f)}$ is a function of both space and time, whereas $M^{(b)}$ is a function of time only. The reason is that, after a hydrogen atom is trapped, it either remains immobile or does not change with respect to spatial position; the atom changes only with respect to time as the hydrogen is sooner or later freed. The time rate of change of $M^{(b)}$ is given by [18-21]

$$\frac{\partial M^{(b)}}{\partial t} = C_1 M^{(f)} - C_2 M^{(b)} \qquad (22a)$$

C_1 and C_2 denote constants associated with probabilities of hydrogen being captured and freed respectively. The total moisture concentration M, from the assumptions given above, is related as follows.

$$M = M^{(f)} + M^{(b)} \qquad (22b)$$

$$\dot{M} = \dot{M}^{(f)} + \dot{M}^{(b)} \qquad (22c)$$

$$M_{,i} = M^{(f)}_{,i} \qquad (22d)$$

The expressions (22a-d) will be incorporated into the two-phase diffusion equations.

CONSTITUTIVE EQUATION

The time rate of change of free energy per unit volume in equation (20) combined with equations (14) and (9) yields, for an irreversible process

$$D = D^{(T)} + D^{(M)} = \sigma_{ij}\dot{\gamma}_{ij} - \rho\left(\frac{\partial\Psi}{\partial\gamma_{ij}}\dot{\gamma}_{ij} + \frac{\partial\Psi}{\partial\theta}\dot{\theta} + \frac{\partial\Psi}{\partial M}\dot{M} + \frac{\partial\Psi}{\partial\alpha_{ij}^{(r)}}\dot{\alpha}_{ij}^{(r)}\right) - \rho\eta^{(T)}\dot{\theta} - \rho\eta^{(M)}\dot{M} \geq 0 \qquad (23)$$

This expression provides the following constitutive relations

$$\sigma_{ij} = \rho\frac{\partial\Psi}{\partial\gamma_{ij}} \qquad (24)$$

$$\rho\eta^{(T)} = -\rho\frac{\partial\Psi}{\partial\theta} \qquad (25)$$

$$\rho\eta^{(M)} = -\rho\frac{\partial\Psi}{\partial M} \qquad (26)$$

$$D^{(M)} = -\phi\sum_{r=1}^{n}\frac{\partial\Psi}{\partial\alpha_{ij}^{(r)}}\dot{\alpha}_{ij}^{(r)} \geq 0 \qquad (27)$$

$$D^{(T)} = -(1-\phi)\sum_{r=1}^{n}\frac{\partial\Psi}{\partial\alpha_{ij}^{(r)}}\dot{\alpha}_{ij}^{(r)} \geq 0 \qquad (28)$$

Note that the hygroscopic entropy assumes the same form as the conventional chemical potential, which represents the derivative of Helmholtz energy with respect to concentration. In view of the functional representation in equation (20) and the small strain assumption, it is appropriate to expand the free energy in a quadratic Taylor series form of the variables γ_{ij}, T, M, and $\alpha_{ij}^{(r)}$. This gives

$$\rho\Psi = \frac{1}{2}E_{ijkl}\gamma_{ij}\gamma_{kl} - \beta_{ij}^{(T)}T\gamma_{ij} - \beta_{ij}^{(M)}M\gamma_{ij} - \frac{1}{2}\frac{c}{T_0}T^2 - \frac{1}{2}\frac{b}{M_0}M^2 - \chi TM - \sum_{r=1}^{n}B_{ij}^{(T)}(r)\,T\alpha_{ij}^{(r)} - \sum_{r=1}^{n}B_{ij}^{(M)}(r)\,M\alpha_{ij}^{(r)} + \frac{1}{2}\sum_{r=1}^{n}\xi_{ijkl}^{(r)}\alpha_{ij}^{(r)}\alpha_{kl}^{(r)} + \sum_{r=1}^{n}\xi_{ijkl}^{(r)}\alpha_{ij}^{(r)}\gamma_{kl} \qquad (29)$$

E_{ijkl} denotes the fourth order tensor of anisotropic elastic moduli; $\beta_{ij}^{(T)}$ and $\beta_{ij}^{(M)}$ are the second-order tensors of anisotropic thermoelastic moduli and anisotropic hygroelastic moduli respectively. The constants c and b are the heat capacity and hygroscopic capacity respectively. The symbol χ is defined as the hygrothermal coefficient. $B_{ij}^{(T)}(r)$ and $B_{ij}^{(M)}(r)$ are the second order tensors of anisotropic dissipative thermoelastic and hygroelastic constants respectively; $\xi^{(r)}_{ijkl}$ denotes the fourth order tensor of dissipative elastic constants.

It follows from expressions (24) - (28) that

$$\sigma_{ij} = E_{ijkl}\gamma_{kl} - \beta^{(T)}_{ij}T - \beta^{(M)}_{ij}M + \sum_{r=1}^{n} \xi^{(r)}_{ijkl}\, \alpha^{(r)}_{kl} \quad (30)$$

$$\rho\eta^{(T)} = \beta^{(T)}_{ij}\gamma_{ij} + \frac{c}{T_0}T + \chi M + \sum_{r=1}^{n} \beta^{(T)}_{ij}(r)\alpha^{(r)}_{ij} \quad (31)$$

$$\rho\eta^{(M)} = \beta^{(M)}_{ij}\gamma_{ij} + \frac{b}{M_0}M + \chi T + \sum_{r=1}^{n} \beta^{(M)}_{ij}(r)\, \alpha^{(r)}_{ij} \quad (32)$$

Furthermore, adequate forms of heat flux and mass flux must be described. To this end, the diffusion-thermal effect or Duffour effect, $q_{ij}M_{,j}$, is applied to the heat flux; the thermal-diffusion effect or Soret effect, $Q_{ij}T_{,j} - G_{ijkl}\gamma_{kl,j}$, is applied to the mass flux [24] such that

$$q_i^{(T)} = k_{ij}T_{,j} + q_{ij}M^{(f)}_{,j} \quad (33)$$

$$q_i^{(M)} = D_{ij}M_{,j} + Q_{ij}T_{,j} - G_{ijkl}\gamma_{kl,j} \quad (34)$$

where k_{ij} and D_{ij} are the standard coefficients of thermal conductivity and diffusion respectively, q_{ij} is the diffusion-thermal coefficient, Q_{ij} is the thermal-diffusion coefficient, and G_{ijkl} is the hygroelastic modulus. Note that all of these constants refer to anisotropic media and assume appropriate forms of isotropic tensors when the material is isotropic. For example, $G_{ijkl}\gamma_{kl,j}$ becomes $\hat{\zeta}\gamma_{kk,i} = \hat{\zeta}\sigma_{kk,i} = \zeta P_{,i}$. The fourth order tensor G_{ijkl} is thus changed into a scalar, and the equivalent of the gradient of pressure P results. It is well known that the diffusion coefficient D_{ij} can be dependent on temperature [25] so that

$$D_{ij} = D^0_{ij} \exp\left[\frac{-\acute{e}}{R\theta}\right] \quad (35)$$

D^0_{ij} is the frequency factor or permeability index, e is the activation energy, and R is the universal gas constant.

GOVERNING EQUATIONS

In view of expressions (8), (18), (19), and (22) the final forms of the governing equations for an irreversible process are written

Momentum equation

$$\rho\ddot{u}_i - E_{ijkl}u_{k,lj} + \beta^{(T)}_{ij}T_{,j} + \beta^{(M)}_{ij}M_{,j} - \sum_{r=1}^{n} \xi^{(r)}_{ijkl}\alpha^{(r)}_{kl} - \rho f_i = 0 \quad (36)$$

Heat conduction equation

$$\frac{\theta}{T_0}c\dot{T} + \theta\left(\beta^{(T)}_{ij}\dot{\gamma}_{ij} + \sum_{r=1}^{n} \beta^{(T)}_{ij}(r)\dot{\alpha}_{ij}^{(r)} + \chi\dot{M}\right) - (K_{ij}T_{,j})_{,i} - (q_{ij}M_{,j})_{,i} - \rho h^{(T)} - D^{(T)} = 0 \quad (37)$$

Two-phase diffusion equations

$$\frac{M}{M_0}b\dot{M} + M\left(\beta^{(M)}_{ij}\dot{\gamma}_{ij} + \sum_{r=1}^{n} \beta^{(M)}_{ij}(r)\dot{\alpha}_{ij}^{(r)} + \chi\dot{T}\right) - (D_{ij}M_{,j})_{,i} - (Q_{ij}T_{,j})_{,i} + (G_{ijkl}\gamma_{kl,j})_{,i} - \rho h^{(M)} - D^{(M)} = 0 \quad (38)$$

$$\dot{M}^{(b)} = C_1\dot{M}^{(f)} - C_2\dot{M}^{(b)} \quad (39)$$

$$M = M^{(f)} + M^{(b)} \quad (40)$$

Note that for transient analysis the temperature change is small in comparison with reference temperature. Thus, set $\theta/T_0 \simeq 1$, $\theta \simeq T_0$. The variables to be solved are displacement u_i, temperature change T, total moisture M, free phase moisture content $M^{(f)}$, and bound phase moisture content $M^{(b)}$. Expression (40) is applied as a constraint condition. The calculations can be simplified by eliminating $M^{(b)}$ such that expressions (39) and (40) result in a single equation.

$$\dot{M} - \dot{M}^{(f)} - (C_1 - C_2)M^{(f)} + C_2M = 0 \quad (41)$$

If the initial moisture content is zero, the first two terms in expression (38) should be dropped. The simultaneous solution of expressions (36), (37), (38) and (41) takes into account a complete coupling of the deformation field with heat and mass transfer of moisture; this coupling is consistent with the first and second laws of thermodynamics and with observed physical phenomena cited in the literature.

A number of simplifications can be made so that the governing equations become equivalent to special cases reported by other investigators. For example, if

- the process is reversible, $D^{(T)} = D^{(M)} = 0$
- no viscoelastic effect is present, all terms containing the internal state variables α_{ij} are set equal to zero
- the bound phase is negligible, the expressions (39) to (41) are disregarded ($M^{(b)} = 0$, $M = M^{(f)}$)
- the Duffour effect is negligible, set the moisture gradient term in equation (33) equal to zero
- the Soret effect is negligible, the terms of temperature gradient and strain gradient in equation (34) are disregarded
- the hygrothermal coupling effect is negligible ($\chi = 0$), the terms involved with χ in expressions (37) and (38) are set equal to zero
- thermoelastic coupling is negligible, the term associated with $\beta_{ij}^{(T)}$ in expression (37) is disregarded
- hygroelastic coupling is negligible, the term associated with $\beta_{ij}^{(M)}$ in expression (38) is disregarded

With these simplifications the decoupled equations of motion, heat conduction, and diffusion result from expressions (36), (37), and (38) respectively.

High temperature and moisture infiltration into matrix-laminates degrade the material properties through a relation of the type

$$E = \hat{E}\,(1-e^{-d}) \tag{42}$$

where d is the total degradation factor given by

$$d = f\left[\theta,\ M,\ \delta^{(T)},\ \delta^{(M)}\right] \tag{43}$$

Here $\delta^{(T)}$ and $\delta^{(M)}$ are the degradation coefficients due to temperature and moisture respectively, and E is Young's modulus for a one-dimensional matrix fiber composite specimen given by

$$\hat{E} = \nu_f \hat{E}_f + \nu_m \hat{E}_m \tag{44}$$

with ν_m and ν_f denoting the volume contents of matrix and fiber respectively, and E_m and E_f the Young's modulus for the matrix and fiber respectively. Note that the degradation factor can theoretically be between zero and ∞. The practical range, however, should be quite narrow. For example, if the material suffers a loss of strength of 50% to 95%, the corresponding degradation factor should be between 0.7 and 3. The functional relationship of expression (43) can be determined by controlled laboratory experiments. A provision should be made so that the degradation factor is dependent of current temperature and moisture concentration and so that the influence is allowed to disappear at the reference temperature and at zero moisture infiltration.

APPLICATIONS

Solutions of simplified versions of expressions (36) through (40) have been attempted and the results reported for a one-dimensional solution [15] and a two-dimensional solution [16]. Viscoelastic effects were not considered.

In a recent paper [26], two-dimensional viscoelastic behavior was studied in detail; calculations of irreversible dissipation and a two-phase model for moisture distributions were left as future tasks.

CONCLUSIONS

Recent developments in hygrothermoviscoelastic analysis have been reviewed. Most of the previous results by various investigators can be obtained as special cases of the general approach presented herein. The first and second laws of thermodynamics are extended to include moisture diffusion. Duffour and Soret effects and a two-phase diffusion model depecting the free and bound phases can be incorporated into the most general forms of the governing equations.

Future studies should lead to computational efficiency for the solution of general equations and the evaluation of degradation factors from experimental results. When these tasks are completed, it is hoped that the design data for composite materials subjected to hostile environments can be more accurately and speedily obtained.

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BOOK REVIEWS

ENGINEERING DESIGN

J.H. Faupel and F.E. Fisher
John Wiley and Sons, New York
2nd Edition, 1981, 1056 pages, $41.00

The original edition of this book was popular for 15 years; the new edition is an updated version of the first. Stress analysis, materials engineering, and applications of mechanics to engineering design are covered, as are new techniques in composite materials, fracture mechanics, fatigue, and finite elements (FE).

The new edition has been expanded to 15 chapters from the original 12. Chapters 1 and 2 consider materials and properties, tension, and theories on torsion and bending. Chapter 3 deals with strength under combined stresses and includes maximum stress, maximum shear, and distortion energy theories.

Chapter 4 discusses analysis of composites and reinforced materials and includes a new section on sandwich and honeycomb structures. There is hardly any mention of reinforced sheet-stringer combinations. Chapter 5 deals with the design of structures employing plastics and is based on concepts of viscoelasticity; it is an informative introduction to plastic design theory.

Chapter 6 focuses on the subject of the elasto-plastic regime. Basic concepts and stress-strain relations, plasticity in machines, and structural design are applied to heavy wall cylinders and metal working. The reviewer would have preferred a section on applications to composite materials beyond the elastic range.

Chapter 7 introduces energy methods in design and derives various strain energies in tension (compression), uniaxial bending, shear, and torsion. The theory of virtual work and Castigliano's complementary energy theorems are directly applied from the strain energy theory. The chapter concludes with a short discussion of unit load (dummy load method) and an introduction to stiffness and flexibility matrices. The author makes no mention of shear deformation or slope deflection method. The reviewer considers them an important phase in formulating stiffness matrices.

Chapter 8 leads into FE and finite differences. Plates and shells are briefly described; stiffness matrices are not derived. Finite difference applications include plate loading. The reviewer believes this chapter is too concise.

Chapter 9 applies elastic buckling to columns using Euler's and Rankine's formulas and touches upon plastic buckling. An extensive section on buckling of complex structural elements is introduced by beam column theory. Plates, conical shells, and stiffened shells are described. Procedures and specific examples are taken from the ASME Boiler and Pressure Vessel Codes.

The section on dynamic theory includes vibration, shock, and impact. Centrifugal loading effects are applied to bars, cylinders, and discs. A simple application of torsional bending of a beam concludes the chapter. The reviewer believes that the addition of Dunkerly's rule and Holzer's method for torsional analysis would have enhanced this chapter.

Chapter 9 introduces the reader to prestressing a body when stresses are generated within the body. The stresses do not disappear on removal of the load. Among the subjects considered are shrink-fit construction under static and centrifugal forces, autofrettage, and machining stresses. No mention is made of shot-peening and case-hardened surfaces, both of which are practical applications of beneficial residual stress.

Fatigue is the subject of Chapter 12. Included are theories of failure -- i.e., those of Gerber, Soderberg, and Goodman -- and such conditions as surface, size, shape, temperature, residual stress, environment, fretting, and mean stress. The S/N fatigue curve is presented and applied. Cumulative damage theory is touched upon, but Miner's Rule is not mentioned. The chapter concludes with applications based on the Boiler and Pressure Vessel Code. The reviewer would have liked a more detailed section on low cycle fatigue and applications of Langer's approach to shakedown using the Goodman diagram.

Stress concentration in tension (K_T) for holes in plates, cylinders, stepped beams, cylinders, and reinforced cylinders is briefly considered in Chapter 13. Practical examples illustrating the use of K_T are given. This is an abbreviated version of the first edition. The reviewer was disappointed that no mention was made of Neuber's relation and little discussion of the fatigue reduction factor (K_f).

Chapter 14 is new and focuses on fracture mechanics, including the first mode; i.e., K_{IC} (fracture toughness) and two other displacement modes. Transition temperature and Charpy impact are mentioned in this brief but welcome new chapter.

Chapter 15 considers thermal stress, creep, and stress rupture. Time-independent thermomechanics are applied to bimetallics, plates, and cylinders (single and composite). Creep buckling, creep bending, and multiaxial/creep are applied to rotating discs. The final section on stress rupture uses the well-known Larson-Miller parameter; no mention is made of the Manson-Haferd parameter method.

In summary the book is excellent. The next edition should be divided into two parts -- elementary and advanced -- and should incorporate some of the criticisms of the reviewer. It is easy to read and contains no difficult mathematical analyses. The reviewer recommends the book to mechanical designers and analysts as a text or reference.

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PRACTICAL RELIABILITY ENGINEERING

Patrick D.T. O'Connor
Heyden & Sons Ltd., London and Philadelphia
1981, 300 pages, $29.00

At last a reliability expert has explained to non-specialists such as myself what reliability engineering is and what reliability engineers do. O'Connor's efforts will aid those who must integrate reliability engineers into their project teams.

A careful reading of the final chapter should be required of top managers of all firms and agencies aspiring to specify, develop, produce, and use highly reliable hardware.

> **Quality and reliability awareness and direction must start at the top and must permeate all functions and levels where reliability can be affected. It is significant that in Japan the government has made quality a national objective, with a requirement that a product attains set quality standards as a condition of being granted an export license. It is common in Japanese corporations for reliability training to start at Board level, and to be extended downwards to include every designer.**

O'Connor's prediction that reliability efforts (and costs) will escalate further is based upon the high cost of repairs, the need for customer goodwill, product legislation, and military reliability standards.

Reliability engineering must be both executive and advisory. Reliability engineers must be able to give or to withhold approval and decide how a product will be tested. They must be integrated into project teams and report to the same managers as those who do design and testing. The voice of the reliability engineer must be heard when decisions (especially early design decisions) are being made. Accomplishing this might well be carried out on the basis of two suggested organization charts provided. O'Connor offers suggestions on staffing so that reliability engineers will be respected members of their teams and able to make and enforce decisions that could be unpopular.

Management must resist the ever-present pressure to relax reliability requirements because reliability efforts always pay off. Can any reader of this review cite even one experience in which too much effort was devoted to reliability? In which failure modes should not and could not have been discovered and corrected earlier at much less cost?

The costs of reliability are high, but they are smaller, by perhaps 100:1 than the costs of unreliability.

O'Connor gives two approaches to quantifying unreliability costs. One deals with a commercial electronics communication equipment. The other is a unit for a military aircraft. The book closes with comments for writing contracts so that reliability is financially rewarded (reliability incentives).

Chapter 1 introduces nonspecialists to the field of reliability engineering. Reliability programs should be required for all products whose complexity leads to appreciable risks. All engineers (whose training was mainly deterministic) should receive training in variability. Understanding the laws of chance and the causes and effects of variability are needed to create reliable products and to avoid failures. All engineers should understand how and why screening, for example, improves the quality of electronic subassemblies that pass into higher levels of production.

Chapters 2, 3, and 4 deal with the mathematics and analysis of reliability; reliability data, statistical inferences, and proper use of these tools are given. Modern design for variability is compared with traditional safety considerations that have often resulted in over design and weight and cost increases. Comments on the accuracy with which these tools are presented are left to the author's peers. The numerous examples that are presented and calculated should prove helpful to serious students and to instructors.

Chapter 6 describes management and review methods needed to assure that a product is designed to be reliable. Failure-free design is the only acceptable principle. O'Connor lists several items that belong in reliability specifications; they include definitions of failure, a description of environments, and a statement of reliability requirements. Methods of design review are presented; failure reporting is emphasized.

Chapter 7 deals with reliability of design of electronic equipment. Chapter 8 deals with software-based systems. Chapter 9 describes methods for measuring and improving reliability during development, production, and service. In a discussion of reliability demonstration testing per Military Standard 781, no mention is made of random vibration, as demanded by the current C revision. Only fixed and swept frequency tests are mentioned. O'Connor's employer (British Aerospace Dynamics Group, Stevenage, Hertfordshire) uses random vibration, and its omission is surprising. Chapter 10 provides some analytical and experimental methods for determining causes of unreliability.

O'Connor has written a useful and helpful text and has succeeded in presenting a sales message that should motivate his readers to plow through the heavy material to attain a valuable payoff: higher reliability.

W. Tustin
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22 East Los Olivos St.
Santa Barbara, CA 93105

STABILITY OF ELASTIC SYSTEMS

H. Leipholz
Sijthoff & Noordhoff, The Netherlands
1980, 492 pages, $75.00

This book is a survey of the author's work on dynamic stability of certain classes of elastic systems. Its central theme is that elastic systems should be studied from a dynamic stability criterion (the concept of Lyapunov stability) and not just the older criteria of elasto-statics (Euler's theory). The reason for this view, as correctly argued by Leipholz, is that many problems in elastic stability can be analyzed successfully only within a dynamic setting. The book is divided into four sections

- foundations of a theory of stability
- methods of solution
- classes of stability problems
- selected nonconservative problems of stability

It is certainly not a survey of elastic stability theory. (For this topic the author refers us to works by himself and others.) It centers on the special topics of

- stability via Lyapunov's second method as applied to elastics systems
- stability of nonconservative systems
- stochastic stability of elastic systems subject to random perturbations

The text does not require much mathematical sophistication of the reader. A knowledge of advanced calculus and some background in functional analysis suffice.

It is a decent book if one is interested in the special topics given above. On the other hand for a comprehensive survey I would recommend the monograph of R.J. Knops and E.W. Wilkes, "Theory of Elastic Stability," in Handbuch der Physik, Band VI a/3, ed. S. Flügge, Springer-Verlag; Berlin, Heidelberg, New York, 1973.

The English leaves something to be desired. Perhaps Professor Leipholz will in the future exercise more care with his dangling participles.

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610 Walnut St.
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SHORT COURSES

MAY

ADVANCED RANDOM DATA ANALYSIS AND APPLICATIONS

Dates: May 3-7, 1982
Place: Los Angeles, California
Objective: The course is designed for engineers, scientists, technical managers, mathematicians and computer specialists who deal with analysis, interpretation of results, and current engineering applications of random data analysis. The course covers the latest practical techniques of correlation and spectral analysis to solve problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties; predict output responses and noise conditions; determine nonlinear and nonstationary effects; conduct dynamics test programs; and perform digital data analysis.

Contact: Short Course Program Office, UCLA Extension, P.O. Box 24901, Los Angeles, CA 90024 - (213) 825-1295 or 825-3344.

ROTORDYNAMICS OF TURBOMACHINERY

Dates: May 17-19, 1982
Place: College Station, Texas
Objective: To provide a bridge between dynamics theory and the typical hands-on vibrations/instrumentation short course for the engineer who needs a basic understanding of practical turbomachinery rotordynamics. The course will treat balancing, rotordynamic instability, and torsional vibration problems. Fundamentals of each area will be followed up by case histories from engineering practice.

Contact: Dr. John M. Vance, Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843 - (713) 845-1257.

MECHANICAL RELIABILITY AND PROBABILISTIC DESIGN FOR RELIABILITY

Dates: May 17-21, 1982
Place: Washington, D.C.
Objective: This course is designed for engineers, scientists, and others concerned with the design, reliability, product assurance, quality, and safety aspects of critical components, structural members, and equipment. The course will also be of interest to those concerned with the optimization of designs, the elimination of overdesign, as well as underdesign, and the conservation of materials and energy resources needed to produce and operate equipment. Topics to be discussed include the probabilistic-design-for-reliability or the stress-strength-distribution-interference approach to design; the comparison of the conventional design to the probabilistic-design-for-reliability methodology; the determination of the failure-governing stress and strength distributions; the computation of the associated reliability with a desired confidence; and the prediction of the reliability of components and structural members subjected to static and/or to fatigue loads. Computer and Monte Carlo simulation techniques for synthesizing the stress and strength distributions and the associated reliability for any combination of these two distributions will also be discussed. Numerous applications will be presented and discussed.

Contact: Mr. Stod G. Cortelyou, Deputy Director, Continuing Engineering Education Program, The George Washington University, Washington, DC 20052 - (202) 676-6106, (800) 424-9773, Telex: 64374 (International).

FUNDAMENTALS OF TURBOMACHINERY PERFORMANCE

Dates: May 19-21, 1982
Place: College Station, Texas
Objective: The fundamental analysis and applications of the performance of various types of turbomachines will be presented for the engineer seeking a basic understanding of the operation of turbomachinery. A "hand-on" session will be held in

conjunction with a problem solving session in order to provide some experience in using the performance analysis concepts. Also, several experienced engineers from industry will provide insight into the operational and maintenance problems associated with several types of turbomachines.

Contact: Dr. Peter E. Jenkins, Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843 - (713) 845-7417.

