Technical Program, AEWG-46

August 4-6, 2003

Session 1

Estimation of Magnitude of AE Events

Maochen Ge, Pennsylvania State University

Magnitude is one of the most important parameters for AE events. Because of many uncertainties involved in the propagation effect, it is inherently difficult to develop a consistent measurement for magnitude. In this presentation, the issue of magnitude will be discussed from three aspects. First, we will discuss the basic elements of the propagation effect, namely geometric spreading, attenuation and radiation pattern in order to establish a perspective view on the problem. We then analyze the principles of the major approaches used in seismologists in earthquake studies. Finally, we will use the actual AE data to demonstrate the effect of these basic elements.

Wave Propagation in Tubing and Waveguide Characteristics

Kanji Ono, University of California at Los Angeles (UCLA)
H. Nishino, Tohoku University

H. Cho (Aoyama Gakuin University)

We have examined wave propagation behavior in aluminum rods and tubes over 30 kHz to 10 MHz and compared to the calculated dispersion curves. While certain velocity characteristics agree between theory and experiment, consistent disagreement exists. In addition, the wave attenuation is extremely high in certain frequency ranges. Tube waveguides were also evaluated and compared to the solid rod type. Implications of the observed behavior for the application of AE waveguides will be discussed.

Key Differences Between the Acoustic Emission Signals Generated by Monopoles Versus Dipoles

M. A. Hamstad, NIST Boulder and University of Denver

A finite-element-generated database of acoustic emission (AE) signals was used to analyze the differences in the signals generated by monopoles as compared to those generated by dipoles. The signals represented the top surface out-of-plane displacement versus time from buried dipole and monopole sources in aluminum plates 4.7 mm thick. Results were obtained with both a 40 kHz high-pass filter (wideband AE approach) and a 100 to 300 kHz bandpass filter (resonant narrowband AE approach). A wide plate that effectively eliminates edge reflections from the direct signal arrivals was used for the specimen domain. AE practitioners routinely use pencil lead breaks (monopoles) to observe expected signal characteristics, yet real AE sources are almost universally dipoles. Thus, understanding the distinctions between the signals generated by these different sources is of key importance. The signals were obtained from both in-plane and out-of-plane monopole and dipole sources. As a function of source type, significant AE signal differences in amplitudes, frequencies/modes and other signal characteristics were observed.

AE Monitoring of the Composite Propellant Tank at Cryogenic Temperature

Yoshihiro MIZUTANI, Takayuki SHIMODA and Fumio SHIMIZU
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The purpose of this study is to examine Acoustic Emission (AE) monitoring method in cryogenic testing for CFRP propellant tanks. We first measured attenuation of AE signals in the tank and decided the maximum sensor distance as a function of minimum amplitudes for detectable AE. The orientation dependence of AE signals was also measured for examining source location method. Velocities of AE were strongly affected by propagating direction and special analysis is needed for detailed source location was found. Next, the best adhesive for AE sensor at cryogenic temperature was selected from four different types of adhesives by conducting cryogenic immersed testing. A pulse generator that induces reference signals was controlled from the operations room 100 m away from the CFRP tank. The system was successfully used for confirming soundness of AE system during cryogenic tank testing. AE monitoring was conducted during cryogenic testing of a full-scale CFRP tank. The AE energy rate was increased when the delamination occurred at doom part. Although a large amount of moderate amplitude AE signals were recorded during experiment, little can be deduced from them due to noise (secondary AE) from boiling LN2. In order to reduce noise effect, characteristics of noise signals were investigated and alternative new AE setup was proposed. The new AE monitoring setup was evaluated by preliminary test by using glass beaker filled with LN2 and Mode-I type artificial source. New AE monitoring setup showed high tolerance for noise from boiling LN2.

Session 2

A Practical Solution for AE Source Location in Anisotropic Plates and Structures

Oh-Yang Kwon, Jeong-Kon Kim, Department of Mechanical Engineering, Inaha University

For the two-dimensional AE source location, in general, the wave velocity at actual structures has to be determined first to calculate the arrival time differences between sensors. Due to the velocity dependence on the fiber orientation, source location in composite structures has been practically impossible. Although there was a report of analytical solution taking care of the anisotropy problem, no practically applicable method has been implemented. In this approach, we have divided the region of interest (ROI) into a set of finite elements, taken each element as a virtual source, and calculated the arrival time difference between sensors by using the measured velocity at every degree from 0 to 90. The size of elements could be as small as 1 mm by 1 mm within ROI. The calculated and the measured values of the arrival time difference are then compared to minimize the location error. With the experimental corroboration for various plates (aluminum and UD-CFRP) and structures (CFRP-SRM case), the problem of the location error due to anisotropy appeared to be completely solved. The proposed method can be a practically viable solution for AE source location in any type of structure of actual dimension.