JUNE

VIBRATION DAMPING

Dates: June 14-17, 1982
Place: Dayton, Ohio
Objective: The utilization of the vibration damping properties of viscoelastic materials to reduce structural vibration and noise has become well developed and successfully demonstrated in recent years. The course is intended to give the participant an understanding of the principles of vibration damping necessary for the successful application of this technology. Topics included are: damping fundamentals, damping behavior of materials, response measurements of damped systems, layered damping treatments, tuned dampers, finite element techniques, case histories, and problem solving sessions.

Contact: Michael L. Drake, Kettering Laboratory 23, 300 College Park Avenue, Dayton, OH 45469 - (513) 229-2644.

MACHINERY VIBRATION ANALYSIS

Dates: June 15-18, 1982
Place: Seattle, Washington
Dates: August 17-20, 1982
Place: New Orleans, Louisiana
Dates: November 9-12, 1982
Place: Oak Brook, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

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

MECHANICS OF HEAVY-DUTY TRUCKS AND TRUCK COMBINATIONS

Dates: June 21-25, 1982
Place: Ann Arbor, Michigan
Objective: The heavy truck or truck combination is a complex pneumatic-tired system. This course presents analysis programs, parameter measurement methods and test procedures useful in understanding and designing a vehicle. The course describes the physics of heavy-truck components that determine the braking, steering and riding performance of the total system.

Contact: Engineering Summer Conferences, 400 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

JULY

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

Dates: July 19-23, 1982
Place: England
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.

SEPTEMBER

SIMULATION AND ANALYSIS OF COMPLEX MECHANICAL SYSTEMS

Dates: September 6-10, 1982

Place: Northampton, UK

Objective: The goal is to assist participants in becoming proficient in the formulation of equations of motion of complex mechanical systems. With this background, the participants will be able to produce efficient algorithms for the simulation of motions and for the determination of constraint and control forces arising in connection with such systems.

Contact: The Open University, Walton Hall, Milton Keynes, MK7 6AA, Telephone: Milton Keynes 653945, Telex: 825061.

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

Call for Papers

1983 ANNUAL RELIABILITY AND MAINTAINABILITY SYMPOSIUM
January 25-27, 1983
Sheraton Twin Towers Hotel
Orlando, Florida

The 1983 Symposium will address the contributions made by the Assurance Technologies to meet the continuing challenge of increasing productivity. Papers are invited that emphasize basic principles describing work in reliability, maintainability, and related fields that achieves greater productivity. Special consideration will be given to case history papers that discuss actual applications of techniques and the results obtained. Also solicited are papers describing new approaches in achieving increased reliability or maintainability and reduced life-cycle costs.

If you wish to submit a paper, the following is needed as soon as possible, but May 1, 1982 is the submission deadline.

- For each author and co-author: name, work address and phone number, home address and phone number, and brief biographical sketch.
- Paper Title not to exceed 50 letters and spaces -- count them -- the printer will truncate at 50.
- Paper Summary of not more than 1000 words structured in the following three sections: (1) Problems or Questions Addressed; (2) Work Performed; (3) Results and/or Conclusions Reached.

Please note that initial screening for candidate papers is based solely on these summaries. If a Summary does not clearly indicate the paper's value (i.e., the 3 sections itemized above), it will generally receive no further consideration. Threrefore, it is essential that your initial submission be carefully prepared.

All papers must be new and must not have been presented at a national meeting prior to the Symposium. Papers presented at local meetings are acceptable. Authors must indicate the status of any previous or planned presentation/publication of the subject material covered in their submittal. All submittals become the property of the Symposium and cannot be returned.

Ten copies of each author and co-author's name, work address and phone number, home address and phone number, brief biography, paper title and paper summary must be sent to:

Dr. Ralph H. Dudley
RAMS Program Chairman
Varian Associates, Inc. (D-475)
6111 Hansen Way
Palo Alto, CA 94303

Authors will be notified of Program Committee decisions during June 1982. Full text drafts will be required by August 16, 1982 for review. Comments from this review will be returned to the authors by September 15. Final camera ready papers must be submitted not later than October 15, 1982 and must be accompanied by 'he author's signed release for publication in the Symposium Proceedings. These dates do not have slack, and authors should fully recognize the responsibility of their commitment to this schedule when the initial submittal is made.

WORKSHOP ON "MODELING, ANALYSIS AND OPTIMIZATION ISSUES OF LARGE SPACE STRUCTURES"
May 13-14, 1982
Holiday Inn-East
Williamsburg, Virginia

The purpose of the workshop, jointly sponsored by the Air Force Office of Scientific Research, NASA Langley Research Center, and AFWAL Flight Dynamics Laboratory, is to develop a national concensus on the needs for development of analytical techniques unique to Large Space Structures, and approaches to their efficient and economical realization.

Recent studies by NASA, DOD, and contractor organizations have indicated limitations in existing methodology in structural dynamics, flight controls, thermal response, and their mutual interactions. Progress is apparent in some areas; however, specific directions for future effort need to be delineated. To coordinate national efforts, this workshop is being organized to aid planning of a new Air Force initiative and NASA's continued research in large space structures technology.

For further information, contact: Dr. Larry Pinson, NASA Langley Research Center, (804) 827-3054; Dr. Vipperla Venkayya, AFWAL Flight Dynamics Lab., (513) 255-4893; or Dr. Anthony Amos, Air Force Office of Scientific Research, (202) 767-4937.

INTERNATIONAL CONFERENCE ON IMPACT OF AERODYNAMICS ON VEHICLE DESIGN
June 16-18, 1982
England

The International Association for Vehicle Design in collaboration with the Open University, UK, will organize an International Conference on "Impact of Aerodynamics on Vehicle Design" to be held June 16-18, 1982 in England.

The program of the Conference includes Status Lectures by invited speakers to present the state of the art in vehicle aerodynamics and measurements as well as papers presented by international experts in the field.

Anyone interested in presenting a contribution in the Conference should notify Dr. Dorgham. Full manuscripts of accepted papers should be submitted before May 1, 1982.

For further information contact: Dr. M.A. Dorgham, The Open University, Faculty of Technology, Walton Hall, Milton Keynes MK7 6AA, UK - Telephone No. (0908) 653945, Telex No. 825061, Cable Address: SESAME Milton Keynes.

INTERNATIONAL CONFERENCE ON MODERN VEHICLE DESIGN ANALYSIS
June, 1983
England

The International Association for Vehicle Design will sponsor a symposium on Modern Vehicle Design Analysis to be held in England in late June, 1983. Contributed papers are invited in all areas of vehicle design analysis and especially for applications of structural optimization, graphics as a computational and design tool, vehicle noise and vibration control techniques, nonlinear calculations including crashworthiness studies, and new structural materials for weight and cost savings.

Abstracts of appropriate papers are due by July 1, 1982. Review manuscripts should be submitted by October 1, 1982. Reviewers comments will be available by December 1, 1982 and final revised papers will be required by February 1, 1983 so that a bound volume of symposium papers can be printed for availability at the meeting.

For further information contact: Drs. Mounir M. Kamal and Joseph A. Wolf, Jr., symposium organizers, Engineering Mechanics Dept., General Motors Research Labs., Warren, MI 48090 - (313) 575-2929; or Dr. M. Dorgham, International Association for Vehicle Design, The Open University, Milton Keynes, MK7 6AA, England.

1982 SAE AEROSPACE CONGRESS AND EXPOSITION
October 25-28, 1982
Anaheim, California

The SAE Technical Committee G-5 on Aerospace Shock and Vibration is organizing two sessions on "Advances in Dynamic Analysis and Testing" to be presented at the 1982 SAE Aerospace Congress and Exposition, week of October 25, 1982 at the Anaheim Convention Center, Anaheim, California.

Preliminary information on the G-5 technical sessions may be obtained from: Roy W. Mustain, Rockwell Space Systems Group, Mail Sta. AB97, 12214 Lakewood Blvd., Downey, CA 90421.

The final program for the 1982 SAE Aerospace Congress and Exposition may be obtained by writing to SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

Announcement & Call for Papers

ARMY SYMPOSIUM ON SOLID MECHANICS
Critical Mechanics Problems in Systems Design
Red Jacket Beach Motor Inn
South Yarmouth, Cape Cod, Massachusetts
September 21-23, 1982

In order to meet the challenge of developing modern defense systems, the designer has been forced to consider critical solid mechanics problems in system design. This solid mechanics symposium will focus on current and persistent problems which impede systems development. Theoretical and experimental papers are sought within the theme as illustrated below:

- Advanced Materials Issues/Constitutive Relations
- Computational Methods/Design Strategies
- Fracture Mechanics/Failure Analysis
- Life Prediction/Damage Assessment
- Structural Integrity/NDE
- Test and Evaluation

Investigators with questions on the relevancy of their work to this theme area should contact one of the following symposium committee members:

- East Coast - Dr. C.I. "Jim" Chang, Naval Research Lab., Code 5830, Washington, DC 20375 - (202) 767-2239 or AV: 297-2239

- Central Area - Mr. Gene Maddux, Air Force Flight Dyn. Lab., Wright-Patterson AFB, OH 45433 - (513) 255-5159 or AV: 785-5159

- West Coast - Dr. Raymond Foye, R&T Labs. (AVRADCOM), Ames Res. Ctr., Moffett Field, CA 94035 - (415) 965-5578 or AV: 359-5836

This will be the eighth biennial symposium sponsored by the Army Materials and Mechanics Research Center. The objective of these symposia is to improve the effectiveness of mechanics research for the design of advanced military systems. The transactions of this unclassified symposium will be made available at the meeting. Attendance will be limited to U.S. citizens. The program will include 20-minute presentations for which the manuscript requirements and important dates are given below.

Manuscript Requirements

Papers must originate from in-house or contract researchers or designers for Army, Navy, Air Force or other Government Agencies.

All papers must be unclassified, relevant to DoD mechanics problems and should generally address the design community.

A "Prior Publication Statement" will be required along with each manuscript to insure that the substance of the papers will not have been published elsewhere prior to the symposium.

Important Dates

March 19 - Extended abstracts of approximately 500 words in length due, with Figures attached.

March 26 - Authors notified of preliminary acceptance.

May 11 - Manuscripts due for review.

June 18 - Authors notified of selections.

In addition, a session of 10-minute work in progress presentations is planned for which extended abstracts will be due July 30, 1982.

Mail abstracts to: Mrs. J. Ayoub, AMMRC, Watertown, MA 02172. For further information call: (617) 923-5520 or AV: 955-5520.

PREVIEWS OF MEETINGS

INSTITUTE OF ENVIRONMENTAL SCIENCES' 28TH ANNUAL TECHNICAL MEETING
"Enhancement of Quality Through Environmental Technology"
Marriott Hotel, Atlanta, Georgia
April 20-23, 1982

During April 20-23, 1982, the Annual Technical Meeting of the Institute of Environmental Sciences (IES) will be held in Atlanta, Georgia. The theme, "Enhancement of Quality Through Environmental Technology" reflects the application of environmental technology through the use of the production cycle.

The technical program is arranged to present three comprehensive tutorials on April 20th as well as a wide spectrum of interesting environmental subjects, a panel discussion titled "Getting Our Act Together," and several sessions dedicated to "Test Tailoring" and "Recommended IES Practices." To further enhance the conference, four parallel seminars will be presented starting on April 21, dealing with the following key issues and controversies:

- Engineering Methods
- Environmental Stress Impact
- Contamination Control
- Energy and the Environment

During the conference, the IES sponsors technical meetings to provide the membership with the most recent committee findings and positions. Additionally, the Exhibits Chairmen, Ludwig Pulaski and Charles Conrad, have made the necessary arrangements to present to you the latest state-of-the-art in environmental equipment and instrumentation.

TECHNICAL PROGRAM

Wednesday, April 21

- **WELCOME AND KEYNOTE ADDRESS** 8:30 a.m.-10:00 a.m.
- **EQUIPMENT EXPOSITION** 10:00 a.m.-6:00 p.m.
- **PANEL: GETTING OUR ACT TOGETHER** 1:00 p.m. - 3:00 p.m.
- **CERT COST EFFECTIVE TESTING** 3:30 p.m.-5:00 p.m.

Mini Cert -- A Portable Minimum Energy Cert System, William Silver, Westinghouse Electric Corporation

Cost Effectiveness of Cert Testing, Dr. Alan Burkhard, AFWAL, Wright-Patterson Air Force Base

Inexpensive Pneumatic Random Vibration, Wayne Tustin, Tustin Institute of Technology

- **ELECTROSTATIC DISCHARGE PHENOMENA** 3:30 p.m. - 5:00 p.m.

Information is presented on several aspects of Electrostatic Discharge Phenomena and the problems associated with minimization of the effects.

Thursday, April 22

- **SUCCESSFUL TEST TAILORING** 8:30 a.m. - 10:00 a.m.

Test Tailoring in the 1980's, Charles Wright and Peter Bouclin, China Lake Naval Weapons Center

Tailoring the Composite Mission Profile Environments for Reliability Testing, W. Douglas Everett, Pacific Missile Test Center

Tailoring the Dollars, Sharon A. Ogden, Pacific Missile Test Center

Captive Carry Dynamic Environments for the Harpoon Missile on the A-6 Aircraft, Jim Zara, McDonnell Douglas Astronautics Co.

- **COMBINED ENVIRONMENTAL TESTING** 10:30 a.m. - 12 noon

Presentations will deal specifically with the environmental and reliability aspects of Mission Profile Testing (MPT), as well as potential payback time and the constraints of the MPT program, if such a payback is to be achieved.

Stores Combined Environment Test Study, Scott Hall, AFWAL, Wright-Patterson Air Force Base

An In-Depth Evaluation of Mission Profile Testing - Environmental Engineering Aspects, Allen J. Curtis, Hughes Aircraft Company

An In-Depth Evaluation of Mission Profile Testing -- Reliability Engineering Aspects, Irving Quart, Hughes Aircraft Company

- **CURRENT ASPECTS OF DYNAMIC TESTING** 1:30 p.m. - 3:00 p.m.

Presentations represent the most recent contributions to multi-exciter vibration testing as well as shock waveform optimization.

Developments in Digital Control of Multiexciter Vibration Testing, Dr. Richard C. Stroud, Strether Smith and George A. Hamma, Synergistic Technology Inc.

Analysis and Simulation of Missile Response to Gunfire, R.G. Merritt, China Lake Naval Weapons Center

Random Vibration Testing of a Single Test Item with a Multiple Input Control System, David O. Smallwood, Sandia National Laboratories

Optimization of Classical Shock Waveforms, Mark Underwood, Spectral Dynamics

- **PANEL: THE ULTIMATE USER** 1:30 p.m. - 3:00 p.m.

This session will be an open forum in which test and design engineers will have the unique opportunity to learn first-hand the opinions and observations of military hardware users from all three services. Discussions will center on operational use patterns and practices, equipment performance shortcomings in service, and impressions of hardware reliability and availability. Audience interaction will be encouraged.

Panel members are selected from those persons who use military hardware and are thus well equipped to describe performance in the field. These ultimate users include pilots, enlisted personnel, and ground mechanics or technicians.

- **IMPACT OF COMPUTER TECHNOLOGY ON ENVIRONMENTAL TEST OPERATIONS** 3:30 p.m. - 5:00 p.m.

The Changing Role of the Computer in the Environmental Laboratory, Leland G. Smith, Hughes Aircraft Company

- **RELIABILITY GROWTH TESTING** 3:30 p.m. - 5:00 p.m.

Myths and Sacred Cows in Reliability Testing, Henry Caruso, Westinghouse Electric Corporation

Enhancing Product Reliability through Strife Testing, Ken Fedraw, Hewlett-Packard

Regression Analysis of Repairable Systems Reliability, Harry Ascher, Naval Research Laboratoy

Friday, April 23

- **CLIMATIC ENVIRONMENT SIMULATION** 8:30 a.m. - 10:00 a.m.

The use, generation and effects of climatic environment applied to test and evaluation of a wide range of products will be addressed.

Accelerated Stress Testing of Solar Photovoltaic Modules, S.E. Trenchard and K.R. Williams, Coast Guard Research and Development Center

Testing of Thermal Relief Devices -- Bonfire Testing, J. William Battis, HTL Industries Inc.

The McDonnell Douglas Environmental Testing Laboratory, Carl Hilgarth and Jerry Quist, McDonnell Douglas

Overview of the Aerothermal Environment or Air-Launched Missiles, A.C. Victor and B.M. Ryan, China Lake Naval Weapons Center

- **RELIABILITY MODELING** 8:30 a.m. - 10:00 a.m.

This session will present a variety of views on the critical problem of environmental reliability. Variations or improvements on classical modeling techniques are reviewed.

Bathtub Hazard Rate Modeling, An Investigation, Dr. Balbir S. Dhillon, University of Ottawa

Adjustment Factors for Application of MIL-HDBK-217 Failure Rates, Landon A. Stratton, Hughes Aircraft Company

- **SIMULATION OF LOW FREQUENCY VIBRATION ENVIRONMENTS** 10:30 a.m. - 12 noon

The problems in simulating low frequency vibration environments are as diverse as the types of environment simulated. This session includes tonics ranging from seismic excitation of buildings to railroad rolling stock and high performance aircraft tail tip motion simulation.

Development of a High Amplitude Vibration Exciter System, Robert M. Miller, McDonnell Aircraft Company

Building Seismic Vibration Test Project, Prof. Vitelmo V. Bertero, University of California/Berkeley

The Rail Dynamics Laboratory: Low Frequency, Large Deflection Vibration Testing of Massive Test Articles, James. A. Roberts, Boeing Services International, Inc.

- **RELIABILITY IN THE PRODUCTION CYCLE** 10:30 a.m. - 12 noon

The ultimate payoff of an enhancement program is improved performance at a reduced overall cost. By concern with ultimate reliability throughout a production process, the end result is a reduction in life cycle cost. This session deals with concepts of this nature.

Production Sequence Screening -- A Candidate for EVOP? Dr. Halsey B. Chenoweth, Westinghouse Electric Corporation

Development and Production of Advanced Cooling Techniques for Hybrid Microcircuits, Dr. K.S. Sekhon, Hughes Aircraft Company

- **ENVIRONMENTAL STANDARDS** 1:30 p.m. - 3:00 p.m.

Update on MIL-STD-210B, Paul Tattelman, Air Force Geophysical Laboratory/LYT, Hanscom Air Force Base

MIL-STD-810D -- A Climatic Testing Update, Herbert Egbert, U.S. Army Test and Evaluation Command

- **PANEL: ENVIRONMENTAL STRESS SCREENING OF ELECTRONIC HARDWARE** 1:30 p.m. - 3:00 p.m.

This session is intended to present a report on the status or accomplishments of the special groups established to collect screening information, analyze that information and more recommendations for future screening programs at all levels of assembly.

The panel discussion will be open to all in the audience for questions and answers.

- **IES RECOMMENDED PRACTICES** 3:30 p.m. - 5:00 p.m.

Further progress on the proposed drafts of recommended practices is reported. The discussion will include audience participation on the salient factors, problems and directions of the IES Environmental/Peliability Recommended Practice Workshop.

INFORMATION RESOURCES

THE TACTICAL TECHNOLOGY CENTER (TACTEC)

ORIGIN

In 1963, the Defense Advanced Research Projects Agency (DARPA) contracted with Battelle-Columbus Laboratories for the establishment of the Remote Area Conflict Information Center (RACIC). RACIC was directed by DARPA to respond to the information analysis needs of all DoD components where these needs were within the scope of RACIC. As part of this primary responsibility, RACIC was to maintain holdings of technical reports and other information pertaining to counterinsurgency and overseas defense research, development, testing, and evaluation.

During its operation, RACIC responded to approximately 4500 queries from 500 different organizations in the defense community, and 1200 visitors came to the Center to examine its more than 30,000 documents.

In November, 1971, DARPA announced its reorientation of RACIC to include the broader technological scope of tactical warfare and renamed the Center the Tactical Technology Center (TACTEC). Since that time, TACTEC has provided support to the DoD's tactical warfare and technology activities. Throughout this period, TACTEC has held a unique position in the community of information analysis centers. The Center has grown to include over 50,000 documents. Organized as it is within Battelle, TACTEC enjoys a particular advantage in that it can draw upon the capabilities of Battelle's more than 1000 engineers and scientists. Thus, while TACTEC maintains a fullstime staff of specialists who analyze, evaluate, and extract the current DoD scientific and engineering literature and incorporate this information in responses tailored to meet a specific user's needs, the entire technical staff of Battelle's Columbus Laboratories is available to TACTEC to address the research and analytical problems directed to the Center.

MISSION AND SCOPE

The scope of the Tactical Technology Program (TACTEC) covers the full spectrum of tactical warfare, including low-intensity conflict, large-scale conventional warfare, desert warfare, and warfare in built-up areas. This charter allows Battelle to provide support to the DoD with the following:

- R&D tasks to develop or evaluate new or existing systems for specific tactical warfare missions; to perform research on devices or phenomena of potential value in tactical warfare; or to perform feasibility demonstrations for specific systems or devices.
- Quick-response inquiries (QRI's) to determine what information is available on particular topics, to evaluate novel ideas and new applications of existing technologies or systems, or to answer specific technical questions.
- Scientific and other technical assistance to meet the R&D requirements of the DoD either within Battelle's Columbus Laboratories, onsite at the requesting agency's facility, or, by special arrangements, off-site within CONUS or overseas.
- Maintenance of an information center covering the full spectrum of tactical warfare.

SERVICES

Quick-Response Inquiry (QRI)
Battelle has responded to approximately 6000 QRI's from members of the defense community representing more than 500 different organizations. A quick-response inquiry (QRI) comprises technical assistance to the DoD user. This assistance can take the form of an answer to a specific technical ques-

tion, a short-term study, a review of the literature, or a similar effort.

Once a QRI request has been properly authorized and accepted, the TACTEC Program Manager assigns primary responsibility for the response to a Battelle scientist, engineer, researcher, or analyst, who is most knowledgeable of the particular subject area. Depending upon the complexity of the question, the staff member who reviews the assignment may elect to answer the question on his own or seek the assistance of other Battelle staff. This flexible interdisciplinary team approach allows a high level of technical competence to be brought to bear on a problem. The holdings of the TACTEC data base in the particular subject area will in most instances, also be reviewed to provide the most complete response possible within the time and funds allotted. The response will be prepared in the form designated by the requester.

Additionally, Battelle conducts numerous literature surveys for its users.

Interpretative Analyses and R&D
These types of effort involve longer term, in-depth interpretive analyses and R&D studies that require scientific technical investigations conducted by the Battelle staff. As with the shorter term, quick-response efforts, they are initiated in response to specific questions and problems identified by the DARPA TTO Program Managers, and they are initiated in essentially the same way as the quick-response efforts. The Battelle staff also brings to DARPA's attention research areas of potential interest to specific DARPA TTO programs.

As appropriate, the TACTEC data base holdings are searched and relevant information and data are reviewed. The information and data thus obtained may then also be incorporated into the final technical report prepared in response to the request and/or a bibliography of selected reading may be prepared to supplement the actual work performed on the study by Battelle.

Scientific and Other Technical Assistance
One of the keys to the successful accomplishment of the DoD's tactical warfare mission is the effective utilization of science and technology. This requires a comprehensive RDT&E effort which involves:

- The translation of practical problems of tactical warfare into technical requirements to guide the technical people.

- The knowledgeable response to ideas generated by technical people as potential solutions to the practical problems of tactical warfare.

In most instances, Battelle can most effectively contribute to the accomplishment of these objectives in the Columbus Laboratories of Battelle. Occasionally, however, the achievement of these R&D objectives can best be accomplished in the field or on-site at the sponsoring agency's facility. Representative tactical warfare technologies now available through the staff and facilities of Battelle-Columbus are as follows:

- Advanced Materials Development and Fabrication Technologies
- Advanced Sensor Technology
- Advanced Weapons Technology and Design
- Resources Analysis
- Systems and Design
- Advanced Energy Systems
- Advanced Offensive/Defensive Systems Studies
- Information Systems
- Cover and Deception

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ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 809, 909, 910, 919)

82-747

General Linear Theory for Rotor Systems with or without Small Asymmetries (Allgemeine lineare Theorie fur Rotorsysteme ohne oder mit kleinen Unsymmetrien)

P.C. Muller
Sicherheitstechnische Regelungs- und Messtechnik, Universitat - Gesamthochschule - Wuppertal, D-5600 Wuppertal 1, W. Germany, Ing. Arch., 51 (1/2), pp 61-74 (1981) 14 refs
(In German)

Key Words: Rotors, Lateral vibration, Asymmetry, Internal damping, External damping, Unbalanced mass response, Linear theories

For the lateral vibrations of a large class of rotor-bearing-systems a general theory based on a linear approach is developed. The behavior of the natural modes of a system with symmetric elements is discussed in terms of forward and backward precession depending on the rotor speed. The influence of external and internal damping is investigated. The steady-state response due to static and dynamic rotor unbalances is dealt with. In the case of rotor systems with asymmetric elements the technique of parameter and combination resonances of periodic systems is applied to characterize unstable behavior at some critical speeds. Altogether, the general linear approach allows to discuss the dynamic behavior of rotor-bearing-systems in a very general manner independently of a special type of rotor system.

82-748

Stability Analysis of Multi Span Rotor System and Its Application (Part 1, Theory for Rotor System Having Two Bearings)

T. Iwatsubo, R. Kawai, and H. Ikkai
The Faculty of Engrg., Kobe Univ., Rokko, Nada, Kobe, Japan, Bull. JSME, 24 (196), pp 1853-1858 (Oct 1981) 11 figs, 3 tables, 6 refs

Key Words: Rotors, Bearings, Fluid-film bearings, Stability

This paper is the first report on a series of works on stability evaluation of a multi rotor system supported by oil film bearings. Vibrational energy of each element of the system is calculated and relation between the energy behavior and the stability is investigated, with a rotor supported by two bearings. Investigation of energy level of each bearing gives us information on an instabilizing bearing and it is known that the concept of the energy level of the bearings is very useful for design and diagnosis of the rotor system.

82-749

Stability Analysis of Multi Span Rotor System and Its Application (Part 2, Experiment for Rotor System Having Two Bearings and Sensitivity Analysis)

T. Iwatsubo, R. Kawai, H. Ikkai, and M. Okaue
The Faculty of Engrg., Kobe Univ., Rokko, Nada, Kobe, Japan, Bull. JSME, 24 (196), pp 1859-1863 (Oct 1981) 7 figs, 2 tables, 2 refs

Key Words: Rotors, Bearings, Fluid-film bearings, Stability, Experimental test data

This paper describes an experiment of Part 1 and also a sensitivity analysis of a rotor system. In the experiment, energy levels of two bearings in the rotor system are measured and the values obtained are compared with the theoretical results in Part 1. Next the concept of the sensitivity is introduced and a method to improve the rotor/bearing system is studied from the sensitivity analysis and the energy levels.

82-750

Active Vibration Control of a Flexible Rotor on Flexibly-Mounted Journal Bearings

R. Stanway and C.R. Burrows
Dept. of Mech. Engrg., Univ. of Liverpool, UK, J. Dyn. Syst., Meas. and Control, Trans. ASME, 103 (4), pp 383-388 (Dec 1981) 3 figs, 1 table, 23 refs

Key Words: Rotors, Flexible rotors, Bearings, Journal bearings, Flexible foundations, Active vibration control

Some recent experimental studies have been concerned with the stabilization of rotating machinery through control action applied at critical points on the rotor. These studies have tended to ignore fundamental constraints on the positioning of active control inputs and measurement transducers. Such constraints must be considered to ensure both a cost effective design and system integrity in the event of component failure. This paper presents the first stage of a

theoretical examination of active control by investigating a mathematical model of a three-mass flexible rotor symmetrically supported on flexibly mounted journal bearings.

82-751
Spatial Finite Line Element Method for Determining Critical Speeds of Multi-Throw Crankshafts Considering Actual Throw Geometry
C. Bagci and D.R. Falconer
Tennessee Technological Univ., Cookeville, TN, ASME Paper No. 81-DET-141

Key Words: Crankshafts, Critical speeds, Finite element technique

This paper presents a three-dimensional finite element method for the determination of critical speeds of crankshafts considering their three-dimensional actual geometries and as systems experiencing axial, flexural and torsional deformations, and using lumped mass systems.

82-752
Some Considerations on Marine Shafting Design - Part 1
O.C. Larsen
Det Norske Veritas, Indus. Lub. and Tribology, 33 (5), pp 164-171 (Sept/Oct 1981) 3 figs, 1 table, 23 refs

Key Words: Shafts, Marine engines, Alignment

The paper comments on selected items within this design analysis, mainly on shaft alignment and stern tube bearing loading. A review of the more important alignment criteria for geared installations is given.

82-753
Some Considerations of Marine Shafting Design - Part 2
O.C. Larsen
Det Norske Veritas
Indus. Lub. and Tribology, 33 (6), pp 204-209, 237 (Nov/Dec 1981) 6 figs, 23 refs

Key Words: Shafts, Marine engines, Torsional vibration

The first part of this article dealt with marine shaft alignment. In this section torsional shaft vibration is investigated. The author points out the importance of the transient dynamic response of marine shafting systems, because this type of loading may be predominate for the strength of the system.

82-754
Subsynchronous Resonance - An Explanation of the Physical Relationships
M. Canay
Baden, Switzerland, Brown Boveri Rev., 68 (8/9), pp 348-357 (Aug/Sept 1981) 8 figs, 5 tables, 8 refs

Key Words: Shafts, Turbogenerators, Subsynchronous vibration

In high-voltage networks with serious capacitors the phenomenon of subsynchronous resonance (SSR) occurs, which increases the stresses imposed on the shaft lines of turbogenerators both during transient and steady-state conditions. It can be harmful to the equipment during operation. The physical causes and origins of SSR as well as the behavior of the shaft line are explained by reference to examples. The article suggests a general procedure for dealing with the phenomenon of SSR and appropriate protective measures.

82-755
Sub-Combination Tones of a Rotating Shaft Due to Ball Bearings
T. Yamamoto, Y. Ishida, and T. Ikeda
Faculty of Engrg., Nagoya Univ., Chikusa-ku, Nagoya, Japan, Bull. JSME, 24 (196), pp 1844-1852 (Oct 1981) 9 figs, 23 refs

Key Words: Shafts, Ball bearings, Bearings

When a vertical rotating shaft is supported by single-row deep groove ball bearings symmetrical nonlinear spring characteristics appear in the elastic restoring force of the shaft due to the "angular clearance" of the bearings, provided that both bearing center lines at the upper and the lower bearings are aligned well. In such a system, two exciting forces with frequencies of the one and two times angular velocity of the precessional revolution of the balls occur due to the coexistence of irregularities of balls and angular clearances of bearings. As the result of this subcombination tones of the angular velocity, $(3/2)\omega_1$ can occur. In this paper, this kind of nonlinear forced oscillations is treated experimentally and theoretically.

RECIPROCATING MACHINES

(Also see No. 794)

82-756

Experimental and Theoretical Investigation of Gas Vibrations in a Roots Blower (Messtechnische und theoretische Untersuchung der Gasschwingungen in einer Rootsgeblaseanlage)

K. Graunke

Gebruder Sulzer AG im Fachbereich Kolbenkompressoren, Winterthur, Switzerland, Konstruktion, 33 (10), pp 393-401 (1981) 12 figs, 20 refs

(In German)

Key Words: Compressors, Fluid-induced excitation

To be able to reduce the noise of a Root's blower the origin, type, and the degree of flow fluctuation in the Root's compressor must be known. The article describes measurement techniques and the results of a computer program for the instationary flow. The theoretical method has a definite advantage over the experimental one, in that the effect of individual parameters and gas vibrations can be determined simply and quickly.

METAL WORKING AND FORMING

82-757

Squeeze Film Die Support as a Means of Noise Reduction in Forging Machines

D.L. Taylor and M.M. Sadek

Cornell Univ., Ithaca, NY, ASME Paper No. 81-DET-97

Key Words: Forging machinery, Noise reduction, Lubrication

The main source of noise generation in impact forming machines is structural ringing. The interface between the die and the anvil plays a major role in the energy transmission into the machine structure. To minimize this effect, it is proposed to introduce an oil film between the die and the anvil. Preliminary tests show that a reduction of the sound pressure level from 135 dB to 128 dB is achieved by introducing such cushioning. The aim of this paper is the development of a technique for a rational design of such a die support system.

82-758

A Data Dependent Systems Approach to Dynamics of Surface Generation in Turning

S.M. Pandit and S. Revach

Mechanical Engrg. - Engrg. Mechanics Dept., Michigan Technological Univ., Houghton, MI 49931, J. Engrg. Indus., Trans. ASME, 103 (4), pp 437-445 (Nov 1981) 7 figs, 3 tables, 15 refs

Key Words: Cutting

A new investigative approach to metal cutting dynamics is proposed based on wavelength decomposition of surface roughness by data dependent systems (DDS). This approach distinguishes from the commonly used Fourier transform analysis. It is shown to be capable of throwing light on both macroscopic and microscopic aspects of cutting mechanics. Workpiece surfaces from turning experiments, changing only speed and only feed, are used to illustrate that the macro-effects of cutting conditions and vibrations can be related to RMS components due to large wavelengths of a few tenths of mm magnitude. In particular, the so-called Spanzipfel effect is accounted for and its RMS is derived.

82-759

A Method for the Analysis of Machine Tool Chatter

M.M. Nigm

Mech. Engrg. Dept., Ain Shams Univ., Cairo, Egypt, Intl. J. Mach. Tool Des. Res., 21 (3/4), pp 251-261 (1981) 8 figs, 10 refs

Key Words: Machine tools, Chatter

A method for the analysis of machine tool chatter is presented. The method is based on the system approach and can be applied either graphically or analytically in a simple manner for the whole range of overlap factor $0 < \mu < 1$. Stability charts are presented and the effects of various parameters on the stability level and chatter frequency are discussed.

STRUCTURAL SYSTEMS

BRIDGES

(See No. 796)

BUILDINGS

(Also see No. 820)

82-760

Inexact Inference for Rule-Based Damage Assessment of Existing Structures

M. Ishizuka, K.-S. Fu, and J.T.P. Yao
School of Civil Engrg., Purdue Univ., Lafayette, IN,
Rept. No. CE-STR-81-5, NSF/CEE-81016, 23 pp (Feb 1981)
PB81-235913

Key Words: Buildings, Earthquake damage

A rule-based damage assessment system of existing structures subjected to earthquake excitation is described. The principle of inexact inference is applied to obtain a rational solution. Both the fuzzy set theory and a production system, with a certainty factor, are used jointly in the inexact inference to deal with the continuous nature of the damage state and to attain the modularity of uncertainty. An inference network diagram for the damage assessment of existing structures is included.

82-761

Hysteresis Identification of Multi-Story Buildings

S. Toussi and J.T.P. Yao
School of Civil Engrg., Purdue Univ., Lafayette, IN,
Rept. No. CE-STR-81-15, NSF/CEE-81022, 96 pp (May 1981)
PB81-235921

Key Words: Buildings, Multistory buildings, Multidegree of freedom systems, Parameter identification technique, Damping effects, Hysteretic damping

Results of the estimation of the behavior of multidegree-of-freedom structural systems are reported. First, the hysteresis identification method and the corresponding error criterion are presented. Then, a lumped-mass model used to form 'M' different independent responses from the response of an 'M' degrees of freedom structure is described. Finally, the identification technique is applied to estimate the inter-story behavior of a laboratory tested, reinforced concrete frame. In addition, the effect of damping in the response of high-rise buildings was examined. The investigation focused on determining whether damping force plays a significant role in the nature of the structural response.

82-762

Dynamic Testing of As-Built Nuclear Power Plant Buildings: An Evaluative Review

M.G. Srinivasan, C.A. Kot, B.J. Hsieh, and H.H. Chung
Components Tech. Div., Argonne Natl. Lab., Argonne, IL 60439,
Nucl. Engr. Des., 66 (1), pp 97-115 (Aug 1981) 1 table, 58 refs

Key Words: Buildings, Nuclear power plants, Dynamic tests

This is a review and evaluation of tests performed on as-built nuclear power plant buildings in many countries during the past several years. Goals of dynamic tests, excitation techniques, excitation levels, and posttest determination of dynamic characteristics are reviewed, and proposed analytical methods are discussed. Dynamic testing is found to be feasible, and low-level testing is deemed to be useful for verifying analytical models used in design practice. Proof testing at design-level excitation is considered impractical, and only a combined program of low-level testing and analytical modeling is considered to be the means for predicting response to high-level excitations.

82-763

Calculation of Highrise Structure Vibrations Excited by Earthquakes (Berechnung von Hochhausschwingungen im Hinblick auf die Beanspruchung durch Erdbeben)

E. Luz and S. Gurr
Institut f. Mechanik (Bauwesen), Universitat Stuttgart, W. Germany,
Ing. Arch., 51 (1/2), pp 75-88 (1981) 6 figs, 1 table, 5 refs
(In German)

Key Words: Buildings, Multistory buildings, Earthquake response, Natural frequencies, Mode shapes, Finite difference technique

A method is developed which allows to map a highrise structure into a one-dimensional continuum model in a simple manner. Calculation of natural frequencies and modes by means of a finite-difference-method is shown. An example is given where results of calculation and measurements are compared.

82-764

Seismic Response of Structural System with Random Parameters

M. Ghafory-Ashtiany

Dept. of Engrg. Sci. and Mechanics, Virginia Polytechnic Inst. and State Univ, Blacksburg, VA, Rept. No. VPI-E-81-15, 107 pp (Sept 1981)
PB82-123977

Key Words: Buildings, Seismic response, Random parameters

Seismic response of a structural system depends upon its mass, stiffness and damping characteristics. Also, most building systems have eccentricity between their mass and stiffness centers which affect their dynamic response. These quantities can rarely be estimated precisely, and therefore they should be considered as random variables and the calculated dynamic response should reflect the uncertainties associated with these parameters. In this investigation the sensitivity of seismic response with respect to changes in these parameters has been studied. Rates of change of various response quantity with respect to the variables of mass, stiffness and eccentricity have been obtained and then used in the evaluation of structural response uncertainty by a first order perturbation approach. A multistory rigid floor system has been examined; its displacement, base shear, base torsional moment and column moment response characteristics have been studied.

FOUNDATIONS

82-765

Assessment and Propagation of Noise from Conventional and Quiet Pile Drivers

H.S. Gill

Inst. of Sound and Vib. Res., Southampton Univ., UK, Rept. No. ISVR-TR-110, 182 pp (Sept 1980)
N81-28854

Key Words: Pile drivers, Noise generation, Noise barriers

Noise levels, spectra and waveform shapes of noise from commercial pile drivers were studied. Noise propagation characteristics and the effects of interposition of a barrier were also examined. The analog data were analyzed digitally to examine pressure waveforms and sound pressure level time histories. Noise reduction techniques employed by each manufacturer are described.

POWER PLANTS

(Also see No. 762)

82-766

Noise Reduction in Heat Recovery Steam Generators

B. Rolsma and B. Nagamatsu

General Electric Co., Lynn, MA, ASME Paper No. 81-DET-101

Key Words: Boilers, Noise reduction

Acoustic resonances within heat recovery steam generators of combined cycle power plants created pure tones which caused an environmental nuisance. The frequency of these tones was readily associated with gas path characteristics but did not correspond with tube natural vibration frequency. When published data for excitation frequencies generated in cross-flow heat exchanger configurations failed to adequately correlate the tones, an extensive laboratory and field test program was undertaken to extend the range of available data.

82-767

Evaluation of the Seismic Integrity of a Plutonium-Handling Facility

D.W. Coats

Lawrence Livermore Natl. Lab., CA, Rept. No. CONF-810801-4, 8 pp (Feb 4, 1981)
UCRL-85458

Key Words: Nuclear reactors, Seismic response

Many studies have been made by and for the Lawrence Livermore National Laboratory (LLNL) to ensure the seismic safety of its Plutonium Facility. These studies have included seismological and geologic field investigations to define the actual seismic hazard existing at the Laboratory site as well as structural studies of the Facility itself. Because the basic seismic design criteria has undergone changes over the years, numerous structural studies and upgrades have been completed. The seismic criteria in use at the LLNL site is reviewed on a continuing basis as new information on the seismicity and geology of the Livermore Valley is obtained.

82-768

Transient Stress Wave Propagation in HTGR Fuel Element Impacts

I.T. Almajan and P.D. Smith

General Atomic Co., San Diego, CA, Rept. No. CONF-810801-40, 23 pp (Feb 1981)
GA-A-16241

Key Words: Nuclear fuel elements, Seismic response

A study of transient stress wave propagation in graphite HTGR fuel elements has been undertaken as a step toward developing techniques for the evaluation of seismic impact loads. The objectives of the study were to identify appropriate numerical methods, to understand the influence of the geometry and the multiple holes on the response, and to determine the relative importance of high frequency response and lower mode vibrations. A general review is made of the dynamic contact problem, and the methods available to model impact phenomena and stress wave propagation are evaluated.

OFF-SHORE STRUCTURES

(See No. 780)

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 788, 900)

82-769

Staged Collision and Damage Data: Volume 1. Report for Accident Reconstruction of Thirty (30) Test Vehicles

D.H. Hand

Approved Engrg. Test Labs., Fullerton, CA, Rept. No. DOT-HS-805-929, 270 pp (Jan 1981)

PB81-234072

Key Words: Collision research (automotive), Impact tests

Thirty (30) test vehicles were impact tested for compliance with FMVSS 212/219/301-75 and documented in previous submitted reports. As a parallel non-conflicting effort, the test vehicles were instrumented with accelerometers to measure vehicle acceleration resultants. The vehicles were also identified for residual crush and collision deformation classification measurements.

82-770

Staged Collision and Damage Data: Volume II. Report for Accident Reconstruction of Thirty (30) Test Vehicles

Approved Engrg. Test Labs., Fullerton, CA, Rept. No. DOT-HS-805-930, 277 pp (Jan 1981)

PB81-234080

Key Words: Collision research (automotive), Impact tests

Test vehicles were instrumented with accelerometers to measure vehicle acceleration resultants. The vehicles were also identified for residual crush and collision deformation classification measurements.

82-771

Transit Vehicle Noise Emission Levels in Yosemite National Park

W. Bowlby

Demonstration Projects Div., Federal Highway Admn., Arlington, VA, Rept. No. FHWA-DP-45-6, 60 pp (July 1981)

PB81-231276

Key Words: Automobile noise, Noise generation

A study of alternatives to permitting automobiles within Yosemite Valley in Yosemite National Park was conducted and the noise impact of the different strategies was studied. This report documents the results of noise emission level tests conducted on different types of transit vehicles. This data will form the base for predictions of the time-averaged levels expected in the Park from each strategy. This report also presents the results of ambient noise measurements in several areas in the valley.

82-772

Analysis of Drive Train Noise and Vibration

S. Chikamori and N. Yoshikawa

Research Section, Passenger Car Technical Ctr., Mitsubishi Motors Corp., Okazaki-shi, Japan, Intl. J. Vehicle Des., 2 (4), pp 408-427 (Nov 1981) 24 figs, 1 table, 13 refs

Key Words: Automobile noise, Drive line vibrations, Gear noise, Minimum weight design

One of the important themes in this age of conservation of resources and energy is the reduction of vehicle weight, which helps to improve running performance, but which generally produces undesirable effects in terms of noise and vibration. To reduce noise and vibration inside a car and reduce its weight at the same time, it is now necessary to re-examine the conventional method of reducing noise and vibration, and deal with the problem by using a more advanced method. Noise and vibration inside the car is caused by the noise and vibration of the drive train, which can roughly be classified into bending vibration and torsional vibration. Generally, they are combined, and may have nonlinear characteristics. This report introduces a selection of important study results which have been edited to enable the reader to understand the outline of the Japanese studies on drive train. The report covers the following: drive train vibration analysis (linear and nonlinear vibrations); engine surge and drive train vibration; and differential gear noise and drive train vibration.

82-773
Experimental Quiet Sprocket Design and Noise Reduction in Tracked Vehicles
S.A. Hammond, C.A. Aspelund, D.C. Rennison, T.R. Norris, and G.R. Garinther
Ordnance Engrg. Div., FMC Corp., San Jose, CA,
Rept. No. HEL-TM-8-81, 243 pp (Apr 1981)
AD-A102 842

Key Words: Tracked vehicles, Noise reduction

The noise produced by track-laying vehicles has historically been a problem in the US Army. Exterior noise provides enemy forces with a means of detection at great distances. Interior vehicle noise prevents accurate person-to-person or electrically-aided communication and is responsible for excessive hearing loss among exposed personnel. This program provides the Army with advanced technology to reduce tracked-vehicle noise. The work presently being reported, which is the third phase of the program, involved the design and fabrication of a high compliance prototype idler and a high compliance experimental sprocket.

82-774
A Theoretical Study of Limit Cycle Oscillations of Plenum Air Cushions
M.J. Hinchey and P.A. Sullivan
Inst. for Aerospace Studies, Univ. of Toronto, Toronto, Canada, J. Sound Vib., 79 (1), pp 61-77 (Nov 8, 1981) 8 figs, 9 tables, 25 refs

Key Words: Ground effect machines, Self-excited vibrations

Air cushion vehicles (ACV) are prone to the occurrence of dynamic instabilities which frequently appear as stable finite amplitude oscillations. The aim of this work is to ascertain if the nonlinearities characteristic of ACV dynamics generate limit cycle oscillations for cushion systems operating at conditions for which a linear theory predicts instability. The types of nonlinearity that can occur are discussed, and an analysis is presented for a single cell flexible skirted plenum chamber constrained to move in pure heave only. Two cushion feed cases are considered: a plenum box supply and a duct. The results obtained by a Galerkin/describing function analysis are compared with those generated by a full numerical simulation. For the plenum box supply system, it is shown that the limit cycles can be suppressed by using a piston to introduce high frequency small amplitude volume oscillations into the plenum chamber.

82-775
Forced Steering of Rail Vehicles: Stability and Curving Mechanics
C.E. Bell and J.K. Hedrick
MIT, Cambridge, MA 02139, Vehicle Syst. Dyn., 10 (6), pp 357-385 (Nov 1981) 10 figs, 9 refs

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

A forced steering rail vehicle employs linkages between the car body and wheelsets to force a more radial wheelset alignment. It is shown that the curve negotiation capability of forced steering trucks is significantly improved over conventional and self steering radial trucks. Parametric curves are presented showing angle-of-attack and lateral flange force as a function of steering gain parameters and truck bending stiffness. It is also shown that the forced steering concept can produce kinematic instability and severely reduced critical speeds for low conicities and creep coefficients. Analytic expressions are derived that illustrate how these kinematic instabilities can be avoided.

82-776
Road Surfacings and Noise Inside Saloon Cars
J.C. Young and P.G. Jordan
Transport and Road Res. Lab., Crowthorne, UK,
Rept. No. TRRL-SUPPLEMENTARY-655, 28 pp (1981)
PB81-232928

Key Words: Railroad cars, Road roughness, Interior noise, Noise measurement

This report describes an investigation to determine the level and characteristics of road noise generated within passenger

vehicles by a range of commonly used surfacings. Noise measurements were made in four different saloon cars travelling over eleven types of road surfacing at selected speeds between 20 and 95 km/h. Spectral analysis showed that most of the noise energy occurs at the lower audible frequencies, below 5kHz. The surfacings examined did not exhibit significant peaks (or tones) in their spectra. Impulse-type noise was a feature on certain surfacings. The road noise component ranged up to 5 dB(A), depending on surfacing type and its rate of increase with speed was found to be independent of type of surfacing.

82-777

Measurements and Observations on Wheelset Lateral Dynamics of Locomotives on Tangent Track

R. Kummrow
Swiss Locomotive and Machine Works, Sulzer Brothers Ltd., 8401 Winterthur, Switzerland, J. Dyn. Syst., Meas. and Control, Trans. ASME, 103 (4), pp 375-382 (Dec 1981) 19 figs, 2 tables

Key Words: Interaction: rail-wheel

Field tests with an electric Re 6/6 locomotive are summarized in this paper. The test objectives included the assessment of the lateral wheel-rail dynamics on tangent track. A method is presented which measures continuously the wheelset's lateral and yaw displacement from track centerline and local rail deflections. The data are obtained on a spatial base through track side marks in conjunction with wheelset rotary trigger pulses. These measurements give a vivid description of the nature of wheelset motion on real track. They allow to scrutinize some of the assumptions inherent to linear rail vehicle modeling. Linearization of the creep force laws and the contact geometry is found to be questionable particularly in the presence of tractive effort, and generally for near critical speed. The results should be of interest primarily to theoretical and experimental rail vehicle dynamicists.

82-778

Railroad Accident Report: Head-on Collision Between Baltimore and Ohio Railroad Company Train No. 88 and the Brunswick Helper Near Germantown, Maryland, February 9, 1981

Bureau of Accident Investigation, Natl. Transportation Safety Board, Washington, DC, Rept. No. NTSB-RAR-81-6, 34 pp (May 27, 1981)
PB81-218877

Key Words: Collision research (railroad)

At 9:56 a.m. on February 9, 1981, Baltimore & Ohio Railroad Company's Brunswick Helper 7603-7545 and eastbound train No. 88 collided head-on while being operated in opposing directions on the No. 2 eastward main track. The trains collided in a 1 degree 40' curve about 4,000 feet east of Germantown, Maryland. The fireman and front brakeman of No. 88, and the engineer and front brakeman of the Brunswick Helper were injured. Damage was estimated at $701,000. The National Transportation Safety Board determines that the probable cause of this accident was the train dispatcher's oversight in authorizing the Brunswick Helper to operate westward on the No. 2 eastward main track between Gaithersburg and Rocks, while opposing train No. 88 was en route eastward on the same track.

82-779

Transient Response Test Procedures for Measuring Vehicle Directional Control

M.K. Verma
Engrg. Mech. Dept., General Motors Res. Labs., Warren, MI 48090, Vehicle Syst. Dyn., 10 (6), pp 333-356 (Nov 1981), 20 figs, 10 refs

Key Words: Automobiles, Transient response, Testing techniques

A comparative study of four different test procedures for quantifying the transient lateral response of automobiles is presented in this paper. Both full-scale testing and analysis have been used in this study. The random steering technique appears to offer several advantages over other procedures in terms of space-requirement and the amount of transient dynamics information generated, whereas the step-steering procedure is more suited to the measurement of steady-state behavior of the automobile.