Development of A Classifier to Assist in Detection and Diagnosis of Problem Transformers Using New Acoustic Emission (AE) Technique

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Power transformers represent the largest portion of capital investment in transmission and distribution substations. The financial consequence of losing a single unit can have a multimillion-dollar impact on the owner/operator. By contrast, a failing transformer taken out of service in time can usually be economically reconditioned. This requires a detailed knowledge of the type and location of each fault inside the transformer. It is also requires that this information be collected through in-service testing.

A new AE technique has been developed to detect and locate fault conditions such as electric partial discharge, overheating, arcing and other AE sources in a power transformer. The study has accumulated sufficient data to perform a pattern recognition task to establish the characteristic class for each fault condition. This is accomplished using PAC's advanced pattern recognition software, NOESIS™.

In recent development work, a classifier has then been trained that can readily be used to identify the fault type from an unknown AE source inside the transformer. The effort associated with this development as well as the evaluation of the classifier will be presented.

Applications of wavelet transform for Acoustic Emission Analysis

Yoshihiro MIZUTANI, *National Space Development Agency of JAPA*N
Mikio TAKEMOTO, Department of Mechanical Engineering, Aoyama Gakuin University
Jochen VALLEN, *Vallen Systems GmbH*
Kanji ONO, *Department of Materials Science and Engineering, UCLA*

The aim of this paper is to further clarify applications of AGU-Vallen wavelet transform for Acoustic Emission (AE) analysis. In the paper, three applications are introduced. Some parts of the applications have been given previously, we demonstrate examples of the utility of AGU-Vallen WT software.

1) Investigating attenuation of Lamb-waves AE
The attenuation factor of each frequency for wide band Lamb waves propagated on a CFRP tank was investigated by utilizing wavelet transform. The relationship between the minimum amplitude for detectable AE and maximum sensor distance was determined by attenuation factors. This relationship was utilized for determining the maximum AE sensor distance before conducting CFRP-tank testing.

2) Measuring dispersion curves of Lamb-waves AE

The dispersion curves of Lamb waves propagated on a CFRP tank at both the ambient and cryogenic temperatures were measured by utilizing wavelet transform. Orientation dependence of AE signals in the tank was also measured.

3) Enhancing characteristics of AE signals
We investigated characteristics of both fracture-induced AE and secondary AE from boiling noise detected during tank testing by using wavelet transform. Secondary AE signals were classified into two types. High frequency components were observed for fracture-induced AE and the result shows a possibility of separating secondary AE from fracture-induced AE by high-pass filtering.

Current status of the AGU-Vallen Wavelet project and intended future developments

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Yoshihiro MIZUTANI, *National Space Development Agency of JAPA*N
Mikio TAKEMOTO, Department of Mechanical Engineering, Aoyama Gakuin University

This paper presents an overview over the AGU-Vallen Wavelet project, its current status and intended future developments. The AGU-Vallen project is a non-funded international cooperation to introduce the Wavelet Transform (WT) analysis into the Acoustic Emission community more widely. It is based on the most mature WT algorithms available today, which have been developed and continuously improved over the last ten years at the Aoyama Gakuin University, Tokyo, Japan.

The current result of this work is available as a software package that can be downloaded and used by anyone free of cost from **http://www.vallen.de/wavelet**. The software package allows anyone to use a proven and standardized WT and its analysis within minutes for his own data.

The WT is currently the most prospective approach to waveform interpretation in any means. The simple reason for this is that it provides all information from both time and frequency domain in one processing step and in one graph. As a result the waveform is shown either in a 2D contour diagram which shows the change of the frequency on the vertical axis over time and the magnitude information in colours. Or the same information can also be shown in a 3D diagram with the time-frequency dependent magnitudes over frequency and time.