SHIPS

(Also see No. 865)

82-780

A Method for the Determination of the Reaction Forces and Structural Damage Arising in Ship Collisions

I.L. Davies
Taylor Woodrow Construction Ltd., UK, J. Pet. Tech., 33 (10), pp 2006-2014 (Oct 1981) 8 figs, 1 table, 8 refs

Key Words: Off-shore structures, Ships, Collision research (ships)

Recognizing that the risk of collision between a ship and an offshore structure is high, most codes and regulatory documents require designers to assess the consequent effects on the structure. Existing requirements, which demand that all the ship's kinetic energy before impact be absorbed by the structure, are very conservative. The method outlined considers the construction and mass of both the ship and structure and assesses the variation of contact force with time, using a multidegree-of-freedom lumped-mass approach.

82-781

Bending Moments and Shear Forces in Ships Sailing in Irregular Waves

J.J. Jensen and P.T. Pedersen

Dept. of Ocean Engrg., The Technical Univ. of Denmark, Lyngby, Denmark, J. Ship Res., 25 (4), pp 243-251 (Dec 1981) 10 figs, 2 tables, 17 refs

Key Words: Ships, Water waves, Random excitation

This paper presents some results concerning the vertical response of two different ships sailing in regular and irregular waves. One ship is a containership with a relatively small block coefficient and with some bow flare while the other ship is a tanker with a large block coefficient. The wave-induced loads are calculated using a second-order strip theory, derived by a perturbational procedure in which the linear part is identical to the usual strip theory. The additional quadratic terms are determined by taking into account the nonlinearities of the exiting waves, the nonvertical sides of the ship, and, finally, the variations of the hydrodynamic forces during the vertical motion of the ship. The flexibility of the hull is also taken into account.

AIRCRAFT

(Also see No. 795)

82-782

Some Applications of Hartmann-Type Sources in Aircraft Noise Research

T.A. Holbeche and R.W. Jeffery

Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TM-AERO-1877, DRIC-BR-77146, 18 pp (Nov 1980)

AD-A102 869

Key Words: Aircraft noise, Testing techniques

A description is given of a Hartmann-type air-jet noise generator which has been developed at RAE to aid in the assessment of airframe shielding effects. In this application, in-flight shielding experiments were performed with a slender-delta research aircraft, the Handley-Page 115, fitted with needle-stabilized generators having 19 mm diameter driving jets operated from the HP turbine of the aircraft engine. The acoustic power output of the device was about 1 kW and consisted of a strong fundamental 2.8 kHz tone and a few higher harmonics which were easily discernible above engine noise. Comparative wind-tunnel experiments employed quarter-scale versions built to match the tunnel model and these operated at about 11 kHz, the output level being well above tunnel background noise. Calibration in an anechoic room showed the output to be steady and nearly omni-directional.

82-783

Prediction of Aircraft Interior Noise Using the Statistical Energy Analysis Method

V.R. Miller and L.L. Faulkner

Wright-Patterson AFB, OH, ASME Paper No. 81-DET-102

Key Words: Aircraft noise, Interior noise, Noise prediction, Statistical energy methods

An analytical model is developed to predict the transmission of noise into an airplane interior through the fuselage side-wall by the statistical energy analysis method. The fuselage structure is represented as a series of curved, isotropic plates, the isotropic representation resulting from the effects of smearing out the stiffeners.

82-784

Acoustic Properties of Heated Twin Jets

R.A. Kantola

Fluid Mechanics and Combustion Branch, Mechanical Systems and Technology Lab., General Electric Co., Corporate Res. and Dev., Schenectady, NY 12301, J. Sound Vib., 79 (1), pp 79-106 (Nov 8, 1981) 30 figs, 10 refs

Key Words: Jet noise, Aircraft noise, Noise reduction

A thorough experimental study of the noise characteristics of twin jets is presented in this paper. Twin round jets are investigated at typical jet engine conditions; that is, with heated high velocity flow. By varying the nozzle to nozzle spacing, it is possible to discriminate between the effects of turbulent mixing and acoustic shielding. As a result of this investigation, it was established that the turbulent mixing effects (both interaction noise generation and mixing suppression) occur for closely spaced nozzles. While acoustic shielding occurs at all nozzle spacings, it plays the dominant role at wide nozzle spacings. The levels of this acoustic shielding afforded by an adjacent jet can be sufficient to cause a nearly complete masking of the noise of the shielded jet. A significant discovery of this investigation was the importance of the layer of cooler, slower moving ambient air that exists between the twin jet plumes. This inter-jet layer causes acoustic refraction and reflection, and as the nozzle separation increases, the layer extends to shield more of the jet noise sources.

82-785

Sting Interference Effects on the Static Dynamic and Base Pressure Measurements of the Standard Dynamics Model Aircraft at Mach Numbers 0.3 through 1.3

F.B. Cyran

Arnold Engrg. Dev. Ctr., Arnold AFS, TN, Rept. No. AEDC-TR-81-3, 66 pp (Aug 1981)

AD-A102 612

Key Words: Aircraft, Dynamic tests, Wind tunnel tests

Wind tunnel tests were conducted to provide sting-support interference information for planning and directing wind tunnel tests at subsonic and transonic Mach numbers. Sting length and diameter effects on static and dynamic stability derivatives, static pitching moments, and base pressure of the Standard Dynamics Model (SDM) were investigated at Mach numbers from 0.3 to 1.3. Dynamic stability derivatives were obtained at a nominal frequency of 5.2 Hz, at amplitudes of 1.0, 1.5, and 2.0 deg. Pitch and yaw data were both obtained as a function of angle of attack. Previously unpublished static force and moment data for the SDM are also presented.

82-786

The Influence of Unsteady Aerodynamics on Hingeless Rotor Ground Resonance

W. Johnson

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA TM-81302, A-8635, 47 pp (July 1981)

N81-28056

Key Words: Helicopters, Rotors, Hingeless rotors, Aerodynamic loads, Natural frequencies, Damping

Calculations of the model frequency and damping for a hingeless rotor on a gimballed support in hover are compared with measured results for two figurations (differing in blade flap stiffness). Good correlation is obtained when an inflow dynamics model is used to account for the influence of the unsteady aerodynamics. The effect of the unsteady aerodynamics is significant for this rotor system. The inflow dynamics model introduces additional states corresponding to perturbations of the wake-induced velocity at the rotor disk. The calculations confirm the experimental observation that the inflow mode introduced by these additional states is measurable for one configuration but not for the other.

MISSILES AND SPACECRAFT

82-787

Pyrotechnic Shock Testing - Past and Future

H.N. Luhrs

TRW, Redondo Beach, CA, J. Environ. Sci., 24 (6), pp 17-20 (Nov/Dec 1981) 5 figs

Key Words: Spacecraft, Pyrotechnic shock environment, Testing techniques

This paper addresses the history of pyrotechnic shock testing as it applies to spacecraft electro-mechanical equipment. A pyrotechnic shock, as opposed to aircraft landing shock, or shipping and handling shock, is a very high frequency, high acceleration transient which usually decays in less than 20 milliseconds. In a spacecraft, there are many sources of pyrotechnic shock, typically occurring during separation of booster stages or payloads. Separation mechanisms include explosive bolts or nuts, V-band release, and explosive cutting of structure. A second major source of pyrotechnic shock is the release and development of stowables, such as solar panels, which employ explosive bolts and nuts, pin pullers, and bolt or cable cutters. Pyrotechnic shock events can cause flight failures. Of these failures, the most prevalent are relay malfunctions and secondary failures in which a contaminant in a piecepart is loosened by shock, then causes an electrical short. In addition to relay malfunctions, brittle fracture of crystals and alumina substrates has been observed in laboratory tests.

BIOLOGICAL SYSTEMS

HUMAN

82-788

Study of the Effects of Noise on Residents

NASA, Washington, DC, Rept. No. NASA-TM-76578, 9 pp (May 1981) (Engl. transl. of "Etude des Effets de Bruit sur les Habitants" Rept. (Bron), pp 1-8)
N81-28609

Key Words: Automobile noise, Human response

A survey questionnaire is presented which was used to study the effects of noise on residents such as that from automobile traffic.

82-789

Nature of the Annoyance and Noise Annoyance Relation Around Airports

J. Francois

NASA, Washington, DC, Rept. No. NASA-TM-75873, 27 pp (May 1981) (Engl. trans. of Rev. D'Acoustic (France), 12 (48), pp 70-78 (1979))
N81-28606

Key Words: Aircraft noise, Airports, Human response

A survey of 5,000 individuals living around Orly Airport is described. The psobic index was used as the noise index which indicated the intensity of the annoyance experienced by people living around the airport. The results indicate that sensitivity to noise is related to certain personal factors.

82-790

Effects of the Noise of Street Traffic in Switzerland, A Review of Four Surveys

J. Nemecek, B. Wehrli, and V. Turrian

Dept. of Hygiene and Appl. Physiology, Swiss Fed. Inst. of Tech., Zurich, ETH-Center, CH-8092, Zurich, Switzerland, J. Sound Vib., 78 (2), pp 223-234 (Sept 22, 1981) 10 figs, 1 table, 8 refs

Key Words: Traffic noise, Human response, Reviews

The results of four Swiss field studies of the relation between noise and annoyance in housing areas are presented and compared with those of recent studies elsewhere. In all these studies the degree of annoyance is taken to be the percentage of people "highly annoyed," and the ratio (noise level)/(% "highly annoyed") is found to be a nonlinear function. In the Swiss studies the reasons for the nonlinearity have been investigated by analysis of the effects of particular types of annoyance, such as disturbance of rest, of sleep or of communication.

82-791

Aspects of Annoyance Due to Noise of Road Traffic. Survey Results at 10 Sites

NASA, Washington, DC, Rept. No. NASA-TM-76561, 51 pp (May 1981) (Engl. transl. of "Aspects de la Gene Due au Bruit de la Circulation Routiere. Resultats d'Enquetes sur 10 Sites," Paris, pp 1-125 (Feb 1976))

Key Words: Traffic noise, Human response

Results of surveys per highway site are given. A discussion is given of factors studied such as contribution of various noise sources, variation of noise levels at different sites, times and activities disturbed, and noise level and annoyance.

82-792

Motor Car Lateral Impacts and Occupant Injuries

A. Lozzi

Dept. of Mech. Engrg., Univ. of Sydney, Australia, Intl. J. Vehicle Des., 2 (4), pp 470-479 (Nov 1981) 2 figs, 4 tables, 18 refs

Key Words: Collision research (automotive), Human response

Data obtained from in-depth and mass surveys is examined to provide an insight into the characteristics of lateral car impacts in general, and lateral car-to-pole impacts in particular. It is shown that the rate of fatalities per crash is seven times higher in lateral pole impacts than for collisions overall. The probability of injury and fatality is compared for occupants seated on the near side of the impact to those seated on the far side, for a number of different types of lateral impacts. Poles and trees cause the greatest hazard to the far side occupant than any other bullet object that could be differentiated. From theoretical studies, it is argued that the occupant centered on the intrusion suffers the most rapid change in velocity and probably strikes the hardest targets. On balance, there is an argument for the reinforcement and improved padding of the side structure of motor cars to reduce the overall risk to which car occupants are currently exposed.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

82-793

A Finite Element Analysis of Perforated Component Acoustic Systems

D F. Ross
Res. and Advanced Engrg. Lab., Arvin Industries, Inc., West Lafayette, IN 47906, J. Sound Vib., 79 (1), pp 133-143 (Nov 8, 1981) 11 figs, 16 refs

Key Words: Mufflers, Hole-containing media, Finite element technique

A Lagrangian energy expression is presented that is suitable for finite element analysis of perforated component acoustic systems. This technique can be applied to systems with complex shaped boundaries and is not restricted to the limited geometry that inhibits the traditional one-dimensional techniques. The technique has been applied to automotive muffler component configurations and has been verified experimentally. Perforate flow effects have also been included.

82-794

Computer Simulation of Exhaust Silencers for Four-stroke Engines (Ein Berechnungsverfahren fur Abgasschalldampfer von Viertaktmotoren)

K.P. Mayer and B. Nowotny
St. Peter Hauptstrasse 31 b. A-8042 Graz, Germany, MTZ Motortech. Z., 42 (1), pp 391-396 (Oct 1981) 10 figs, 10 refs
(In German)

Key Words: Silencers, Reciprocating engines, Pipes (tubes), Computerized simulation

The present paper describes a computational method for the design and analysis of reflexive and resonator silencers for internal combustion engines. The silencer system is not considered in isolation but in combination with the engine during the exhaust phase. This interaction between the engine and the exhaust system allows the effect on engine performance to be considered with changes in the latter. In contrast to existing methods, the nonlinear partial differential equations describing the unsteady wave-action are solved using a predictor-corrector method.

82-795

A Study of the Performance of an Olson Type Active Noise Controller and the Possibility of the Reduction of Cabin Noise

S.E. Keith and H.S.B. Scholaert
Toronto Univ. Inst. for Aerospace Studies, Downsview, Ontario, BC, Rept. No. UTIAS-TN-228, ISSN-0082-5263, 26 pp (Mar 1981)
N81-29924

Key Words: Active noise control, Noise reduction, Low frequencies, Aircraft noise, Interior noise

Designed to reduce sound levels by means of an electronic transducing system, the active noise controller is a basic feedback control system composed of a speaker, microphone, amplifier and control unit. Because the scheme can be effective in reducing low frequency noise, it is of particular interest to aircraft manufacturers since attenuation of low frequency noise to increase passenger comfort can be at once costly and cumbersome when conventional sound absorption methods are employed.

82-796

Two Case Studies in the Use of Tuned Vibration Absorbers on Footbridges

R.T. Jones, A.J. Pretlove, and R. Eyre
Structures Dept., Royal Aircraft Establishment, UK, The Struc. Engr., 59B (2), p 27 (June 1981)

Key Words: Vibration absorption (equipment), Tuned dampers, Bridges

The work described is part of a research programme into ways of reducing pedestrian-induced vibrations of footbridges, the problem being that these vibrations can cause discomfort to the user. The two case studies presented describe one method by which this has been achieved -- the discrete tuned vibration absorber. Results show that an absorber with a low mass value (approximately 0·6% of the bridge superstructure mass) can achieve very worthwhile reductions in vibration levels. This effect is, however, dependent on optimum damping and accurate tuning of the absorber and on minimum dry friction in the absorber movement.

82-797

Snubber Sensitivity Study

A.T. Onesto
Energy Technology Engineering Ctr., Canoga Park, CA, Rept. No. ETEC-TDR-80-16, 285 pp (July 1981)
NUREG/CR-2175

Key Words: Snubbers, Seismic isolation, Shock absorbers

Snubbers are used widely throughout the nuclear industry as seismic restraints. The validity of the analysis of snubber-supported systems depends on their realistic characterization. The purpose of this work was to identify those parameters which characterize hydraulic and mechanical snubbers which significantly affect snubber dynamic response and determine the response sensitivity to variations of these parameters. Based upon the results of the foregoing, simplified design and analysis procedures are proposed, to maintain system response within acceptable limits.

BLADES

82-798

Vibration Frequency of a Curved Blade with Weighted Edge

S.V. Hoa
Dept. of Mech. Engrg., Concordia Univ., Montreal, Canada, J. Sound Vib., 79 (1), pp 107-119 (Nov 8, 1981) 8 figs, 4 tables, 5 refs

Key Words: Blades, Natural frequencies, Mode shapes, Shells, Cylindrical shells, Finite element technique

The natural vibration frequencies and mode shapes of a curved cylindrical blade with a weighted edge are investigated. A finite element method is used, in which curved cylindrical shell finite elements are utilized to model the blade. The weighted edge is modeled as a beam with its stiffness and mass added into the stiffness and mass of the blade. Vibration frequencies and mode shapes for blades with different boundary conditions and with different radii of curvature are obtained. Finite element results are compared with experimental results.

82-799

A Parametric Study of Dynamic Response of a Discrete Mode of Turbomachinery Bladed Disk

A. Muszynska and D.I.G. Jones
Univ. of Dayton Res. Inst., Dayton, OH, ASME Paper No. 81-DET-137

Key Words: Blades, Disks (shapes), Turbomachinery blades, Coulomb friction, Damping, Tuning

A model consisting of n five-degree-of-freedom subsystems has been developed to characterize some of the mechanical response features of a bladed disk system, including four modes of each blade, n bending modes of the disk, blade-to-blade and blade-to-ground Coulomb friction, structural damping, blade-to-blade mistuning, and various types of excitation.

82-800

Combined Friction and Material Damping of Resonant Steam Turbine Blade Response

C. Fu-Sheng, M. Wassell, and J. Mosimann
Ingersoll-Rand Corp., Windsor, CT, ASME Paper No. 81-DET-136

Key Words: Blades, Turbine blades, Steam turbines, Coulomb friction, Material damping

A method of optimizing Coulomb friction damping in the presence of material damping to reliably operate turbine blades at resonance is presented. The method is applicable to friction dampers continuous among blades or, in the limit, grounded for arbitrary blades either free or continuously banded at the tip.

82-801

Measurement of the Influence of Flow Distortions on the Blade Vibration Amplitude in an Air Turbine

J. Beckmann and J. Wachter
Univ. of Stuttgart, W. Germany, ASME Paper No. 81-DET-135

Key Words: Blades, Turbine blades, Rotating structures, Fluid-induced excitation, Amplitude analysis

Experimental investigations in an air turbine are carried out to determine the influence of exciting forces due to flow distortions on the vibration amplitudes of a rotating bladed disk.

82-802

On the Formulation of Coupled/Uncoupled Dynamics Analysis of Blade-Disc Assemblies

P.S. Kuo
Avco Lycoming Division, Stratford, CT, ASME Paper No. 81-DET-126

Key Words: Blades, Disks, Resonant response, Coupled response, Finite element technique

The interaction between the blades and their attachments on a flexible rotor-disc assembly may induce potential vibration problems. Coupled blade-disc resonance, the dissimilar behavior of blade groups, and the uncoupled blade or disc natural frequencies must all be evaluated. To satisfy all of the requirements and at the same time reduce the complexity of the analysis, an efficient analytical formulation

of a combined blade-disc segment model using finite element rotational symmetry techniques was developed.

82-803

An Investigation of Dual Mode Phenomena in a Mistuned Bladed Disk

W.A. Stange and J.C. MacBain

Wright-Patterson AFB, OH, ASME Paper No. 81-DET-133

Key Words: Blades, Disks, Tuning, Modal analysis

This paper presents the results of an investigation addressing the effects of mistuning on the lower modes of vibration of a simple bladed-disk model. The phenomena of dual modes, also known as mode splitting, is studied using holographic interferometry and strain gage measurements under non-rotating and rotating conditions.

BEARINGS

(Also see Nos. 750, 755)

82-804

Plain Bearing Properties at High Speeds (Eigenschaften von Gleitlagern bei hohen Umfangsgeschwindigkeiten)

J. Glienicke, D.-C. Han, and M. Leonhard

Univ. Karlsruhe, Konstruktion, 33 (11), pp 441-448 (Nov 1981) 12 figs, 11 refs

(In German)

Key Words: Bearings, Plain bearings, High speed rotors, Stability

The authors examine theoretically and experimentally how the static and dynamic characteristics of plain bearings are affected by lubricating film turbulence, or by inertia forces in laminar range. The lubricant gap turbulence power loss increases, while the bearing-dependent stability limit is decreased. This effect can be partially compensated by reducing the size of the bearing. Inertia forces in the laminar lubricating film also lead to a reduction of the stability limit of speed.

82-805

The Derivation of General Hydrodynamically Effective Angular Velocities for Unstationary Radial Bearings (Ableitung der allgemeinen, hydrodynamisch wirksamen Winkelgeschwindigkeit bei instationaren Radialgleitlagern)

O.R. Lang

Daimler-Benz AG, Stuttgart, Germany, Konstruktion, 33 (11), pp 456-458 (Nov 1981) 1 fig, 1 table

(In German)

Key Words: Bearings, Angular velocity, Hydrodynamic excitation

The hydrodynamic angular velocity used for the calculation of dynamically loaded plain radial bearings is derived in a form applicable to any system of equations. The form presently used is found to be valid. The choice of the system of equations for the load does not affect the hydrodynamically effective angular velocity; only the displacement path of the shaft center in the same system is determined.

82-806

Dynamic Loading of Micropolar Fluid Lubricated Short Journal Bearings

C. Singh and P. Sinha

Indian Inst. of Tech., Kanpur, India, J. Mech. Engrg. Sci., 23 (1), pp 37-44 (Feb 1981)

Key Words: Bearings, Journal bearings, Squeeze film bearings

Dynamically loaded bearings in which the load alternates or rotates are studied in this paper. The Reynolds equation for the general case of a dynamically loaded infinitely short bearing is derived, where the lubricant is assumed to be micropolar. Detailed consideration is given to the dynamic behavior of squeeze films in a short journal bearing under a sinusoidal load with no journal rotation. Various bearing characteristics are calculated, assuming a full film to exist. The micropolarity of the fluid results in more resistance to journal motion, thereby allowing smaller eccentricities for a constant load. The overall conclusion of this study is an increase in the effective viscosity due to the micropolarity of the lubricant. This theory may find application in lubrication when additives are used.

82-807

How to Apply Pivoted-Pad Journal Bearings

M.L. Adams and E. Makay

Univ. of Akron, OH, Power, pp 90-92 (Oct 1981) 5 figs, 4 refs

Key Words: Bearings, Journal bearings, Tilting pad bearings, Design techniques, Vibration control

The fundamentals of pivoted-pad bearings are discussed, which are indispensible in the design of rotating machinery with superior vibration control characteristics.

82-808

Design of Journal Bearings for Rotating Machinery

P.E. Allaire and R.D. Flack

Dept. of Mech. and Aerospace Engrg., Univ. of Virginia, Charlottesville, VA, Turbomachinery Symp., Proc. of the 10th, held Dec 1-3, 1981, Texas A&M Univ., College Station, TX, pp 25-45, 32 figs, 8 tables, 16 refs

Key Words: Bearings, Journal bearings, Rotating machinery, Vibration control

Rotating machinery is often subject to vibrations due to critical speeds, unbalance, and instability. Usually the least expensive modification of a machine to make is the bearing. A wide variety of bearings have been developed to combat some of the different types of vibration problems. This paper discusses the geometry and theoretical and experimental results which have been obtained for a number of bearing types. The three main bearing types discussed in this work are multilobe, pressure dam, and tilting pad bearings. A bearing summary chart indicating some of the advantages and disadvantages of these bearing types as well as others is included in the paper.

82-809

Field Experience and Solution of a Fractional Frequency Vibration Problem on a High Speed Centrifugal Compressor

A.B. Crease

Lagoven S.A., Venezuela, Turbomachinery Symp., Proc of the 10th, held Dec 1-3, 1981, Texas A&M Univ., College Station, TX, pp 47-54, 12 figs, 2 tables, 3 refs

Key Words: Compressors, Centrifugal compressors, Bearings, Clearance effects

This paper describes how a serious field vibration problem on a high speeo centrifugal compressor using tilting pad bearings was identified, following the introduction in the plant of simple methods of vibration recording and analysis, as being due to fractional frequency whirl at around 40% of the running speed. A clear correlation was discovered between the vibration behavior and the bearing clearance. This correlation is shown to match closely the predictions of a theoretical study of the effect of bearing geometry (clearance and preload) on the stability of the particular rotor/bearing system, when a commonly used empirical criterion for stability is employed, namely that the logarithmic decrement of the system should be at least 0.25 for instability to be avoided.

GEARS

(Also see No. 906)

82-810

Vibration Analysis of a Large Naval Gear

L.K.H. Lu and P.C. Warner

Westinghouse, Sunnyvale, CA, ASME Paper No. 81-DET-142

Key Words: Gears, Marine engines, Vibration analysis, Statistical energy methods

This work represents a portion of the initial results of investigation into prediction of high frequency bull gear response using analytical methods. Although the NASTRAN calculations provide results which are in better agreement with experimental measurements than those from the statistical energy analysis (SEA) method, the potential of the SEA method when applied to high frequency ranges and complex structures makes the SEA method a strong candidate for further, more complete investigations.

FASTENERS

82-811

Response of Reinforced Concrete Plate-Column Connections to Dynamic and Static Horizontal Loads

D.G. Morrison and M.A. Sozen

Dept. of Civil Engrg., Univ. of Illinois at Urbana-Champaign, Rept. No. STRUCTURAL RESEARCH SER-490, UILU-ENG-81-2004, NSF/CEE-81024, 266 pp (Apr 1981)

PB81-237380

Key Words: Joints (junctions), Reinforced concrete, Concretes, Dynamic tests

The response of interior reinforced concrete plate-column connections was investigated. Eight speciments were tested, 5 statically and 3 dynamically, (the rate of loading was significant). Other experimental variables were reinforcement ratio and the amount of superimposed vertical load. The specimens had certain common characteristics. The statically tested specimens provided information on the influence of the change in reinforcement ratio and the amount of superimposed vertical load on the response to horizontal loading. An analysis model was developed to interpet the results from the statically tested specimens. The dynamically tested specimens were used to obtain data on the response of the specimens, the observed hysteresis, and calculated damping.

82-812

Dynamic Fracture of Imperfectly Bonded Lap Joints (Dynamisches Verhalten von imperfekt geklebten, einfach uberlappten Klebeverbindungen)

H.P. Rossmanith and A. Shukla
Institut f. Mechanik, Technische Universitat Wien, Karlsplatz 13, A-1040 Wien, Oesterreich, Ing. Arch., 51 (3/4), pp 275-285 (1981) 10 figs, 10 refs

Key Words: Joints (junctions), Fracture properties

Dynamic photoelasticity in conjunction with linear elastic fracture mechanics was utilized to study the dynamic behavior of imperfectly bonded single lap joints. Transient phenomena of propagation, reflection and diffraction of explosively generated plane elastic stress field disturbances about the tips of a crack located at the interface between the two adherends are investigated in detail. Fracture mechanics aspects of dynamic initiation under stress wave loading in similar and dissimilar lap joints are discussed.

82-813

Fatigue Strength of Screwed Fastenings in Thin Sheet Components

M. Strnad
Building Res. Ctr., Prague, Czechoslovakia, The Structural Engineer, 59B (3), pp 33-39 (Sept 1981) 18 figs, 18 refs

Key Words: Fasteners, Screws, Fatigue life

The paper is concerned with the analysis of the behavior of screwed fastenings subjected to repeated loading that can lead to fatigue. Earlier experiments have shown that, in the process of repeated loading, considerable discrepancies in the behavior of identical fastenings can be observed which cannot always be accounted for in terms of loading data alone. It is postulated that these discrepancies are due to the different character of the development of plastic deformations in the process of loading which determines whether the failure observed is caused by high-cycle fatigue, low-cyclic fatigue, or an increase of plastic deformations. This relation also has significant consequences for the experimental establishment of the design strength of a fastening, because it determines whether the approach from above (reduction of the ultimate strength) or from below (limitation of the plastic allowable deformation) should be chosen. The theoretical interpretation is verified by the author's experiments.

82-814

Isolation and Damping of Flexural Waves in Joints (Zur Dämmung und Dämpfung von Biegewellen an Fügestellen)

L. Gaul
Institut f. Mechanik, Universität Hannover, Germany, Ing. Arch., 51 (1/2), pp 101-110 (1981) 7 figs, 9 refs (In German)

Key Words: Joints (junctions), Beams, Flexural waves, Wave transmission

The dynamics of composed structures is influenced by the transfer behavior of interfaces of bolted, riveted and compression joints etc. The measured nonlinear behavior of such interfaces is represented by equivalent linearized models and coupled with models of the members. Characteristics of damping and wave transmission for two jointed beams are calculated for a flexural wave excitation.

SEALS

82-815

Dynamic Response to Rotating-Seat Runout in Noncontacting Face Seals

I. Etsion
Dept. of Mech. Engrg., Technion, Haifa, Israel, J. Lubric. Tech., Trans. ASME, 103 (4), pp 587-592 (Oct 1981) 6 figs, 11 refs

Key Words: Seals

The dynamic response of a flexibly-mounted ring to runout of the rotating seat in mechanical face seal is analyzed

assuming small perturbations. It is found that tracking ability of the stator depends only on its dynamic characteristics and operating conditions and is not affected by the amount of runout. Three different modes of dynamic response are shown and the condition for parallel tracking is presented. The presented analysis is limited to flat-faced seals with no secondary seal damping. Nevertheless it provides a good insight into the dynamic behavior of noncontacting face seals.

STRUCTURAL COMPONENTS

CABLES

(See No. 876)

BEAMS

82-816

The Derivation of Eigenvalues and Mode Shapes for the Bending Motion of a Damped Beam with General End Conditions

J.H.B. Zarek and B.M. Gibbs
Dept. of Bldg. Engrg., Univ. of Liverpool, Liverpool L69 3BX, UK, J. Sound Vib., 78 (2), pp 185-196 (Sept 22, 1981) 9 figs, 15 refs

Key Words: Beams, Damped structures, Eigenvalue problems, Natural frequencies, Mode shapes

The eigenvalues and mode shapes for the bending motion of a beam with restricted classes of end support and generally undamped have been derived separately by a number of authors for use in particular applications. A general method is presented here for the derivation of the complex eigenvalues and eigenvectors for a uniform beam governed by the classical fourth order bending wave equation, the constraints of the supports to shear and rotation being expressed as complex impedances with any desired frequency dependence and damping (with any necessary frequency dependence) being included in the beam material as well as in the supports. The matrix describing the motion is written in a form which can be handled numerically on a computer to provide finite, complex, solutions for any set of dimensionless parameters (describing the magnitude of the support constraint in terms of the beam characteristics) each permitted to vary over the whole range from zero to infinity. The distinction between the effects of damping in the beam material and in the supports is considered, and it is noted that the effect of material damping is dependent on the end conditions.

82-817

The Equations of Motion of Initially Stressed Timoshenko Tubular Beams Conveying Fluid

B.E. Laithier and M.P. Paidoussis
Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Sound Vib., 79 (2), pp 175-195 (Nov 22, 1981) 9 figs, 1 table, 25 refs

Key Words: Beams, Cylindrical shells, Fluid-filled containers, Follower forces, Equations of motion, Timoshenko theory

The equations of motion of an initially stressed Timoshenko tubular beam subjected to a tensile follower load and conveying fluid are derived by using the appropriate statement of Hamilton's principle. This latter is obtained first for "open" systems, the instantaneous total mass of which does not necessarily remain constant in the course of deformation -- "open" denoting that there is momentum transport in and out of the system. The equations of motion are derived separately for a cantilevered system and for one with both extremities of the tube clamped. Yet another derivation for the cantilevered tube is presented with the system considered to be quasi-closed, where all flow-induced effects are incorporated through the virtual work, as if they were "external" forces. All three sets of equations are found to be identical. These equations are then compared with those obtained, more simply, by the Newtonian force-balance approach. Some differences between them are found to exist, the principal of which are associated with the follower or other tensile forces; these are discussed at some length, and the equations of motion obtained here are compared to those obtained by other researchers for Timoshenko beams subjected to follower or tensile forces.

CYLINDERS

82-818

Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part I

S.T. Fleischmann and D.W. Sallet
Dept. of Mech. Engrg., The Univ. of Maryland, College Park, MD 20742, Shock Vib. Dig., 13 (11), pp 9-22 (Nov 1981) 10 figs, 1 table

Key Words: Cylinders, Fluid-induced excitation, Vortex shedding, Reviews

This two-part paper presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part I contains an introduction to the phenomenon of vortex shedding from cylinders and the Karman vortex street. The relation between the formation of the vortex street and the forces on the cylinder is discussed, as are the flow regimes of vortex shedding from stationary, circular cylinders. A flow regime is here defined as a Reynolds number range that is characterized by a particular experimentally obtained relationship of the Strouhal number to the Reynolds number.

82-819

Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomena, Part II

S.T. Fleischmann and D.W. Sallet
Dept. of Mech. Engrg., The Univ. of Maryland, College Park, MD 20742, Shock Vib. Dig., 13 (12), pp 15-24 (Dec 1981) 3 figs, 93 refs

Key Words: Cylinders, Vortex shedding, Fluid-induced excitation, Reviews

This two-part paper presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration. Experimental values of the unsteady lift and drag coefficients and experimental values of the Strouhal number for circular cylinders over a wide range of Reynolds numbers obtained from numerous investigators are presented.

FRAMES AND ARCHES

82-820

A Simplified Method for Evaluating the Natural Frequencies and Corresponding Modal Shapes of Multistorey Frames

E.H. Roberts and R.H. Wood
Building Research Establishment, The Structural Engineer, 59B (1), pp 1-7 (Mar 1981) 8 figs, 1 table, 6 refs

Key Words: Frames, Buildings, Multistory buildings, Natural frequencies, Mode shapes, Wind-induced excitation

With limit state design, sidesway of buildings may become more critical than collapse; there is considerable difficulty in specifying safe sidesway, since wind gusts are dynamic and opposed by inertia as well as by frame stiffness. Dynamic analysis necessitates using large computers but many designers prefer simplified desk methods of analysis. This paper describes an analogous method for dynamic behavior of multistory frames, in particular the natural frequencies and modal shapes that could be developed to study the effects of forced vibration.

PANELS

82-821

Blast-Resistant Capacities of Cold-Formed Steel Panels

W. Stea, F.E. Sock, and J.P. Caltagirone
Ammann and Whitney, NY, Rept. No. ARLCD-CR-81001, AD-E400 610, 119 pp (May 1981)
AD-A101 915

Key Words: Panels, Steel, Blast resistant structures

Cold-formed steel panels are widely used in the construction of steel structures and pre-engineered buildings at explosives manufacturing and storage facilities. The behavior of these panels differs significantly from that of the hot-rolled structural members due to the large width-to-thickness ratios of the elements that constitute their cross-sections. In an earlier project designed criteria were established for cold-formed steel panels. This report documents subsequent tests which were performed to verify or refine these design criteria.

PLATES

82-822

Non-Linear Transient Analysis of Plates by Mixed Elements

J.A.C. Martins and C.A. Mota Soares
Universidade Tecnica de Lisboa, Lisbon, Portugal, ASME Paper No. 81-DET-146

Key Words: Plates, Transient response

A mixed model is developed for the geometrically nonlinear transient analysis of plates subjected to arbitrary forces. The mixed formulation is based on a quadratic isoparametric mixed element and the central-difference and Newmark techniques of transient response.

82-823

Effects of Rotary and Longitudinal Inertias on Transient Response of Undamped Sandwich Plates

A.S. Grover and A.D. Kapur

Dept. of Mech. Engrg., Punjab Engrg. College, Chandigarh, India, J. Sound Vib., 78 (2), pp 175-183 (Sept 22, 1981) 4 figs, 13 refs

Key Words: Plates, Sandwich structures, Elastic core-containing media, Pulse excitation, Rotatory inertia effects

The transient response of a simply supported three layer sandwich plate with an elastic core subjected to half sine pulse acceleration, has been analyzed, with account taken of the effects of the transverse, rotary and longitudinal inertias. The response thus obtained is compared with the corresponding values found when the rotary and longitudinal inertias are neglected. This comparison is given for a wide range of shock durations and different parameters of the sandwich plate.

82-824

Driving Point Impedances of Thick Homogeneous Plates in Flexure

K.J. Buhlert

Institut f. Technische Akustik der Technischen Universitat Berlin, Einsteinufer 27, D1000 Berlin 10, Germany, J. Sound Vib., 78 (2), pp 235-245 (Sept 22, 1981) 10 figs, 7 refs

Key Words: Plates, Mechanical impedance, Mechanical admittance, Flexural vibration

The input admittance of a plate is derived, Mindlin's plate equation being used to take into account rotatory inertia and finite shear stiffness. The real part of the admittance is very similar to the well-known result from Kirchhoff's plate theory; only at higher frequencies does one find differences depending on the size of the exciting area. The imaginary part of the admittance has a spring-like character; it is inversely proportional to the shear stiffness and becomes very large when the exciting area goes to zero. The calculated results are compared with measurements. The agreement is good.

82-825

Large Amplitude Free Vibrations of Simply Supported Equilateral Triangular Plate Using Tri-Linear Co-Ordinates

S.K. Chaudhuri

Dept. of Math., Acharya B.N. Seal College, Cooch-Behar, West Bengal, India, Mechanics Res. Comm., 8 (6), pp 355-360 (1981) 1 fig, 13 refs

Key Words: Plates, Triangular bodies, Free vibration, Large amplitudes

The object of the present study is to apply von Karman equations for investigating amplitude frequency characteristic of a simply supported equilateral triangular plate. The tri-linear co-ordinates have been used and the numerical results obtained have been exhibited graphically.

82-826

Non-Linear Vibrations of a Clamped Circular Plate with Initial Deflection and Initial Edge Displacement, Part 1: Theory

N. Yamaki, K. Otomo, and M. Chiba

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Sound Vib., 79 (1), pp 23-42 (Nov 8, 1981) 15 figs, 1 table, 37 refs

Key Words: Plates, Circular plates, Flexural vibration, Galerkin method, Harmonic balance method

Theoretical analyses are presented for axisymmetric nonlinear vibrations of a clamped circular plate of isotropic materials, under uniformly distributed lateral loading, with the effect of both initial deflection and initial edge displacement taken into consideration. The dynamic analog of the Marguerre equations is used and the steady state solutions are obtained by first applying the Galerkin method and then the harmonic balance method. Actual calculations are carried out for the three degree of freedom Galerkin system and the frequency response characteristics and typical waveforms are determined under various initial edge displacements including initially buckled cases. Effects of both initial deflection and initial edge displacement on the static deflection as well as the lower natural frequencies are also clarified.

82-827

Non-Linear Vibrations of a Clamped Circular Plate with Initial Deflection and Initial Edge Displacement, Part II: Experiment

N. Yamaki, K. Otomo, and M. Chiba

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Sound Vib., 79 (1), pp 43-59 (Nov 8, 1981) 14 figs, 5 refs

Key Words: Plates, Circular plates, Flexural vibration, Experimental test data

To compare with the theoretical results of Part I, detailed experimental results have been obtained on the nonlinear response of a clamped circular plate under a uniformly distributed periodic load, which is subjected to various initial edge displacements. An aluminum test specimen with radius 100 mm and thickness 0•51 mm was used and tests were conducted by shaking the supporting frame with a constant peak acceleration and measuring the relative displacement of the plate to the frame. For the steady state axisymmetric periodic responses, the theoretical results are found to be in good agreement with the experimental ones, with the exception of some quantitative differences in the large amplitude vibrations.

82-828

Approximation Formulae for Natural Frequencies of Simply Supported Skew Plates

T. Sakata
Dept. of Mech. Engrg., Chubu Inst. of Tech., Kasugai, Nagoya-sub, 487, Japan, Intl. J. Mech. Sci., 23 (11), pp 677-685 (1981) 3 figs, 4 tables, 10 refs

Key Words: Plates, Skew plates, Natural frequencies, Reduction methods

By using the reduction method proposed previously by the author and the exact relation between natural frequencies of an isotropic simply supported skew plate and a skew membrane with the same boundary shape, a few approximation formulae for estimating the natural frequency of simply supported isotropic and orthotropic skew plates are derived from the natural frequency of skew membranes without solving the partial differential equation governing the free vibration of the orthotropic skew plate.

82-829

Nonlinear Vibration of Layered Composite Plates Including Transverse Shear and Rotatory Inertia

J.N. Reddy
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, ASME Paper No. 81-DET-144

Key Words: Plates, Composite structures, Layered materials, Flexural vibration, Transverse shear deformation effects, Rotatory inertia effects, Finite element technique

The large-amplitude, free, flexural vibration of layered composite plates, incorporating the effects of transverse shear and rotatory inertia, is studied using a finite element based on the displacement field of a shear deformable theory and the strain-displacement equations of von Karman's plate theory.

SHELLS

(Also see Nos. 798, 817)

82-830

Modes and Frequencies of Vibrating Liquid-Filled Cylindrical Tanks

H. Parkus
Institut f. Mechanik, Karlsplatz 13, A-1040 Wien, Austria, Intl. J. Engrg. Sci., 20 (2), pp 319-326 (1982) 3 figs, 3 refs

Key Words: Storage tanks, Fluid-filled containers, Natural frequencies, Mode shapes

A method is presented for the determination of the natural modes and frequencies of liquid-filled storage tanks. The method is based on an analytical solution of the problem.

82-831

Dynamic Response of a Cylindrical Shell Imperfectly Bonded to a Surrounding Continuum of Infinite Extent

S. Chonan
Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan, J. Sound Vib., 78 (2), pp 257-267 (Sept 22, 1981) 6 figs, 8 refs

Key Words: Shells, Cylindrical shells, Elastic media, Bonded structures

This paper is a study of the dynamic response of a cylindrical shell imperfectly bonded to a surrounding elastic continuum of infinite extent. The shell and the continuum are joined together by a bond which is thin and elastic. The steady state solution of the problem is obtained by using the Fourier transform method with respect to an axial space variable, it being assumed that the shell bends according to a thick shell theory, while the surrounding continuum behavior is in accord with the linear theory of elasticity. The critical speed of the applied load for which a resonance effect occurs in the system is obtained and is plotted as a function of the stiffness of the bond. For subcritical load speeds the radial displacements of the shell are calculated and are shown graphically for several values of the bond stiffness. The results are also compared with those from the classical thin shell theory.

82-832

Vibrations of Cylindrical Shells with Varying Thickness

S. Takahashi, K. Suzuki, T. Kosawada, and E. Anzai
Faculty of Engrg., Yamagata Univ., Yonezawa, Japan,
Bull. JSME, 24 (196), pp 1826-1836 (Oct 1981) 13 figs, 1 table, 14 refs

Key Words: Shells, Cylindrical shells, Variable cross section, Vibration analysis, Boundary condition effects

The asymmetric vibrations of cylindrical shells with variable thickness are studied by the improved shell theory and the classical one. The equations of vibration and the boundary conditions are obtained from stationary conditions of the Lagrangian of vibrations of cylindrical shells. The solutions are obtained in such a case that the thickness of cylindrical shells, built in at one end, varies exponentially along its axis. After numerical calculations, all boundary conditions at the other end are discussed, the effects of parameters on vibrations are investigated and the results by the improved theory are compared with those by the classical one.

PIPES AND TUBES

82-833

Fatigue and Fracture Behavior of Straight Pipe with Flaws in Inner Surface

K Shibata, T. Oba, T. Kawamura, S. Miyazono, and N. Yokoyama
Div. of Reactor Safety, Japan Atomic Energy Res. Inst., Tokai-mura, Ibaraki-ken, Japan,
Nucl. Engr. Des., 66 (1), pp 33-45 (Aug 1981) 14 figs, 4 tables, 7 refs

Key Words: Pipes (tubes), Fatigue tests

Fatigue and fracture tests of piping models with flaws in the inner surface were carried out to investigate the fatigue crack growth, coalescence of multiple cracks and fracture behavior. Two straight test pipes with and without weldment in the test section of AISI type 304L stainless steel were tested under almost the same test conditions by imposing moment loads. Three artificial defects were machined in the inner surface of the test section of the test pipes and the fatigue test was performed until the cracks coalesced and grew through the thickness. Subsequently, a static load was imposed on the test pipe which contained a large crack in the test section. The fatigue test results are compared with an analytical crack growth behavior predicted by the method described in Section XI of ASME Code, and show slower crack growth than that of the prediction. From the fracture test results, it is found that the test pipes can endure considerably high load.

82-834

Use of Spar Elements to Simulate Fluid Acoustical Effects and Fluid-Solid Interaction in the Finite Element Analysis of Piping System Dynamics

R.E. Schwirian and M.E. Karabin
Westinghouse Advanced Reactors Div., Madison, PA,
Nucl. Engr. Des., 66 (1), pp 47-59 (Aug 1981) 16 figs, 1 table, 3 refs

Key Words: Interaction: structure-fluid, Finite element technique, Computer programs, Pipelines

A technique is presented for using existing options in structural analysis finite element computer programs to simulate fluid acoustical effects and fluid-structure interaction in piping system dynamic analysis. With this technique, the fluid in straight pipe sections is represented as a sequence of spar elements coupled to the pipe motion in the transverse direction but free to move independently in the axial direction. Special modeling considerations for treating the acoustical and fluid-structure interaction effects at elbows, tees and area changes are also derived.Results using this kind of modeling are presented for a pulse loading of a leg of piping with the same cross-sectional dimensions and elbow radii as the Clinch River Breeder Reactor Plant primary piping.

82-835

Frequency Response of Blocked Annular Fluid Transmission Lines

M.E. Franke, G.R. Franey, and E.F. Moore
Air Force Inst. of Tech., Wright-Patterson AFB, OH,
J. Dyn. Syst., Meas. and Control, Trans. ASME, 103 (4), pp 366-369 (Dec 1981) 4 figs, 1 table, 14 refs

Key Words: Tubes, Pneumatic lines, Frequency response

Frequency response measurements on blocked annular pneumatic transmission lines with five different radius ratios have been obtained and compared with annular transmission line theory. The agreement between theory and experiment was good.

DUCTS

(Also see No. 794)

82-836

Design Charts for Low Frequency Acoustic Transmission through the Walls of Rectangular Ducts

A. Cummings

Dept. of Mech. and Aerospace Engrg., Univ. of Missouri-Rolla, Rolla, MO 65401, J. Sound Vib., 78 (2), pp 269-289 (Sept 22, 1981) 10 figs, 7 refs

Key Words: Ducts, Rectangular bodies, Walls, Sound transmission, Air conditioning equipment

Design charts are presented from which the low frequency acoustic transmission loss of the walls of rectangular ducts may be found. The upper frequency limit on the applicability of this method is at cut-on for the first cross mode in the equivalent rigid walled duct, and it is shown how a quasi-static theory can easily be used to extend the results, as obtained from the charts, to lower frequencies. The data are given in terms of nondimensional parameters, in order to keep the number of charts to reasonable proportions. Two design examples are described here, and it is felt that the accuracy in the use of the charts is sufficient for most practical purposes.

82-837

Aerodynamic Sound Production in Low Speed Flow Ducts

P.A. Nelson and C.L. Morfey

Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 79 (2), pp 263-289 (Nov 22, 1981) 10 figs, 19 refs

Key Words: Ducts, Sound propagation

Measurements of spoiler aerodynamic noise, generated in a low velocity flow duct and radiated from an open exhaust termination, have been made in the form of sound power spectra. The individual 1/3 octave power measurements are satisfactorily collapsed with the aid of derived theoretical scaling laws. Nondimensional spectra are presented which permit generalized predictions of flow noise for bluff bodies, including splitter attenuators, mounted in low speed flow ducts.

BUILDING COMPONENTS

(Also see No. 876)

82-838

Response Measurements for Glass Cladding Panels

J.I. Craig and B.J. Goodno

School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA 30332, ASCE J. Struc. Div., 107 (11), pp 2199-2214 (Nov 1981) 8 figs, 5 tables, 12 refs

Key Words: Windows, Structural members, Dynamic response

Response measurements in the laboratory of full scale glass cladding panels are presented and compared with the predictions of finite element models. The detailed static and dynamic behavior of a glass panel (window) mounted within a flexible frame and attached to a building frame by means of flexible connections is the focus of the studies. Both singles as well as double pane glass panels are handled. The present results are limited to dynamic response analyses and measurements only. The dynamic response measurements reveal the presence, as predicted, of double plate modes in which the plates move out of phase with respect to each other. One of these, involving no net interpane volume change, is found to occur at a low enough frequency to pose potential problems in large windows where significant pressure nonuniformity might provide excitation. For the range of parameters studied, the results are in good agreement with the predictions of the models and thus confirm their validity and appropriateness.

82-839

Noise from Neighbours and the Sound Insulation of Party Walls in Houses

F.J. Langdon, I.B. Buller, and W.E. Scholes

Bldg. Res. Station, Garston, Watford WD2 7JR, UK, J. Sound Vib., 79 (2), pp 205-228 (Nov 22, 1981) 4 figs, 17 tables, 11 refs

Key Words: Walls, Noise transmission, Acoustic insulation

Residents in a sample of attached houses constructed since 1970 were interviewed in the course of a national survey dealing with nuisance occasioned by noise from neighbors. The airborne sound insulation of the party walls, measured prior to occupation, ranged from zero to 120 dB AAD. Two-thirds of the respondents heard noise from their neighbors and even at performance levels meeting or exceeding the minimum requirements of the building regulations, nearly 50% did so. Of the total sample, 18% were seriously bothered by neighbors' noise. Highly significant relationships were found between physical performance rated in dB AAD (Aggregate Adverse Deviation) and a variety of subjective responses. These results provide, for the first time, empirical validation of the UK performance rating procedure. In addition, the survey findings emphasize the importance of impact noises, not included in the standardized performance measurements, but which contribute substantially to nuisance, particularly between houses where airborne sound insulation is comparatively good.

82-840

Racking Tests of Non-Structural Building Partitions (The Behavior of Architectural (Non-Structural) Building Components During Earthquakes)

S.S. Rihal
Dept. of Architectural Engrg., California Polytechnic State Univ., San Luis Obispo, CA, Rept. No. ARCE-R80-1, NSF/RA-800526, 114 pp (Dec 1980)
PB81-220790

Key Words: Buildings, Structural members, Walls, Seismic response, Testing techniques

The effects of inter-story displacement (drift) during earthquake-like conditions are reported. A series of experiments were conducted to study the correlation between inter-story relative displacement and building partition behavior under horizontal racking loads; to assess the threshold levels of partition damage during horizontal racking actions; and to determine the fundamental characteristics of non-structural building partitions (stiffness and energy absorption capacity and strength) under horizontal racking actions simulating earthquake motion. Parameters in this study consist of geometry of partition configuration and placement of gypsum wallboard panels. Development of the testing program is described and test results, sources of error, and future research plans are presented. Included in the appendices are drawings of test frame and partition test specimens, results of racking tests, and photographs.