These display types show very comfortably a maximum of information. The WT already includes similar or even more information compared to other analysis approaches, such as:

- Frequency analysis with FFT
- Time frequency analysis with subsequent FFTs or overlapping FFTs
- Low pass, high pass, band pass filter operations
- Peak detection operations at certain frequency bands
- Denoising

This opens a wide variety of possibilities for detailed waveform analysis to extract useful information out of waveforms which were not available at all before or required at least tremendous more efforts. Compared to other techniques the WT provides easy access to:

- Frequency dependent amplitude ratios to distinguish in-plane from out-of-plane signals
- Wave mode detection
- Wave mode identification and arrival time detection for improved source location
- AE source interpretation, characterization, and classification

The package has a documented open data interface that allows one to get any type of waveform data from any technical application into the system. The calculated wavelet table can be directly exported by a simple click into an MS-Excel spread sheet for further analysis and easy feature extraction. There is also an ASCII output of the result data that enables one to analyze even those large wavelet tables which exceed the capabilities of standard spread sheet software.

Session 3

Mechanisms of Corrosion Cracking in Concrete by AE and BEM

Masayasu Ohtsu, Uddin Farid, A. K. M, Kumamoto University

Due to chloride penetration, reinforcing steel-bars (rebars) in reinforced concrete are often corroded. This is one of serious deteriorations in concrete, because corrosive products expand and generate cracks in concrete. In order to predict further corrosion damage and make a decision for repair, mechanisms of corrosion cracking in concrete are investigated. Crack extension due to corrosion was analyzed by the two-domain boundary element method (BEM). Thus, fracture mechanisms were identified analytically. To confirm these mechanisms, corrosion cracks were experimentally simulated by employing expansive agent. During extension of cracks, AE waveforms were detected and analyzed by SiGMA procedure. Thus, the mechanisms of such cracks as a surface crack, a spalling crack and an internal crack are kinematically identified. Comparing these results with those of BEM analysis, the mechanisms of corrosion cracks are clarified.

Acoustic Emission (AE) Source Identification Through Multimodal Analysis

Fang Shu, Valery F. Godinez-Azcuaga, Richard D. Finlayson, PAC

In this presentation we will present recent work we have performed for the Petroleum Environmental Research Forum (PERF) using Multimodal Analysis techniques. Based on previous work made available by PERF, showing that an AE source can be identified from a single waveform, we have further developed user-friendly software that allows the user to extract information about AE sources from RF waveforms. The software can accept variable thickness plates, and can address different sampling rates, materials, and fluid loading conditions.

We have also examined the practical aspect of this approach using PLB tests. Results for two types of sensors, narrow band and broad band, will be presented as well as evaluation of Signal-to-Noise Ratios (SNR) as a function of frequency and source–to-receiver distance for both sensors. A short presentation, followed by a demonstration of the operational software, will be presented at the meeting.

Acoustic Emission Detection and Location of High Velocity Foam Impact

William H. Prosser, NASA Langley Research Center, Michael R. Gorman, Digital Wave Corporation, Eric I. Madaras, NASA Langley Research Center

Waveform based acoustic emission (AE) measurements were made during a series of high velocity impact tests using foam projectiles. The purpose of these measurements was to investigate the capabilities of using AE for the detection and location of impact damage on space structures. The target material was a 0.5 in. thick aluminum plate with lateral dimensions of 48 X 130 inches. AE signals were captured from impact on the bare aluminum plate as well as on a plate covered by foam, intended to simulate the effect of thermal protection materials. The projectiles were fired at a nominal velocity of 700 ft/s and impacted the target at shallow angles ranging from 5 to 13 degrees. Two projectile sizes were used. The larger size projectile was nominally 5.5 X 11.5 X 19 in. and the smaller projectile was nominally 3.5 X 11.5 X 21.25 in. An array of 8 sensors was used to detect the AE signals at a variety of distances from the point of impact. Preliminary data analysis indicates that the AE signals from such foam impacts were readily detectable and could be accurately located, even for impact events on a foam covered aluminum plate. Further testing is ongoing to investigate AE detection of impacts on more realistic space structures.

Session 4: Student Award Entry Session

Extended abstracts for these presentations are listed separately

Monitoring Corrosion Damage in Reinforced Concrete by Acoustic Emission

Masatoshi Tanaka , Masayasu Ohtsu, Graduate School of Science and Technology, Kumamoto University, JAPAN

Use Of AE to Understand A Weldability Test

Sameer Bachani, Jack Devletian, Portland State University

Full Waveform Inversion of the Kinematics of a Simulated Crack Inside an Artificial Rock

Albert To, Steve Glaser, University of California, Berkley

Session 5

Surface Roughness Measurement System (SRMS)

Marco Luzio, Richard D. Finlayson, Mark Carlos, Physical Acoustics Corporation

The Surface Roughness Measurement System (SRMS), from Physical Acoustics Corporation (PAC), has been designed as a "Turn Key" system to inspect surfaces such as metals, composites, wood, etc., using Acoustic Emission (AE) technology. This system is designed around a 2-D scanning bridge and application specific software specifically developed for the system. A patent is pending on this technology,

This presentation will be given in two parts, Part I “Technology Development” and Part II “Development of the test system”, which will discuss the overall technology behind the system, how this technology was implemented into an operating system, and present some results.