ELECTRIC COMPONENTS

MOTORS

82-841

The Behavior of Electrically Driven Flexible Rotors in Torsion and Bending at High Speed (Das Verhalten von elektrisch angetriebenen dreh- und biegeelastischen Rotoren beim Hochlauf)

U. Hollburg
Fortschritt-Berichte VDI-Zt., Reihe 11, No. 42, 174 pp (1981) 48 figs, 6 tables. Summarized in VDI-Z, 123 (15/16), p 660 (Aug 1981). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, price: 112.00 DM
(In German)

Key Words: Motors, Torsional vibration, Flexural vibration, Electromagnetic properties

A transient start-up process of alternatively inductive motor causes a coupling of electric current with mechanical deflection. A method for the evaluation of electrically driven motor vibrations is presented, which considers the mechanical system flexible in bending and torsion simultaneously with electromagnetic characteristics of the motor.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see No. 793)

82-842

Nomographs for Some Common Problems in Acoustics

T.D. Thunder
Sargent and Lundy, Chicago, IL, S/V, Sound Vib., 15 (10), pp 13-17 (Oct 1981) 3 figs, 3 refs

Key Words: Industrial facilities, Noise generation, Sound propagation, Graphic methods

The nomographs presented here were designed to solve attenuation vs. distance problems, particularly for line or plane sound sources in reverberant spaces typical of most industrial plants. These graphs can also be used to estimate the room constant of a space based on sound pressure level measurements. Graphical procedures are also presented for determining the free-field distance of a sound field and for estimating in situ sound levels based on free-field data.

82-843

Industrial Noise: Properties, Sources and Solutions

L.E. Glassburn
Sundstrand Fluid Handling, Arvada, CO, Hydrocarbon Processing, 60 (8), pp 127-130 (Aug 1981) 2 figs

Key Words: Industrial facilities, Noise reduction

Presented is an overview of the sources of industrial noise, the fundamentals of sound and how noise levels can be reduced.

82-844

Industrial Noise Pollution, Part 3: The Practical Function of Acoustical Engineering

R.H. Lyon, R.N. Fleischman, and R.G. Cann
Dept. of Mech. Engrg., MIT, Cambridge, MA. Mech. Engrg., 103 (9), pp 42-47 (Sept 1981) 5 figs, 2 refs

Key Words: Industrial facilities, Noise reduction, Noise generation

Although acoustical engineering is normally thought of in terms of product design or plant environment, it can also provide crucial input on product planning, manufacturing process control, and quality control. The authors have drawn on their extensive experience with one manufacturer of consumer products to illustrate the breadth and magnitude of the impact of acoustics in a number of areas. While the relative importance of the various divisions or operations of an organization will differ from case to case, the projects described here will undoubtedly find their counterparts in many firms, and thus should have a wide spectrum of applications, above and beyond the confines of the single company that was chosen as an example. The purpose of this article is to demonstrate in practical terms that acoustical expertise can significantly help industrial companies reduce their noise pollution problems through a diverse selection of applied engineering techniques.

82-845

Elastic Wave Propagation in Hexagonal Honeycombs: I. Method of Analysis and Low-Frequency Characteristics

S.K. Park and H.L. Bertoni
Dept. of Elect. Engrg., Polytechnic Inst. of New York, 333 Jay St., Brooklyn, NY 11201, J. Acoust. Soc. Amer., 70 (5), pp 1445-1455 (Nov 1981) 9 figs, 2 tables, 14 refs

Key Words: Elastic waves, Wave propagation, Honeycomb structures

Elastic waves propagating in honeycomb panels may be used to inspect for defects induced during manufacture or during use. In order to develop techniques for rapid inspection, it is necessary to know the properties of waves propagating in the honeycomb itself. Physically the wave consists of vibrations of the cell walls of the honeycomb, assuming the cells to be empty. Sensitive inspection would require the use of high frequencies where the wavelength is on the order of cell diameter. At high frequencies the periodic nature of the honeycomb must be accounted for. In this paper a method is developed for analytically finding the properties of Bloch waves propagating in a hexagonal honeycomb. Results presented show that the honeycomb acts as an elastic continuum of hexagonal symmetry at low frequencies.

82-846

Elastic Wave Propagation in Hexagonal Honeycombs: II. High-Frequency Characteristics

S.K. Park and H.L. Bertoni
Dept. of Elect. Engrg., Polytechnic Inst. of New York, 333 Jay St., Brooklyn, NY 11201, J. Acoust. Soc. Amer., 70 (5), pp 1456-1462 (Nov 1981) 13 figs, 7 refs

Key Words: Elastic waves, Wave propagation, Honeycomb structures

Based on the methods developed in a companion paper, computations are made of the propagation characteristics of waves in hexagonal honeycomb structures. The dispersive character of the propagation induced by the periodic nature of the honeycomb is investigated. The dispersion is found to have three aspects, one being the variation of wave velocity with frequency. A second aspect is the variation of wave velocity with propagation direction in the x-y plane. Finally, the polarization type of the waves is found to depend on the direction of propagation relative to the cell axes.

82-847

Space-Time Dependence of Acoustic Waves in a Borehole

M. Schoenberg, T. Marzetta, J. Aron, and R.P. Porter
Schlumberger-Doll Research, P.O. Box 307, Ridgefield, CT 06877, J. Acoust. Soc. Amer., 70 (5), pp 1496-1507 (Nov 1981) 16 figs, 2 tables, 14 refs

Key Words: Elastic waves, Modal analysis

A combined theoretical and experimental study, using a scale laboratory model with a cylindrical borehole, has been performed to study the space-time dependence of modal propagation. Wave analysis has been expanded to include cased hole as well as the more usual situation of open hole propagation. A general formalism for cylindrically layered media is presented. Experimental results include 40 waveforms with transmitter-receiver spacings in increments of 12.7 mm which is sufficient to avoid significant spatial aliasing. Wavenumber-frequency spectral estimation is used to resolve trapped modes in the data set. Good agreement between theory and experiment has been obtained for both modal dispersion and mode cutoff frequencies.

82-848

Effective Lengths of Parametric Acoustic Sources

M.B. Moffett and R.H. Mellen

Naval Underwater Systems Ctr., New London Lab., New London, CT [illegible] J. Acoust. Soc. Amer., 70 (5), pp 1424-1426 (Nov 1981) 4 figs, 12 refs

Key Words: Elastic waves, Sound waves

Computation of effective virtual-source array lengths for parametric acoustic sources are presented. The effective length is defined as the distance from the primary projector where the difference-frequency source level is 1 dB different from (it may be greater or less than) the farfield value.

82-849

Asymptotic Behavior of the N-Wave Solution of Burgers' Generalized Equation for Cylindrical Acoustic Waves

B.O. Enflo

Dept. of Mechanics, Royal Inst. of Tech., S-100 44 Stockholm, Sweden, J. Acoust. Soc. Amer., 70 (5), pp 1421-1423 (Nov 1981) 8 refs

Key Words: Elastic waves, Sound waves

Asymptotic solutions for large distances and for long times are found of Burgers' generalized equation for a cylindrical wave when the boundary condition is an N-shaped (in the time variable) disturbance at a cylindrical surface. The solution is found to have a tail as in the case of linear waves. The amplitude of the faraway solution is determined by the condition that it should be consistent with a long-time solution, which matches a Taylor shock solution.

82-850

STC Calculation

V. Salmon

Menlo Park, CA, S/V, Sound Vib., 15 (10), pp 22-24 (Oct 1981) 3 figs, 7 tables, 1 ref

Key Words: Sound transmission loss, Graphic methods, Computer-aided techniques

By suitably modifying transmission loss values, the calculation of STC (Sound Transmission Class) can be simplified for graphical, tabular or machine methods. With this procedure the reference curve is modified to become a horizontal straight line, rather than the three-segment curve specified in the standard. A flow chart facilitates application of the procedure to calculators or computers.

82-851

Sound Propagation in Shallow Water: A Detailed Description of the Acoustic Field Close to Surface and Bottom

F.B. Jensen

SACLANT ASW Res. Ctr., 19026 La Spezia, Italy, J. Acoust. Soc. Amer., 70 (5), pp 1397-1406 (Nov 1981) 9 figs, 16 refs

Key Words: Underwater sound, Sound propagation

Experimental data are compared with normal-mode predictions for an isovelocity shallow-water propagation channel overlying a complicated layered bottom. Measurements were made close to both the sea surface and the sea floor with a vertical hydrophone spacing of 1 m. Excellent agreement between theory and experiment is obtained over the frequency range 50-3200 Hz and for ranges up to 30 km. Some problems associated with deterministic modeling are also discussed and appropriate solutions are indicated.

82-852

Effect of the Sound Field Structure on Array Signal Gain in a Multipath Environment

J.A. Neubert

Naval Ocean Systems Ctr., San Diego, CA 92152, J. Acoust. Soc. Amer., 70 (4), pp 1098-1102 (Oct 1981) 3 figs, 9 refs

Key Words: Acoustic arrays

A wide-aperture, horizontal line array receiving a low-frequency, long-range signal is considered. It is shown that the sound field structure as manifested by amplitude nonhomogeneity and the wave-front corrugation can reduce the performance of a conventional linear beamformer. Beamformer expressions that explicitly show the effects of amplitude nonhomogeneity and wave-front corrugation in a multipath environment are given. The limitations of some array algorithms that are inappropriate for a multipath environment are indicated. Array signal gain and side-lobe suppression relations for an ocean multipath environment are generalized from similar relations that are not valid in an ocean multipath environment.

82-853

Diffraction of Sound by a Convex or a Concave Dome in an Infinite Baffle

H. Suzuki and J. Tichy
Appl. Res. Lab., Pennsylvania State Univ., University Park, PA 16802, J. Acoust. Soc. Amer., 70 (5), pp 1480-1487 (Nov 1981) 12 figs, 8 refs

Key Words: Acoustic diffraction

In a previous paper the radiation from a convex or a concave dome in an infinite baffle was discussed. This paper is concerned with the second part of the work, dealing with the diffraction of sound by a convex or a concave dome. The effect of the dome on the on-axis sound pressure responses and directivity patterns of a concentric ring source were calculated using a least-square error method. The representation of the sound field by the energy flow as well as the pressure distribution around the source was quite successfully used to discuss the diffraction phenomena.

82-854

Scattering of Acoustic Waves by a Finite Elastic Cylinder Immersed in Water

S.K. Numrich, V.V. Varadan, and V.K. Varadan
Naval Res. Lab., Washington, DC 20375, J. Acoust. Soc. Amer., 70 (5), pp 1407-1411 (Nov 1981) 7 figs, 19 refs

Key Words: Acoustic scattering, Sound waves, Cylinders

The scattering of acoustic waves by a finite elastic cylinder immersed in water has been explored theoretically using the T-matrix method. Numerical results were obtained for an aluminum circular cylinder with hemispherical end caps. Cylinders of this type were immersed in water and subjected to detailed acoustic backscattering measurements as a means of verifying the numerical computations. Comparisons between theory and experiment were made at several angles of incidence. The frequency range covered was sufficient to include major, identifiable resonances at each of these angles. In all cases, the numerical results accurately delineated the observed resonances and compared favorably with the off-resonance, backscattered form function.

82-855

Acoustic Scattering from Fluid Spheres: Diffraction and Interference Near the Critical Scattering Angle

P.L. Marston and D.L. Kingsbury
Dept. of Physics, Washington State Univ., Pullman, WA 99164, J. Acoust. Soc. Amer., 70 (5), pp 1488-1495 (Nov 1981) 6 figs, 32 refs

Key Words: Acoustic scattering, Acoustic diffraction

The scattering of plane waves from an inviscid fluid sphere of specified sound speed and density imbedded in a fluid is considered. Naive application of ray acoustics predicts that the derivative of the modulus of the form function f has an unphysical divergence as the scattering angle approaches a critical scattering angle and that with scattering angle less than critical the surface reflectivity is unimodular with a phase advancement. A divergence-free model is given here which is analogous to the physical-optics approximation in "Scattering by a bubble in water near the critical angle: Interference effects."

82-856

Sound Diffraction by a Many-Sided Barrier or Pillar

T. Kawai
Takenaka Technical Res. Lab., Tokyo 136, Japan, J. Sound Vib., 79 (2), pp 229-242 (Nov 22, 1981) 12 figs, 11 refs

Key Words: Acoustic diffraction, Sound propagation, Noise barriers

The sound field produced when a spherical sound wave is incident on a rigid many-sided barrier or pillar is calculated on the basis of Keller's geometrical theory of diffraction, Kouyoumjian and Pathak's asymptotic solution for a single wedge, and Pierce's method for a doubly diffracted wave. From a comparison between calculated results and experimental results, it is shown that the method described is applicable to the prediction of the propagation of noise around a thick barrier, a building, a number of these obstacles, or a number of thin barriers, with an extremely high accuracy.

82-857

Acoustic Diffraction by a Finite Barrier; Theories and Experiment

G.M. Jebsen
Naval Postgraduate School, Monterey, CA, Master's Thesis, 130 pp (Mar 1981)
AD-A102 664

Key Words: Acoustic diffraction, Noise barriers

The Biot-Tolstoy (B-T) exact impulse solution of diffraction by an infinite half-plane is compared to the usual Helmholtz-

Kirchoff (H-K) integral formulation and to the exact continuous wave (CW) solution of Macdonald. For backscatter the B-T and H-K solutions are found to differ significantly, especially near the surface of the half-plane, where the B-T solution gives close agreement with experiment. For forward scatter the two exact solutions and experimental data are in agreement. B-T is found to agree well with measurements of diffraction by a barrier perpendicular to a rigid base. By considering source and source image in the base separately the concept of image of the source in the barrier is found to be unnecessary. Use of the time domain form of B-T solution in calculating the forward diffraction near a corner and behind a thin strip is shown to give results which agree well with measured data.

82-858

The Attenuation of Sound Propagating through a Radial Diffuser with Absorptive Walls

D.K. Holger
Dept. of Engrg. Science and Mechanics, Iowa State Univ., Ames, IA 50011, J. Sound Vib., 79 (1), pp 1-9 (Nov 8, 1981) 5 figs, 2 tables, 3 refs

Key Words: Walls, Sound attenuation, Computer programs, Acoustic linings, Acoustic impedance

An analytical model for acoustic propagation through an idealized radial diffuser under zero flow conditions has been developed. The model has been used to generate a computer program which is capable of predicting radial attenuation for a variety of diffuser wall impedance combinations. Numerical results are presented for the following three cases: (1) one hard diffuser wall and one finite impedance wall, (2) equal finite impedance diffuser walls, and (3) unequal finite impedance diffuser walls. The results for cases (1) and (2) are found to be in good agreement with analytical results from the literature.

82-859

Sound Attenuation Over Ground Cover III

K. Attenborough
Engrg. Mechanics, Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK, Shock Vib. Dig., 13 (11), pp 3-6 (Nov 1981) 31 refs

Key Words: Sound attenuation, Noise barriers, Trees (plants)

This review of recent developments in predicting noise from surface transport sources takes into account ground effects and the presence of purpose-built noise barriers. Mechanisms of sound attenuation in forests are outlined. Developments in the measurement of acoustic properties of the ground are discussed. Finally, useful directions for further work are proposed.

82-860

Sound Propagation Over Grass Covered Ground

K.B. Rasmussen
The Acoustics Lab., Tech. Univ. of Denmark, DK-2800 Lyngby, Denmark, J. Sound Vib., 78 (2), pp 247-255 (Sept 22, 1981) 1 fig, 12 refs

Key Words: Sound propagation, Grass

Results from field measurements of sound propagation from an approximate point source over grass covered ground are shown. The experimental data are compared with theoretical predictions of the sound pressure levels. The theoretical results are based upon different ground models for which local reaction within the ground is assumed. The possibility of extended reaction properties in the ground is also touched upon.

82-861

Variational Formulations for the Finite Element Analysis of Noise Radiation from High-Speed Machinery

B.S. Thompson
Dept. of Mech. Engrg., Wayne State Univ., Detroit, MI 48202, J. Engrg. Indus., Trans. ASME, 103 (4), pp 385-391 (Nov 1981) 3 figs, 17 refs

Key Words: Machinery noise, Finite element technique

Variational theorems are presented for analyzing the vibrational response of flexible linkage mechanisms and the surrounding acoustic medium in which they are immersed. These theorems are established by generalizing Hamilton's principle through using Lagrange multipliers to incorporate field equations and boundary conditions within the functional. The same philosophy is adopted to handle the conditions at the fluid-structural interface. When independent arbitrary variations of the system parameters are permitted, these acousto-elastodynamic theorems yield as characteristic equations the equation of motion for each member of the linkage, the acoustical wave equation, the compatibility conditions at the interface between the fluid and solid continua, and also the boundary conditions. These variational statements provide the foundations for several different classes of finite element analysis.

82-862

Lightweight Impulsive Noise Suppressor

J.H. Arszman

Dept. of the Army, Washington, DC, PAT-APPL-6-280 602, 6 pp (July 6, 1981)

Key Words: Noise reduction, Gunfire effects

An apparatus is described for producing a significant reduction in the impulsive noise of high performance, antitank weapons of the military services while retaining the necessary packaging constraints. The reduction is achieved by the release of the hot gases in a controlled manner such that the rate at which the initial gas is expelled to the ambient air is reduced. This programmed gas release causes a significant reduction in impulsive noise.

SHOCK EXCITATION

82-863

Shock-Compression Measurements at Pressures > 1TPa

C.E. Ragan, B.C. Diven, M. Rich, E.E. Robinson, and W.A. Teasdale

Los Alamos National Lab., NM, Rept. No. LA-UR-81-1824, CONF-810684-21, 6 pp (1981) (Pres. at APS Conference on Shock Waves in Condensed Matter, Menlo Park, CA, USA, June 23, 1981) DE81025313

Key Words: Shock waves, Nuclear explosion effects

A nuclear explosive generated planar shock has been used to perform impedance-matching experiments relative to a molybdenum standard. Shock velocities were measured with accuracies of 1.5% to 2.5%, thus providing Hugoniot data for samples of Al, quartz, Fe, Mo, and low-density Mo at pressures from 2 to 5 TPa.

82-864

Non-Linear Propagation of General Directional Spherical Waves

S.G. Kelly and A.H. Nayfeh

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 79 (1), pp 145-156 (Nov 8, 1981) 2 figs, 14 refs

Key Words: Shock wave propagation, Wave propagation, Spherical waves, Harmonic excitation

The method of renormalization is used to determine a uniformly valid expansion for the problem of nonlinear waves produced in a fluid by the general harmonic pulsations of a sphere. For a uniform expansion, only the radial distance needs to be strained. The effect of dimensionless quantities upon the shock-formation distance is examined.

82-865

Shock Wave Reflection from Supersonic Sea-skimming – A First Look

G.M. Moss

Appl. Mech. Branch, The Royal Military College of Science, UK, Aeronaut. J., 85 (850), pp 459-466 (Dec 1981) 18 figs, 1 table, 4 refs

Key Words: Shock wave reflection, Wave reflection, Guided missiles, Ships

There is currently some interest in supersonic sea-skimming as a possible terminal phase for anti-ship guided weapons. The flight of a supersonic vehicle, close to a density interface, will produce an additional series of shock waves from the reflection of the shock waves generated by the vehicle from the interface. The angle of reflection of these shock waves will depend, inter alia, on the slope of the surface upon which they are incident. Given a surface with a periodic positional displacement, such as would be produced by a train of surface waves, the variation in position of the reflected shocks, in relation to the generating vehicle, will also be periodic in nature. This coherent motion could produce periodically fluctuating forces and moments on the vehicle generating the incident shocks and these, in turn, could cause stability or control problems for the missile autopilot. The magnitude and frequency of these fluctuating forces and moments will depend to a first order on the surface waveform, the speed and size of the vehicle and the vehicle height above the sea surface. This paper is a preliminary analysis of the problem; results are given which should allow a designer to assess whether or not reflected shock interaction is likely to occur under given conditions of operating altitude and sea state. The estimation of forces and moments produced on a particular missile requires detailed knowledge of the missile geometry but a simple model is proposed in the paper which enables the effects of the main parameters to be comparatively assessed.

VIBRATION EXCITATION

82-866

On the Integration of the Nonconservative Hamilton's Dynamical Equations

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The Faculty of Technical Sciences, Univ. of Novi Sad, V. Vlahovića 3, 21000 Novi Sad, Yugoslavia,
Intl. J. Engrg. Sci., 19 (12), pp 1739-1747 (1981) 7 refs

Key Words: Equations of motion, Hamiltonian principle

This paper exhibits a method of integrating Hamilton's canonical equations of motion by supposing that one component of the momentum vector can be represented as a field depending on time, generalized coordinates and the rest of the components of the momentum vector. The motion of a conservative or nonconservative dynamical system can be determined by purely algebraic operations if a complete solution of a quasi-linear partial differential equation is known. The method is equally suitable for initial and boundary value problems.

82-867

Subharmonic Vibration of Order 1/2 in System under External Force with Constant Term

Y. Iwata and Y. Kobori
Dept. of Mech. Engrg., Kanazawa Univ., 2-40-20, Kodatsuno, Kanazawa, 920, Japan, Bull. JSME, 24 (196), pp 1837-1843 (Oct 1981) 9 figs, 7 refs

Key Words: Subharmonic oscillations, Single degree of freedom systems

In the case when a single-degree-of-freedom system, which has the symmetrical nonlinearity with a linear term and a cubic nonlinear term, is subjected to the periodic force containing a constant force, the possibility that a subharmonic vibration of order 1/2 appears has been suggested and its characteristic has been investigated. The necessary condition for the subharmonic vibration of order 1/2 is expressed by the parameters of damping, coefficient of cubic nonlinear term and constant force. Further, the relationship between the constant force and the waveform of the subharmonic vibration is determined. The validity of the analysis has been shown by means of the experiment.

82-868

Random to Deterministic Transform

S.M. Metwalli and R.W. Mayne
Dept. of Mech. Engrg., Cairo Univ., Cairo, Egypt, J. Sound Vib., 79 (2), pp 197-204 (Nov 22, 1981) 13 refs

Key Words: Random vibration, Fourier transformation, Root mean squares

A method of transforming an ergodic random signal to its deterministic equivalent is presented. The transform requires that the spectral density of the random signal should be known. It also depends on the ability to obtain the inverse Fourier transform of a function. A specific relationship is developed to evaluate the root mean square of a random signal based on its deterministic equivalent. A sample application is presented to demonstrate that a step input can be equivalent to a hyperbolic spectral density. A linear system is subjected to the hyperbolic spectral density and the equivalent step. The calculated root mean square outputs are found to be identical. Deterministic equivalents for other random signals are also indicated.

82-869

Harmonic Waves in Layered Transversely Isotropic Composites

S. Nemat-Nasser and M. Yamada
Dept. of Civil Engrg., Northwestern Univ., Evanston, IL 60201, J. Sound Vib., 79 (2), pp 161-170 (Nov 22, 1981) 3 figs, 10 refs

Key Words: Wave propagation, Harmonic waves, Composite structures, Layered materials

The dispersive property of laminated elastic composites consisting of transversely isotropic layers is studied. Harmonic waves with various propagation directions with respect to the direction of layering are considered. Exact solutions are presented and compared with the results of the new quotient method recently developed by one of the authors.

82-870

Acceleration and Deceleration of Single-Degree-of-Freedom Systems

R. Markert and H. Pfutzner
Inst. f. Mechanik, Hochschule d. Bundeswehr, Hamburg, Germany, Forsch. Ingenieurwesen, 47 (4), pp 117-125 (1981) 8 figs, 20 refs

Key Words: Single degree of freedom systems, Acceleration analysis, Deceleration

This paper is concerned with the vibration during acceleration or deceleration of a linear heteronomous single-degree-of-freedom system. The frequency of the exiting function varies linear with time. The right-hand side of the differential

equation is so generally represented that all possible exciting mechanisms are included. In contrast to other publications, an analytical solution was given, expressed by error functions with complete arguments.

82-871

The Stable Self-Excitations of the Nonlinear Wave Equation of Van der Pol Type

R.W. Lardner and G. Nicklason
Mathematics Dept., Simon Fraser Univ., Burnaby, BC V5A 1S6, Canada, SIAM J. Appl. Math., 41 (3), pp 480-492 (Dec 1981) 3 figs, 3 refs

Key Words: Self-excited vibrations, Wave equation, Van der Pol method

The weakly nonlinear wave equation in which the nonlinearity is of the van der Pol type is considered. This equation has been proposed as a model for the wind-induced oscillations of overhead power lines. It is shown that any initial disturbance generates a solution of finite amplitude which consists of the superposition of two traveling waves having sawtooth profiles. A stability analysis provides a complete classification of all such waves which can be generated.

28-872

Experimental and Theoretical Study of Nonlinear Flutter

S.C. McIntosh, Jr., R.E. Reed, Jr., and W.P. Rodden
Nielsen Engrg. and Research Inc., Mountain View, CA, J. Aircraft, 18 (12), pp 1057-1063 (Dec 1981) 6 figs, 5 tables, 12 refs

Key Words: Flutter, Nonlinear theories, Experimental test data

A typical-section flutter model, incorporating linear and nonlinear spring restraints in torsion and plunge, has been designed, built, and tested in a wind tunnel. The principal goal of the experiments was to produce high-quality stability and response data, for a number of different types of nonlinearities, from a model whose properties are known very accurately. An additional goal was to develop and validate an accurate mathematical model of the system to aid in theoretical studies. Experiments were performed for both hardening and softening springs in plunge, and hardening springs in torsion. Both limit-cycle and divergent amplitude-sensitive instabilities were observed. The experimental results and some comparisons with theoretical nonlinear time-history calculations and linear stability analyses are described. Generally excellent agreement was obtained between linear experimental and theoretical results, and an amplitude-sensitive instability was predicted theoretically that agreed with experimental observations. Comments are also given concerning improvements to be made to the theoretical model and additional theoretical and experimental work to be done.

82-873

Transient Cavitation in Fluid-Structure Interactions

C.A. Kot, B.J. Hsieh, C.K. Youngdahl, and R.A. Valentin
Components Technology Div., Argonne National Lab., Argonne, IL 60439, J. Pressure Vessel Tech., Trans. ASME, 103 (4), pp 345-351 (Nov 1981) 13 figs, 9 refs

Key Words: Interaction: structure-fluid, Cavitation

A generalized column separation model is extended to predict transient cavitation associated with fluid-structure interactions. The essential feature of the combined fluid-structure interaction calculations is the coupling between the fluid transient, which is computed one dimensionally, and the structural response which can be multidimensional. Proper coupling is achieved by defining an average, one-dimensional, structural velocity and by assuming a spatially uniform pressure loading of the structure. This procedure is found to be effective even for very complex finite element structural models for which the required computational time step is orders of magnitude smaller than that for the fluid transient. Computational examples and comparison with experimental data show that neglecting cavitation and setting the fluid velocity at all times equal to that of the structural boundary leads to unreal negative pressure predictions. On the other hand a properly coupled column separation model reproduces the important features of fluid-structure interactions, converges rapidly, and gives reasonable fluid and structural response predictions.

82-874

Fluid Dynamics of a Flow Excited Resonance, Part I: Experiment

P.A. Nelson, N.A. Halliwell, and P.E. Doak
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 78 (1), pp 15-38 (Sept 8, 1981) 16 figs, 25 refs

Key Words: Fluid-induced excitation, Resonant response

This is the first of two companion papers concerned with the physics and detailed fluid dynamics of a flow excited

resonance. The phenomenon has been examined by using a rather different approach in which usually stability theory has been applied to small wave-like disturbances in an unstable shear layer with an equivalent source to describe the radiation of sound providing the feedback. The physics of the flow acoustic interaction is explained in terms of the detailed momentum and energy exchanges occurring in the fluid itself. Gross properties of the flow and resonance are described in terms of the parameters necessary to determine the behavior of the self-oscillatory system. A full experimental investigation of a flow excited Helmholtz resonator is described, in which the detailed fluid dynamical and acoustic data necessary to develop a mathematical model for the flow was obtained. The investigation described involved the use of a two-component Laser-Doppler Velocimeter and probe microphones to specify completely the velocity and pressure fields and a flow visualization to give qualitative information of the vortex shedding process.

82-875

A Variational Principle for a Solid-Water Interaction System

Y. Yamamoto
Dept. of Naval Architecture, Univ. of Tokyo, Bunkyo-ku, Tokyo 113, Japan, Intl. J. Engrg. Sci., 19 (12), pp 1757-1763 (1981) 14 refs

Key Words: Interaction: solid-fluid, Fluid-induced excitation

A variational principle for a coupled dynamic system of a solid and a water field with a free surface is derived with the aid of Hamilton and Toupin's dual principles. It is helpful for better understanding solid-water interaction problems.

82-876

The Vortex-Induced Oscillation of Non-Uniform Structural Systems

W.D. Iwan
California Inst. of Tech., Pasadena, CA 91125, J. Sound Vib., 79 (2), pp 291-301 (Nov 22, 1981) 6 figs, 11 refs

Key Words: Fluid-induced excitation, Structural members, Underwater structures, Cylinders, Cables

A simple analytical model is presented for the vortex-induced oscillation of non-uniform structures. The effects of limited spatial extent of lock-in and fluid damping of inactive elements are accounted for. For a particular response mode, the equations describing the system response reduce to the form obtained for a rigid cylinder. Empirical formulas for the rigid cylinder response problem can therefore be readily incorporated into the analysis. Three illustrative examples are given which show that the response of a non-uniform cable system may differ markedly from that of a uniform cable system. In general, it is found that the response of the non-uniform system is less than that of the corresponding uniform system.

MECHANICAL PROPERTIES

DAMPING

(Also see Nos. 761, 796)

82-877

Damping in Metals under Combined Stress Loading

R.J. Hooker
Dept. of Mech. Engrg., Univ. of Queensland, St. Lucia, Queensland 4067, Australia, J. Sound Vib., 79 (2), pp 243-262 (Nov 22, 1981) 11 figs, 5 tables, 12 refs

Key Words: Damping, Material damping, Metals, Experimental test data

Studies have been made of damping behavior under conditions of combined stress (i.e., biaxial loading) for six high damping metals -- two alloys of manganese-copper and four grades of cast iron. Measured values of damping are presented from tests covering a range of combined stress states and the damping behavior is interpreted in terms of dependence on stress state. The measured values were obtained from a new experiment in which various combined stress conditions are generated by coupled torsion/bending vibration of a cantilever. The range covered is from all torsion to all bending, i.e., principal stress ratios from -1 to 0. Damping is determined from energy input during steady state resonant vibration, but frequency response and free decay methods can also be used. Details of the apparatus are given.

FATIGUE

(Also see No. 925)

82-878

Effect of Grain Size on Low Cycle Fatigue in Low Carbon Steel

K. Hatanaka and T. Yamada

Dept. of Mech. Engrg., Faculty of Engrg., Yamaguchi Univ., Ube, 755, Japan, Bull. JSME, 24 (196), pp 1692-1699 (Oct 1981) 11 figs, 28 refs

Key Words: Fatigue (materials), Steel

Low cycle fatigue tests were performed on a low carbon steel of 0.1 percent carbon content, which has various grain sizes. The cyclic softening is followed by a stationary state in cyclic deformation behavior in the fine grain material, while the coarse grain one exhibits a rapid cyclic hardening in the early stage, which is followed by a saturation hardening. Such a difference in cyclic deformation property can be interpreted well by considering that in the yielding behavior between the fine and the coarse grain materials. The cyclic stress-strain property is not influenced by the grain size.

82-879

Corrosion Fatigue Crack-Growth Behavior of HY-130 Steel and Weldments

D.A. Davis and E.J. Czyryca

David Taylor Naval Ship Res. and Dev. Ctr., Annapolis, MD 21402, J. Pressure Vessel Tech., Trans. ASME, 103 (4), pp 314-321 (Nov 1981) 19 figs, 2 tables, 17 refs

Key Words: Fatigue (materials), Crack propagation, Steel

Fatigue crack propagation was studied in HY-130 steel base plate, as-deposited shielded metal-arc weld metal, and gas metal-arc weld metal using compact specimens. The effects of seawater, cathodic protection, frequency and hold time were investigated. Results of the environmental effects of weld metals indicated that, even under the most severe conditions of cathodic potential in seawater, fatigue crack-growth rates in weld metal were lower than those observed with base plate in air.

82-880

Ultrasonic Fatigue Test of Mild Steel

K. Terao, T. Kuno, T. Ono, and M. Mizuno

Keio Univ., Yokohama, Bull. JSME, 24 (196), pp 1708-1715 (Oct 1981) 30 figs, 12 refs

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

In an ultrasonic fatigue test of mild steel, the authors investigated the effects of strain amplitude, mean stress, and pre-strain on the changes of resonant frequency, and found a close relationship between the reduction of resonant frequency due to ultrasonic fatigue and the change of the microscopic structure. 'The yield point for the stress of vibration' was defined by a strain amplitude which causes a rapid decrease of resonant frequency. Moreover, from an ultrasonic fatigue test with mean stress, a fatigue limit diagram was made for practical use.

82-881

Proposed Acoustic Emission Location System for a Full-Scale Fatigue Test

I.G. Scott

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/MAT-TM-378, 23 pp (Apr 1981)
AD-A102 326

Key Words: Acoustic emission, Fatigue tests

Various aspects of proposed AE location system are reviewed. Basic sensor arrays are considered, solutions to the describing equations are found, and various problems are identified. Location using AE appears to be based on simple premises and, as a consequence, practical application involves the use of a variety of experience-based techniques.

82-882

Modern Fatigue Data for Designing Component Parts in Grade GTS 55 Malleable Iron - Part I (Moderne Schwingfestigkeitsunterlagen fur die Bemessung von Bauteilen aus Temperguss GTS 55 vor allem fur den Fahrzeugbau)

M. Huck, W. Schutz, and H. Walter

Asternweg 25, 8011 Vaterstetten, Germany, Automobiltech. Z., 83 (10), pp 523-526 (Oct 1981) 6 figs, 3 tables, 16 figs
(In German)

Key Words: Automobiles, Fatigue tests

The design of light weight component parts which are fatigue loaded involves increased expense. Two design methods, or a combination of both, are normally used. Either the design is calculated from reliable fatigue test data of the material or an empirical design is made based on extensive tests done on the component part [1 bis 6]. Test costs can considerably be reduced when reliable, practice oriented material property data is available. This economic factor was one reason for the fatigue testing of grade GTS 55 malleable iron which is described here. The material and testing technique were modified to fit the present state of the art. The objective was to provide fatigue data for designers, material engineers, and testing engineers, especially those in the automotive sector and related fields, so that this extended knowledge of the materials would allow castings to be more precisely designed.

82-883

Modern Fatigue Data for Designing Component Parts in Grade GTS 55 Malleable Iron - Part 2 (Moderne Schwingfestigkeitsunterlagen für die Bemessung von Bauteilen aus Temperguss GTS 55 vor allem für den Fahrzeugbau)

M. Huck, W. Schutz, and H. Walter

Automobiltech. Z., 83 (11), pp 599-602 (Nov 1981) 19 figs, 4 tables, 29 refs
(In German)

Key Words: Fatigue (materials), Metals, Experimental test data

Extensive vibration tests were carried out to provide fatigue data for designers, material engineers, and testing engineers.

82-884

On the Propagation Behavior of the Fatigue Crack along the Interface of Metal Composites

T. Tanaka and M. Hori
Faculty of Science and Engrg., Ritsumeikan Univ., Kyoto, Japan, Bull. JSME, 24 (196), pp 1700-1707 (Oct 1981) 16 figs, 14 refs

Key Words: Fatigue tests, Plates, Composite structures, Crack propagation

Push-pull fatigue tests were conducted on butt-bonded three layer composite plates composed of iron and copper to study the propagation behaviors of fatigue cracks along interfaces. Observations showed that the cracks along interfaces are classified into three patterns -- interface cracks propagating precisely along the interface between iron and copper, sub-interface cracks propagating in copper region at a distance of $20\sim30\mu m$ from the interface and copper cracks propagating in copper region far away from the interface.

ELASTICITY AND PLASTICITY

82-885

Shakedown Analysis of Elastoplastic Structures: A Review of Recent Developments

J.A. König and G. Maier
Polish Academy of Sciences, Warsaw, Poland, Nucl. Engr. Des., 66 (1), pp 81-95 (Aug 1981) 2 figs, 87 refs

Key Words: Shakedown theorem, Elastoplastic properties

Classical shakedown analysis rests on the assumptions of perfectly plastic, associative temperature-independent constitutive laws, negligible inertia and damping forces and negligible geometric effects. This paper provides a survey of the recent literature on the structural behavior under variable repeated loads, with emphasis on the developments which relaxed some of the above assumptions, but preserved the character of generalization of limit analysis typical of the classical shakedown theory and methods of analysis and design (in contrast to evolutive, step-by-step approaches of incremental plasticity).

82-886

An Average Theory for the Dynamic Behavior of a Laminated Elastic-Viscoplastic Work-Hardening Medium

J. Aboudi and Y. Benveniste
Dept. of Solid Mech., Tel-Aviv Univ., Ramat-Aviv, Tel-Aviv, 69978, Israel, Z. angew. Math. Mech., 61 (7), pp 315-324 (July 1981) 5 figs, 8 refs

Key Words: Layered materials, Viscoplastic properties, Strain hardening

An average theory which models the dynamic behavior of a bilaminated medium under specific types of loading, made of elastic viscoplastic work-hardening materials is developed. Each constituent is represented by a unified theory of elasto-viscoplasticity including work-hardening, which requires neither a yield criterion nor loading or unloading conditions. The resulting effective theory appears in the form of a system of nonlinear differential equations for the average stresses, displacement and plastic work. The theory is applied to construct the effective stress-strain curves of the laminated medium in which the transition from the elastic to the plastic domain can be determined. The theory is also applied to obtain the dynamic response of a laminated slab subjected to velocity or stress input.

82-887

A Method for Determining Dynamic Stress Intensity Factors from Crack Measurement at the Notch Mouth in Dynamic Tear Testing

T. Nishioka and S.N. Atluri

Ctr. for the Advancement for Computational Mechanics, Georgia Inst. of Tech., Atlanta, GA, Rept. No. GIT-CACM-SNA-11, TR-13, 20 pp (July 1981) AD-A103 077

Key Words: Dynamic stress concentration, Crack propagation

A formula is derived for determining dynamic stress intensity factors directly from crack mouth opening displacements in dynamic tear test specimen. The results obtained by the present estimation method for stationary as well as propagating cracks agree excellently with those directly obtained through a highly accurate moving-singularity finite element method. The present method can also be applied for other types of specimen which have a relatively short edge crack without any loading on the crack surface. The present simple estimation method should be of great value in the experimental measurement of dynamic stress-intensity factors for propagating cracks in (opaque) structural steel dynamic tear test specimens.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

(Also see No. 927)

82-888

Stability Investigations of Linear Systems with Periodically Variable Parameters (Stabilitätsuntersuchungen an linearen Systemen mit periodisch zeitveränderlichen Parametern)

K. Naab

Fortschritt-Berichte VDI-Zt., Reihe 11, No. 41 (1981), 130 pp, 34 figs, 4 tables. Summarized in VDI-Z, 123 (15/16), p 656 (Aug 1981). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, price 77 DM

(In German)

Key Words: Stability, Linear systems, Time-dependent parameters, Frequency domain method

Frequency domain methods for the determination of stability of linear systems with periodically variable parameters are presented in detail and demonstrated by two examples. They are the determination of stability of single step gear drives with straight and inclined teeth and the stability of a two-member rotor-bearing system with asymmetric rotor and bearing parameters. An efficiency of a factor of 10^3 was achieved with fully sufficient conditions for operation.

82-889

Calibration of Sound Measuring Instruments

W.R. Kundert

Industrial Resources, Harvard, MA, S/V, Sound Vib., 15 (10), pp 19-21 (Oct 1981) 4 figs

Key Words: Calibrating, Measuring instruments, Sound measurement, Standards and codes

The meaning of calibration is discussed and highlights of the draft ANSI standard for field calibrators are presented. Recommendations for periodic calibration are given along with some tips on using field calibrators.

82-890

Instrument for Measuring of Dynamic Angular Acceleration and Torque (Aufnehmer zur Messung schnell veranderlicher Drehbeschleunigungen und Drehmomente)

A. Denne, H. Rausch, and W. Freise

Universität Kaiserslautern, Fachbereich Elektrotechnik, Postfach 3049, 6750 Kaiserslautern, Germany, Techn. Messen-TM, 48 (10), pp 339-342 (Jan 1981) 2 figs, 5 refs

(In German)

Key Words: Measuring instruments, Torsional vibration

In case of fast changing of angular acceleration and torque it is necessary to fullfil some conditions concerning the behavior of the measuring system. Different methods of measurement are studied with respect to these conditions. Construction, performance and results of a suitable system are described.

82-891

Acoustic Emission Determination of Deformation Mechanisms Leading to Failure of Naval Alloys. Phase I

J.T. Glass, S. Majerowicz, and R.E. Green, Jr.
Dept. of Materials Science and Engrg., Johns Hopkins Univ., Baltimore, MD, Rept. No. DTNSRDC/SME 81-44, 60 pp (July 1981)
AD-A 102 762

Key Words: Acoustic emission, Measurement techniques

The purpose of the present research is to use innovative optical techniques and superior signal capture and processing systems to determine the waveforms, frequency spectra, and propagational behavior of the acoustic emission signals generated by the various mechanical deformation mechanisms leading to failure of metal alloys of prime importance to naval structures. The ultimate goal of this research is to absolutely determine the degree to which precise characterization of the acoustic emission signals can serve to remotely assess the severity of mechanical damage and give early warning of impending failure.

82-892

Investigations of Cepstrum Analysis for Seismic/Acoustic Signal Sensor Range Determination

F.M. Ingels and G. Koleyni
Engrg. and Industrial Res. Station, Mississippi State Univ., Mississippi State, MS, Rept. No. MSSU-EIRS-EE-81-2, AFOSR-TR-81-0603, 221 pp (Jan 1981)
AD-A102 358

Key Words: Cepstrum analysis

Cepstrum analysis is performed for damped sinusoids with arbitrary starting times within a discrete time window. Computer simulations are presented to verify the mathematical analysis.

82-893

Spectrum Analysis -- A Modern Perspective

S.M. Kay and S.L. Marple, Jr.
Dept. of Electrical Engrg., Univ. of Rhode Island, Kingston, RI 02881, IEEE, Proc., 69 (11), pp 1380-1419 (Nov 1981) 18 figs, 5 tables, 278 refs

Key Words: Time domain method, Spectrum analysis, Reviews

A summary of many of the new techniques developed in the last two decades for spectrum analysis of discrete time series is presented. An examination of the underlying time series model assumed by each technique serves as the common basis for understanding the differences among the various spectrum analysis approaches. Techniques discussed include the classical periodogram, classical Blackman-Tukey, autoregressive (maximum entropy), moving average, autoregressive-moving average, maximum likelihood, Prony, and Pisarenko methods. A summary table in the text provides a concise overview for all methods, including key references and appropriate equations for computation of each spectral estimate.

82-894

Analysis of Fly-Shuttle Loom Noise by Multi-Channel Digital Signal Processing Techniques

M. Caliskan, J.R. Bailey, and F.D. Hart
North Carolina State Univ., Raleigh, NC, ASME Paper No. 81-DET-100

Key Words: Textile looms, Signal processing techniques, Vibration analysis, Noise generation

Multi-channel digital signal processing techniques are employed to analyze sound and vibration signals generated by a fly-shuttle loom. Acceleration data from the flying shuttle are transmitted by a telemetry system to the data analysis instrumentation. Coherence functions are used to pinpoint and verify major noise sources. Power spectra and time domain studies are also evaluated.

82-895

Automation of Internal Friction Measurement Apparatus of Inverted Torsion Pendulum Type

I. Yoshida, T. Sugai, S. Tani, M. Motegi, K. Minamida, and H. Hayakawa
Fundamental Res. Labs., R & D Bureau, Nippon Steel Corp., 1618 Ida, Nakahara-ku, Kawasaki, Japan 211, J. Phys. E: Sci. Instrum., 14 (1), pp 1201-1206 (Oct 1981) 6 figs, 13 refs

Key Words: Measuring instruments, Internal friction

The design of an automated internal friction apparatus of inverted torsion pendulum type is described. Waveform analysis instead of traditional wave height analysis was employed. A complete internal friction against temperature profile is obtainable as well as temperature, period of oscillation and internal friction data in table format. In addition to the elimination of manual operation and supervision, the accuracy of measurement was greatly increased because by using Fourier transformation of the waveform of damped oscillation the disturbing components of parasitic motions such as flexural or precessional are separated out from the genuine torsional motion and eliminated on calculating the decay constant.

82-896

The Use of Frequency Analysis Techniques in Paper-Machine Trouble Shooting

J. Keighley

Beloit Walmsley, Bury, UK, Paper Technology and Industry, 22 (5), pp 164-167 (June 1981) 10 figs

Key Words: Frequency analysis

Examples are given to show how information of practical value can be obtained from the use of frequency analysis in field investigations. These techniques can be applied to a wide range of subjects such as noise, vibration, and hydraulic pressure pulsations. Any parameter which can be converted into a suitable electrical signal may be subjected to analysis of this sort.

82-897

Resonance Tests on Glass Reinforced Plastic Composite Panels

A. Goldman and B. Quinn

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC-TM-329, 14 pp (Apr 1981)
AD-A102 325

Key Words: Resonance tests, Panels, Plastics, Glass reinforced plastics, Foams, Sandwich structures, Natural frequencies, Mode shapes

Resonance tests have been undertaken on four panels of glass reinforced plastic and foam sandwich construction to determine their natural frequencies and mode shapes up to 100 hertz.

82-898

A State-of-the-Art Assessment of Mobility Measurement Techniques -- Results for the Mid-Range Structures (30-3000 Hz)

D.J. Ewins and J. Griffin

Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7 2BX, UK, J. Sound Vib., 78 (2), pp 197-222 (Sept 22, 1981) 7 figs, 2 tables, 4 refs

Key Words: Mobility method, Mechanical impedance, Measurement techniques, Measuring instruments, Reviews

During the period 1979-80, a survey was conducted in Europe to assess the state-of-the-art of structural mobility measurement technology. The results from this exercise -- a selection of which are presented here -- indicated a considerable degree of inconsistency and highlighted the need for more careful measurement practice and for greater use of checks on measured data.

DYNAMIC TESTS

82-899

Dynamic Elastic Modulus and Internal Friction in G-10CR and G-11CR Fiberglass-Cloth-Epoxy Composites

H.M. Ledbetter

Natl. Bureau of Standards, Washington, DC, Final Rept., 4 pp (Nov 1980)
PB81-235327

Key Words: Internal friction, Dynamic modulus of elasticity, Dynamic tests, Fiberglass, Fiber composites

Young's moduli were determined dynamically for two fiberglass-cloth-epoxy composites in the warp, fill and normal directions between room temperature and liquid-nitrogen temperature. Dynamic internal friction relates inversely to dynamic modulus in the studied materials. The experimental arrangement consisted of a Marx three-component oscillator at frequencies between 40 and 90 kHz.

82-900

The Daimler-Benz Roller-Type Noise Test Stand for Commercial Vehicles - Part 2 (Der Geräuschrollprüfstand für Nutzfahrzeuge der Daimler-Benz AG - Teil 2)

P. Fietz and T.Koch

Im Asemwald 4/17, 7000 Stuttgart 70, Germany, Automobiltech. Z., 83 (10), pp 509-510, 515 (Oct 1981) 19 figs
(In German)

Key Words: Test facilities, Noise measurement, Measuring instruments, Ground vehicles, Trucks

In the first part of the article the construction, acoustic characteristics, and operational modes of the roller-type noise test stand were described; the tests performed are discussed in the second part. The signals are transferred to the measuring and evaluation room by the so-called signal processing blocks with the necessary pre-amplifiers. The possibilities of signal processing in the measuring and evaluating room as well as future extensions are described.

82-901

A Theory for Predicting Boundary Impedance and Resonance Frequencies of Slotted-Wall Wind Tunnels, Including Plenum Effects

R.L. Barger

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TP-1880, L-14480, 22 pp (July 1981)

N81-29096

Key Words: Test facilities, Wind tunnels, Hole-containing media, Acoustic impedance, Resonant frequencies

Wave-induced resonance associated with the geometry of wind-tunnel test sections can occur. A theory that uses acoustic impedance concepts to predict resonance modes in a two dimensional, slotted wall wind tunnel with a plenum chamber is described. The equation derived is consistent with known results for limiting conditions. The computed resonance modes compare well with appropriate experimental data. When the theory is applied to perforated wall test sections, it predicts the experimentally observed closely spaced modes that occur when the wavelength is not long compared with the plenum depth.

82-902

Nondestructive Testing of Pavements and Pavement Bases. 1964-June, 1981 (Citations from the NTIS Data Base)

National Technical Information Service, Springfield, VA, 174 pp (July 1981)

PB81-807562

Key Words: Testing techniques, Nondestructive tests, Pavements

Nondestructive methods for quality assurance of pavements and pavement bases are investigated in these Government-sponsored research reports. Vibration, nuclear activation, radiometry, and acoustic detection are among the various techniques employed. (This updated bibliography contains 167 citations, 16 of which are new entries to the previous edition.)

82-903

Acoustic Emission Signature and Source Microstructure Using Indentation Fatigue and Stress Corrosion Cracking in Aluminum Alloys

R.B. Clough, J.C. Chang, and J.P. Travis

National Bureau of Standards, Washington, DC, Scripta Metallurgica 15, pp 417-422 (1981)

PB81-227704

Key Words: Nondestructive tests, Acoustic emission, Acoustic signatures, Steel

Acoustic emission due to indentation is a new NDE technique for directly correlating acoustic emission behavior with the microstructure of a particular source. Previous work with this method demonstrates that reproducible acoustic emission signals can be generated in embrittled steels by incremental growth of cracks. Here the technique is illustrated for use in more ductile materials through the new techniques of indentation fatigue and indentation stress corrosion cracking. By these methods a direct correlation can be made between a particular source microstructure and the resulting acoustic emission behavior.

82-904

Shock Simulator

W.G. Soper

Dept. of the Navy, Washington, DC, PAT-APPL-6-242 199, 10 pp (Mar 10, 1981)

Key Words: Shock tests, Test equipment and instrumentation

A projectile ground shock simulator is described for simulating the force pulse on a projectile in testing for shock effect on the guidance system of the projectile. The simulator incorporates a liquid/solid material as an energy absorbing and storing spring for simulating the force pulse on the projectile. The projectile is positioned in a drop tube and impacted with a drop vehicle to simulate the force created during firing of the projectile. The drop vehicle is provided with the liquid/solid spring having a pistion and cylinder on the impact face of the drop vehicle. The cylinder is filled with a liquid or solid polymer material having a high bulk modulus of compressibility which gives the spring volumetric stiffness. The spring thus duplicates the force pulse acting on a fired projectile and also allows for the drop vehicle to be reused.