Part I Technology Development:
To perform the roughness measurement a thin stainless steel fin directly senses the roughness of the surface. During the scan, the bottom edge of the fin detects the sound generated from the uneven surface and processes this sound as an AE signal. The magnitude of the AE signal is related to the roughness of the measured surface.

Part II: Development of the test system:
The system was developed to perform the surface roughness measurement in an automated fashion using a scanning-bridge and stand. A sensing head assembly is mounted to the scanning bridge and controlled by the software. The sensing head incorporates a PAC wideband, AE sensor with integral preamplifier, a pair of Teflon wheels and a thin stainless steel swipe fin that is attached to the AE sensor. It is here where the surface to be measured is scanned, the roughness signals are generated and detected and a surface roughness map is generated.

Evaluating the Structural and Mechanical Integrity of Vessels by means of AET

Claudio Allevato, Napolean Douglas, Stress Engineering Services

This presentation gives a review of the basic principles behind the AET method, and a list of case studies from real inspections in the field and throughout the world.

AE MODAL RATIOS AND LEAK DETECTION

H.L. Dunegan, DECI

Modal ratios have been used since the mid-90's for many conventional AE sources, most prominently as a filter for eliminating extraneous noise sources in crack detection studies, and for the measurement of surface roughness. It is anticipated that Modal Ratios will also find good use in leak detections studies. A field investigation on Modal Ratios of leaks is being undertaken in June of 2003. 500 feet of coiled tubing used for selective drilling by the oil industry will be used in the study. Both above ground and below ground tests will be performed. The below ground tests will be conducted with the use of wave guides with point contact attached to the AE transducer and driven through the ground to make contact with the tubing. Sections of the pipe containing fatigue cracks will be welded to the pipe. The pipe will then be pressurized and the AE from the resulting leaks will be recorded.

Preliminary results of these tests will be presented at AEWG-46 in Portland in July of 2003.

LEATHER QUALITY ASSESSMENT USING ACOUSTIC EMISSION (AE)

Valery F. Godinez-Azcuaga, Richard D. Finlayson, PAC, Cheng-Kung Lui, Nicholas P. Latona, Agricultural Research Service, Wyndmoor, Pennsylvania 19038

The potential of using Acoustic Emission (AE) as a quality assurance and quality control method during the different stages of the leather making process is discussed in this presentation. Some interesting results obtained in the use of AE for studying the tensile strength, quality of final coatings, and evaluation of the break in the leather are presented. These results show that AE can be used in the inspection, assessment, and on-line monitoring of leather properties and their quality level at each stage of the fabrication process. Also, the results presented in this paper show that the AE technology has the potential to be adapted to other industries such as synthetic fiber manufacturing.

The long-range goal of this work is the production of an AE instrument, which will provide the leather industry with a Nondestructive Evaluation (NDE) method to monitor the quality of leather at every stage of the leather-making process. Using this instrument the tanners would be able to adjust their leather-making processes accordingly to yield high quality leather.

Session 6

Life Management of Seam Welded Elbows on a Fossil Hot Reheat Line

Rick Neimann (Portland General Electric), John Rodgers (Acoustic Emission Consulting)

Evaluation of excavation induced microcracks at the underground power plant using AE

Tomoki Shiotani, Research Institute of Technology, Tobishima Corporation

In order to evaluate spatial and temporal development of microcracking with excavation for the underground power plant, acoustic emission technique was conducted. AE monitoring was performed by installing a metal waveguide into an excavated borehole. Four AE sensors were lineally set along the waveguide. The void between the waveguide and the borehole was filled with cement-based material, which has the same mechanical properties as objective rock. Temporal and spatial development of microcracks were evaluated by AE activity and AE sources. The behavior of microcracking determined by the AE activity was further studied in comparison with borehole strains, axial stress of rock bolts and crack conditions. As a result, the followings were obtained:

1) It was possible to evaluate spatial and temporal evolution of microcracks due to excavation by the waveguide-based AE monitoring.
2) AE signals continued to generate for almost one hour when excavate upper rock mass from the AE monitoring location, while continued for more than 4 hours in case of the excavation in the lower part from the AE monitoring location.