82-905

The Resonance-Impedance Method as a Means for Quality Control of Advanced Fiber Reinforced Plastic Structures

R.J. Schliekelmann

Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, The Netherlands, Rept. No. FOK-BO-1239, 16 pp (1980)

N81-28462

Key Words: Testing techniques, Resonance tests, Impedance technique, Fiber composites

The principles of resonance impedance testing applied to the mechanical properties of bonded structures are reviewed. For fiber reinforced laminates, the influence of laminate thickness, voids and density variations are discussed. The use of reference standards, showing acceptable laminate quality for each configuration, is cited for complicated composite structures. Ultrasonic C-scan pictures of a carbon fiber epoxy laminate are compared with Fokker Bond Tester readings of the same panel, showing the presence of voids. Applications of the resonance-impedance method during the fabrication of structures for the F-14, the B-1 bomber, and for the DC-10 are mentioned.

DIAGNOSTICS

82-906

EHD-Forces Acting on Teeth Flanks (Beanspruchung der Zahnflanken unter EHD-Bedingungen)

H. Winter and P. Oster

Forschungsstelle f. Zahnräder und Getriebebau (FZG), der TU Munchen, Germany, Konstruktion, 33 (11), pp 421-434 (Nov 1981) 14 figs, 3 tables, 27 refs

(In German)

Key Words: Gear teeth, Damage prediction

Load capacity of gear teeth surfaces changes with angular speed. The loading at teeth contact locations and the stresses in teeth surfaces are determined by comparical nominal values (Nennwerte) using electrohydrodynamic theory. Theoretical results are compared with the damage of teeth surfaces obtained experimentally.

82-907

Contribution of Technical Diagnostics in the Reliability of Machinery Using Gear Drives as an Example (Beitrag der technischen Diagnostik für zuverlässige Maschinenbauerzeugnisse, dargestellt am Beispiel der Zahnradgetriebe)

G. Hennigs

Magdeburg, Maschinenbautechnik, 30 (8), pp 370-372 (Aug 1981) 3 figs, 3 tables, 6 refs

(In German)

Key Words: Diagnostic techniques

A method for the measurement of teeth surface damage and its application for the determination of the reliability of the method is presented. The degree of damage caused by pitting and the changes in the teeth thickness fiber as a result of wear is measured by the impression method.

82-908

Methods, Results and Problems of Vibro-Acoustic Machine Diagnosis (Methoden, Ergebnisse und Probleme der vibroakustischen Maschinendiagnose)

E. Unger

Technische Hochschule Leipzig, Sektion Automatisierungsanlagen, Germany, Maschinenbautechnik, 30 (9), pp 403-407 (1981) 4 figs, 22 refs

(In German)

Key Words: Diagnostic techniques, Reviews

Various vibroacoustic machine diagnostic analysis techniques and their applications are reviewed.

BALANCING

82-909

Experimental Investigation of Balancing Flexible Rotors in Large Motors and Generators

W.H. Miller

Large Motor and Generator Dept., General Electric Co., Schenectady, NY, Turbomachinery Symp., Proc. of the 10th, held Dec 1-3, 1981, Texas A&M Univ., College Station, TX, pp 73-79, 7 figs, 4 tables, 12 refs

Key Words: Balancing techniques, Flexible rotors, Influence coefficient method, Computer programs

The balancing of large motor and generator rotors is accomplished by a combination of balance machine corrections plus the calculated corrections determined by an influence coefficient balancing computer program. The method has been applied to an 8000 HP two-pole induction machine rotor and the results are presented. The vibration is measured at several locations and speeds and the results are used to ensure that the vibration levels are not excessive as the rotor speed is increased, and to calculate the balance correction weights using a least squares influence coefficient method. Measured and calculated results are presented which provide a check on the method. The results show that a multi-plane balance correction was necessary to minimize the rotor unbalance through the second critical speed.

82-910

A Practical Guide to In-Place Balancing

R.L. Fox

IRD Mechanalysis, Inc., Houston, TX, Turbomachinery Symp., Proc. of the 10th, held Dec 1-3, 1981, Texas A&M Univ., College Station, TX, pp 113-129, 26 figs, 1 table, 9 refs

Key Words: Balancing techniques, Rotors

Rotor unbalance remains one of the leading causes of deterioration and vibration of rotating machinery; but, if physical weight corrections can be made, many machines can be successfully balanced in-place with considerable savings in downtime and labor costs. In-place balancing can, however, pose some unique problems, and a prime concern is the time, expense, and wear and tear to simply start and stop the machine for trial data. This paper provides guidelines for recognizing and overcoming some of the more common in-place balancing problems so that the number of balance runs can be kept to a minimum. Vibration analysis techniques are presented as the first step to verify that the problem is truly unbalance and not looseness, weakness, distortion, resonance, misalignment, eccentricity, or other problems which could be mistaken for unbalance. Problems such as repeatability, rotor sag, stratification, thermal distortion, load effects, rotor speed and other variables which can influence rotor balance are discussed. Measurement techniques and common sources of measurement error are also presented. The importance of identifying the type of rotor unbalance (static, couple, quasi-static, or dynamic) is presented along with a review of common single- and two-plane balancing procedures with emphasis on their suitability for in-place balancing. Methods are presented for determining suitable trial weights -- both amount and position -- to achieve the desired results. Finally, guidelines are presented for establishing realistic balance and vibration tolerances for rotors balanced in-place.

MONITORING

82-911

Guidelines for Improving Rotating Equipment Reliability

C. Jackson

Monsanto Co., Texas City, TX, Hydrocarbon Processing, 60 (9), pp 223-228 (Sept 1981) 8 figs, 1 table

Key Words: Monitoring techniques, Rotating machinery

Presented are a variety of guidelines covering compressors, monitoring systems, lube consoles, couplings, etc., which have enabled a plant to achieve 99 percent availability for rotating equipment.

82-912

New Instrumentation Techniques Accurately Predict Bearing Life

D.A. McLain

Westvaco Corp., Covington, VA, Energy Processing Canada, pp 25-30 (Nov/Dec 1981) 10 figs

Key Words: Monitoring techniques, Bearings, Instrumentation

This article is intended to serve as a guide for establishing a bearing monitoring program, choosing equipment, and teaching maintenance personnel the necessary basic skills. The methods outlined here have proven extremely effective in predicting defects in the slow-speed, heavily loaded bearings common in paper mills, which had been impossible to effectively analyze with earlier techniques.

82-913

Hydraulic Diagnostic Monitoring System

J.J. Duzich

Grumman Aerospace Corp., Bethpage, NY, Rept. No. NADC-TR-81073-60, 303 pp (Mar 2, 1981)
AD-A100 730

Key Words: Monitoring techniques, Flight vehicles, Flight vehicle equipment response

Task I encompassed the design, development and procurement of hardware, sensors, and microprocessors for two diagnostic monitoring systems. The first system was installed on the F-14 Hydraulic Flight Simulator on Task II of the program. Task II included the installation of one system on the F-14A Hydraulic Simulator for system component reliability demonstrations. The task also covered simulated component failures and diagnostic system reaction. In Task III, the Diagnostic System was integrated into A6E B/N 155628. The system was debugged and a 12 month flight test scheduled. This reports covers Task III.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

82-914

Second Order Averaging and Bifurcations to Subharmonics in Duffing's Equation

C. Holmes and P. Holmes
Dept. of Theoretical and Appl. Mechanics, Cornell Univ., Ithaca, NY 14853, J. Sound Vib., 78 (2), pp 161-174 (Sept 22, 1981) 7 figs, 19 refs

Key Words: Duffing's differential equation, Bifurcation theory

Periodic motions near an equilibrium solution of Duffing's equation with negative linear stiffness can evolve, lose their stability, and undergo period doubling bifurcations as excitation amplitude, frequency and damping are varied. For bifurcations to period two it is shown that these can be either sub- or supercritical, depending upon the excitation frequency. The analysis is carried out by the averaging method, and, to retain important nonlinear effects, averaging must be taken to second order. Some remarks on higher order subharmonics are made.

MODELING TECHNIQUES

82-915

Two Efficient Schemes for Dynamic Analyses with Finite Elements

R. Ushijima and E. Kausel
Dept. of Civil Engrg., MIT, Cambridge, MA, Nucl. Engr. Des., 66 (1), pp 141-146 (Aug 1981) 4 figs, 1 table, 17 refs

Key Words: Finite element technique, Frequency domain method, Nuclear power plants, Seismic excitation

This paper proposes two efficient schemes that may be applied to finite element analyses in the frequency domain, such as those currently used to analyze nuclear power plants under seismic loads. The first scheme consists of a reduction in the number of degrees of freedom necessary to model an axisymmetric system, using what is referred to as the quasi-cylindric approximation (not a plane strain approximation!). The second scheme is the use of Hermite interpolation to decrease the computational effort associated with the determination of the transfer functions. The application of the technique is reviewed for the case of a Waas-Lysmer transmitting boundary (a similar boundary is used in the computer program FLUSH), and the relative efficiency is discussed.

82-916

A Unified Model for Non-Stationary and/or Non-Gaussian Random Processes

O. Kropac
Aeronautical Res. and Test Inst., Prague-Letnany, Czechoslovakia, J. Sound Vib., 79 (1), pp 11-21 (Nov 8, 1981) 1 table, 13 refs

Key Words: Mathematical models, Random response, Normal density functions

An analytical model for non-stationary and/or non-Gaussian random processes described in the paper is based on a normal stationary random process. The non-stationarity is introduced as a deterministic dependence of the parameters of the marginal distribution function or those of the correlation function upon the argument t. Consideration that the mentioned parameters are random variables or stationary random processes results in generating non-Gaussian distributions of the unconditioned process. By combining deterministic and random components of the parameters' dependencies, non-stationary and simultaneously non-Gaussian random processes may be easily specified. The model described may be useful for analytical treatment, for identification of experimentally obtained realizations of random processes and for simulation of random processes on computers as well as in the laboratory.

82-917

Mixture Theories for Modeling the Dynamic Response of Composite Materials

Y. Benveniste and J. Aboudi
Dept. of Solid Mechanics, Materials and Structures, School of Engrg., Tel-Aviv Univ., Ramat-Aviv, Israel, Intl. J. Engrg. Sci., 20 (2), pp 193-216 (1982) 3 figs, 51 refs

Key Words: Mathematical models, Composite structures

Mixture theories developed in the last years by the authors are reviewed and discussed. Some of the theories represent 3-dimensional elastodynamic phenomena by equivalent 2-dimensional models and are applied to investigate dynamic

crack problems in laminated and fiber reinforced media. Composites with constituents obeying a variety of constitutive laws are considered. These include laminated solids with linear isotropic elastic, linear anisotropic elastic, nonlinear elastic, thermoelastic and elastic-viscoplastic laminae. Debonding phenomena and large deformations are also treated. In all of the formulated theories, the appearing interaction terms are determined and related to the constituent material parameters. The proposed theories represent the dynamic response of the considered composites to a good degree of accuracy and are governed by field equations which are suitable for solution by proper numerical methods.

82-918

Automated Dynamic Analytical Model Improvement

A. Berman

Kaman-Aerospace Corp., Bloomfield, CT, Rept. No. NASA-CR-3452, R-1624, 48 pp (July 1981) N81-29462

Key Words: Mathematical models, Dynamic structural analysis

A method is developed and illustrated which finds minimum changes in analytical mass and stiffness matrices to make them consistent with a set of measured normal modes and natural frequencies. The corrected model is an improved base for studies of physical changes, changes in boundary conditions, and for prediction of forced responses. Features of the method are: efficient procedures not requiring solutions of the eigenproblem; the model may have more degrees of freedom than the test data; modal displacements at all the analytical degrees of freedom are obtained; the frequency dependence of the coordinate transformations are properly treated.

82-919

Dynamics of Mechanisms and Machine Systems in Accelerating Reference Frames

R.R. Allen

Hewlett-Packard, San Diego Div., San Diego, CA 92127, J. Dyn. Syst., Meas. and Control, Trans. ASME, 103 (4), pp 395-403 (Dec 1981) 10 figs, 1 table, 17 refs

Key Words: Mathematical models, Machinery vibration

Matrix equations of motion are derived for a general machine system in an accelerating reference frame. These equations are highly-nonlinear in the displacements of inertial elements and describe the dynamics of large motions. This analysis permits study of dynamic interactions between the moving elements of a machine and the motion of the machine body. The latter may undergo general translation and rotation as a result of internal and external forces. Power-conserving transformations relating inertial, kinematic, and generalized velocities provide a highly formal procedure for kinematic and dynamic analyses and produce explicit equations in generalized variables which are efficient for numerical solution. The theory is applied to study a machine with a four-bar linkage and driveshaft elasticity mounted on a spring-damper suspension. In this example, torsional oscillations in the drive are compared to those obtained with the machine body fixed in inertial space.

NUMERICAL METHODS

82-920

Difference Equation Analysis of Non-Linear Subharmonic and Superharmonic Oscillations

A. Krishnan

Dept. of Electrical and Electronics Engrg., Coimbatore Inst. of Tech., Coimbatore-641014, India, J. Sound Vib., 79 (1), pp 121-131 (Nov 8, 1981) 2 figs, 17 refs

Key Words: Subharmonic oscillations, Difference equations, Perturbation theory

This paper deals with sub- and superharmonic oscillations in strongly excited nonlinear systems described by difference equations. An adaptation of the discrete multiple time perturbational technique is used. A Duffing type of equation is considered and the possible sub- and superharmonic oscillations are investigated. The results deduced from the proposed method are compared with those obtained by using the well known method of harmonic balance.

STATISTICAL METHODS

82-921

Spatial Stochastic Systems Theory and Its Application to Fields and Waves in Random Moving Media, I: General Theory

K.C. Liu

Dept. of Physics and Elect. Engrg., Univ. of Bremen, 2800 Bremen 33, Fed. Rep. Germany, J. Sound Vib., 79 (3), pp 321-339 (Dec 8, 1981) 12 figs, 22 refs

Key Words: Stochastic processes, Wave propagation

A method for finding the statistical properties of fields and waves in random moving media is presented. The theoretical foundation of this method is the generalization of linear system theory to the following case: both the input and output are random fields with different or equal dimensions, and the characteristics (or parameters) of the system are randomly varied with respect to both the time and the space co-ordinates. Some general relations between input (source) and output (field) are obtained. Four kinds of basic connections between spatial stochastic systems are suggested and the expressions for the transfer functions of the connected systems are derived.

PARAMETER IDENTIFICATION

82-922

Parameter Identification by Means of a Modified Maximum Likelihood Method (Parameteridentifikation mit einem modifizierten Maximum-Likelihood Verfahren)

H. Schäufele

Fortschritt-Berichte VDI-Zt., Reihe 8, No. 40 (1981), 200 pp, 37 figs, 11 tables. Summarized in VDI-Z, 123 (11), p 482 (June 1981).Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, Price 103-DM

(In German)

Key Words: Parameter identification technique, Maximum likelihood method

An iterative identification method is described which is very useful in parameter identification of dynamic systems. The method is illustrated in an analysis of natural vibrations of aircraft. However, it is just as applicable in science and technology, where dynamic systems are present and need to be identified.

82-923

Formulation and Implementation of a Practical Algorithm for Parameter Estimation with Process and Measurement Noise

R.E. Maine and K.W. Iliff

NASA Dryden Flight Res. Ctr., Edwards, CA 93523, SIAM J. Appl. Math., 41 (3), pp 558-579 (Dec 1981) 5 figs, 6 tables, 38 refs

Key Words: Parameter identification technique

A new formulation is proposed for the problem of parameter estimation of dynamic systems with both process and measurement noise. The formulation gives estimates that are maximum likelihood asymptotically in time. The means used to overcome the difficulties encountered by previous formulations are discussed. It is shown how the proposed formulation can be efficiently implemented in a computer program. A computer program using the proposed formulation is available in a form suitable for routine application. Examples with simulated and real data are given to illustrate that the program works well.

82-924

Determination of Dynamic Parameters of Rigid-Body Systems by Means of the Method of Adaptive Modelling (Bestimmung der dynamischen Parameter von Starrkörpersystemen mit Hilfe der Methode der adaptiven Modellfindung)

S. Döge

Technische Universität Dresden, Sektion Grundlagen des Maschinenwesens, Bereich Dynamik und Betriebsfestigkeit, Germany, Maschinenbautechnik, 30 (9), pp 399-402 (1981) 9 figs, 2 tables, 10 refs

(In German)

Key Words: Mathematical models, Elastic foundations

A procedure for modeling of elastically supported rigid bodies with six degrees of freedom is presented. Two examples are used to illustrate the procedure, taking the exciter function into consideration.

COMPUTER PROGRAMS

82-925

A Computer Program for Predicting Fatigue Crack Propagation

S.K. Imtiaz and B.L. Smith

Beech Aircraft Corp., Wichita, KS, SAE Paper No. 810594

Key Words: Computer programs, Fatigue life, Crack propagation

A general computer program has been developed for analytic fatigue crack growth. It is designed so that the user does not need to have an extensive background in Fracture Mechanics Theory. This FORTRAN program can analyze the growth of most common types of cracks and accounts for the transition from part-thru to completely thru-the-thickness crack. The input loading may be a mission profile or arbitrary cyclic stresses with or without concentrated loads and may be repeated a number of times. There are built-in corrections for geometry, plastic-zone size, plane-stress vs. plane-strain and applicability of Linear-Elastic-Fracture-Mechanics, and there are options available for crack growth rate calculations, retardation models and plastic zone corrections.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

82-926

Zeitschrift für Angewandte Mathematik und Mechanik, 61 (4), April 1981

Key Words: Proceedings

The entire issue is devoted to the papers presented at the annual meeting of the (German) Society of Applied Mathematics and Mechanics (Gesellschaft f. Angewandte Mathematik u. Mechanik), held April 8-11, 1980, at the Technical University of Berlin (West). A total of 97 papers were presented in four sessions: Mechanics of Rigid Bodies; Problems of Vibration and Stability; Mechanics of Elastic and Plastic Bodies; and Mechanics of Fluids. At the Problems of Vibration and Stability session, 27 papers were read. With the exception of two main lectures, the papers published in this issue consist of one or two pages.

TUTORIALS AND REVIEWS

82-927

Digital Signal Processing for Sonar

W.C. Knight, R.G. Pridham, and S.M. Kay

Systems Engrg. Lab., Submarine Signal Div., Raytheon Co., Portsmouth, RI 02871, IEEE, Proc., 69 (11), pp 1451-1506 (Nov 1981) 65 figs, 4 tables, 253 refs

Key Words: Signal processing techniques

This paper is a tutorial which describes main stream sonar digital signal processing functions along with the associated implementation considerations. The attempt is to promote further cross-fertilization of ideas among digital signal processing applications in sonar, radar, speech, communications, seismology, and other related fields.

AUTHOR INDEX

TECHNICAL NOTES

S.L. Hendricks
Instability of a Damped Rotor Partially Filled with an Inviscid Liquid
J. Appl. Mechanics, Trans. ASME, 48 (3), p 674 (Sept 1981) 5 refs

T.L. Alley
Optimal Isolation of a Single-Degree-of-Freedom System with Quadratic-Velocity Damping
J. Appl. Mechanics, Trans. ASME, 48 (3), pp 676-678 (Sept 1981) 2 refs

S.J. Elliott
Errors in Acoustic Intensity Measurements
J. Sound Vib., 78 (3), pp 439-443 (Oct 8, 1981) 1 fig, 1 table, 6 refs

I. Nakayama and A. Nakamura
A Theoretical-Experimental Comparison of the Transient Waveform from a Circular Plate Excited by a Triangular Sound Pulse
J. Sound Vib., 78 (3), pp 446-451 (Oct 8, 1981)

W.R. Garrott and R.A. Scott
A Note on the Calculation of Tire Side Forces
J. Sound Vib., 78 (2), pp 306-309 (Sept 22, 1981) 1 fig, 3 refs

W.D. Rutledge and D.E. Beskos
Dynamic Analysis of Linearly Tapered Beams
J. Sound Vib., 79 (3), pp 457-462 (Dec 8, 1981) 6 figs, 4 refs

H.D. Fisher
Solution of a Generalized One Dimensional Wave Equation by the Boundary Operator Method
J. Sound Vib., 79 (2), pp 316-318 (Nov 22, 1981) 5 refs

P.A.A. Laura and R.H. Gutierrez
Transverse Vibrations of Annular Plates of Variable Thickness with Rigid Mass on Inside
J. Sound Vib., 79 (2), pp 311-315 (Nov 22, 1981) 2 figs, 1 table, 4 refs

P.A.A. Laura and B.V. De Greco
A Note on Vibrations and Elastic Stability of Circular Plates with Thickness Varying in a Bilinear Fashion
J. Sound Vib., 79 (2), pp 311-315 (Nov 22, 1981) 3 figs, 6 refs

C.T. Leung and N.W.M. Ko
Resonance Effect of Acoustic Excitation on Heat Transfer
J. Sound Vib., 79 (2), pp 303-305 (Nov 22, 1981) 1 fig, 7 refs

S. Vajpayee, M.M. Nigm, and M.M. Sadek
Noise Reduction in Material-Handling Machines
Appl. Acoust., 14 (6), pp 471-476 (Nov-Dec 1981) 4 figs

M. Hinchey and P. Sullivan
Kelvin-Heimholtz Stability Analysis of Air Cushion Landing Gear Trunk Flutter
J. Aircraft, 19 (1), pp 76-80 (Jan 1982) 12 figs, 9 refs

CALENDAR

MAY 1982

12-14 Pan American Congress on Productivity [SAE] Mexico City *(SAE Hqs.)*

24-26 Commuter Aircraft and Airline Operations Meeting [SAE] Savannah, GA *(SAE Hqs.)*

JUNE 1982

7-11 Passenger Car Meeting [SAE] Dearborn, MI *(SAE Hqs.)*

JULY 1982

1-3 2nd Intl. Conf. on Applied Modeling and Simulation [IASTED] Paris, France *(AMSE, 16 avenue de Grange Blanche, 69160 Tassin la Demi Lune, France)*

13-15 'Environmental Engineering Today' Symposium and Exhibition [SEE] London, England *(SEECO 82 Organisers, Owles Hall, Buntingford, Herts. SG9 9PL, England - Tel: Royston (0763) 71209)*

19-21 12th Intersociety Conference on Environmental Systems [SAE] San Diego, CA *(SAE Hqs.)*

AUGUST 1982

16-19 West Coast International Meeting [SAE] San Francisco, CA *(SAE Hqs.)*

SEPTEMBER 1982

12-15 1982 Design Automation Conference [ASME] Washington, DC *(Prof. Kenneth M. Ragsdell, Purdue Univ., School of Mechanical Engrg., West Lafayette, IN 47907 - (317) 494-8607)*

13-16 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

OCTOBER 1982

4-6 Convergence '82 [SAE] Dearborn, MI *(SAE Hqs.)*

4-7 Symp. on Advances and Trends in Structural and Solid Mechanics [George Washington Univ. and NASA Langley Res. Ctr.] Washington, DC *(Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Res. Ctr., Hampton, VA 23665 - (804) 827-2897)*

12-15 Stapp Car Crash Conference [SAE] Ann Arbor, MI *(SAE Hqs.)*

25-28 Advances in Dynamic Analysis and Testing [SAE Technical Committee G-5] 1982 SAE Aerospace Congress & Exposition, Anaheim, CA *(Roy W. Mustain, Rockwell Space Systems Group, Mail St. AB97, 12214 Lakewood Blvd., Downey, CA 90421)*

25-28 Aerospace Congress and Exposition [SAE] Anaheim, CA *(SAE, 400 Commonwealth Drive, Warrendale, PA 15096)*

26-28 53rd Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Danvers, MA *(Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, DC 20375)*

NOVEMBER 1982

8-10 Intl. Modal Analysis Conference [Union College] Orlando, FL *(Prof. Raymond Eisenstadt, Union College, Graduate and Continuing Studies, Wells House, 1 Union Ave., Schenectady, NY 12308 - (518) 370-6288)*

8-12 Acoustical Society of American, Fall Meeting [ASA] Orlando, FL *(ASA Hqs.)*

8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN *(SAE Hqs.)*

14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ *(ASME Hqs.)*

DECEMBER 1982

14-16 11th Turbomachinery Symposium [Texas A&M University] Houston, TX *(Turbomachinery Labs., Dept. of Mechanical Engineering, Texas A&M Univ., College Station, TX 77843 - (713) 845-7417)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

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

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173

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PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> **Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].**
>
> **Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .**

The format and style for the list of References at the end of the article are as follows:

- **each citation number as it appears in text (not in alphabetical order)**
- **last name of author/editor followed by initials or first name**
- **titles of articles within quotations, titles of books underlined**
- **abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)**
- **volume, number or issue, and pages for journals; publisher for books**
- **year of publication in parentheses**

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).

2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).

3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).

4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).

5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).

6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).

7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

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