Noise Localization in Large Moveable Structures

David Prine (Northwestern University, Infrastructure Technology Institute)

Noises in large structures resulting from mechanical problems such as improper bearing operation are nearly impossible to localize audibly. Acoustic Emission (AE) monitoring is a very effective tools for application to this problem. The contact high frequency sensors commonly used for AE monitoring provide good isolation from the confusing airborne sound and can clearly determine the source of the noise by means of source location or first hit channel analysis. This presentation describes a recent field application of this technique on the moveable roof of a sports facility.

Acoustic Emission Testing of Steel Reinforced Concrete Bridge Girders Subjected to Shear Zone Cracking

Steven Lovejoy, Senior Mechanical Engineer, Bridge Engineering Section, Oregon Department of Transportation

The Oregon Department of Transportation is testing to failure forty-four, 24-foot long by 4-foot deep by 3-foot wide reinforced concrete beams. Each beam is fully instrumented with reinforcing steel strain gages, surface strain gages, end rotation meters, crack opening gages and acoustic emission sensors. Beam design parameters such as shear steel spacing, concrete strength, flexure steel cut-off location, and dowel steel between girder and deck components are being investigated. Loading includes slow monotonic load / unload increments up to beam failure, moving loads, and fatigue loading of pre-cracked beams. This presentation will give an overview of the test program with specific emphasis on the work done in acoustic emission monitoring during the testing. Large quantities of test data have been gathered to study the felicity and unloading effects discussed in recent papers on this subject as well as fatigue behavior, signal recognition, and practical field testing and evaluation of in-service bridges.

Session 7

Acoustic Emission Testing Defects Environmentally Assisting Damaging Mechanisms

Claudio Allevato, Napolean Douglas, Stress Engineering Services

Hydrogen Induced Cracking (HiC) can be detected and located by means of an in-service overpressurization monitoring with AET, on pressure vessels in "Sulphur rich" and Amine loaded environments.

AE-UT method designed for the determination of sound velocity in rods

I. Roman and F. Zeides, Graduate School of Applied Science, Hebrew University of Jerusalem

This work describes a new experimental technique for determination of sound velocity in cylindrical rods. The technique is based on phenomenon observed in cylindrical rods driven by an AE transducer. The sensor is attached to one edge of a rod to produce longitudinal vibration. Two sets of experiments were conducted: firstly, rods partly immersed in liquid were moved

vertically either up or down in a liquid. In the second set of experiments, the rods were made to slide in air through a bushing.
In both sets of tests, periodic changes in the voltage across the piezoelectric (R15, PAC) AE sensor were observed during rods movement. The distance between any two neighboring voltage peak positions is equal to one half of the effective wavelength predicted by appropriate mathematical treatment.
The experimentally determined wavelengths and ultrasonic driving frequency were used to calculate wave velocities for rods of different diameters. This newly developed method may be employed for studying guided elastic waves and elastic properties of solids including wires and fibers.

Acoustic Emission (AE) Loose Parts Monitoring Application in a Nuclear Power Plant

Mark Carlos, Physical Acoustics Corporation

This presentation describes an automated Acoustic Emission (AE) Loose Parts Monitoring (LPM) application which was developed and implemented in a Nuclear Power Plant. The purpose of the LPM System is to monitor for, uniquely detect and evaluate, metallic loose parts, in the presence of severe environmental noise and vibration, using transient acoustic emission signal analysis. The presence of loose parts in the coolant system can signal a degradation in the reactor safety and ultimately result in component damage and material wear or coolant flow blockage. These serious situations must be detected immediately before permanent damage occurs, while at the same time eliminating false alarms caused by routine and non-routine process noises.

This presentation will describe the Loose parts monitoring application, the LPM system with some of its unique signal processing functions, the Loose Parts detection algorithm which is a multi-parameter, multiple level, time and frequency based analysis and some application testing results.

Using AE Technique to Detect Fatigue Related Damages in Cemented Total Hip Arthroplasty

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2Department of Biomedical Engineering, Joint program of The University of Memphis and University of Tennessee Health Science Center
3Department of Engineering, University of Denver

The present work is a preliminary report of an ongoing research project that uses the acoustic emission technique to investigate initiation and progression of fatigue failure in a cemented femoral stem of total hip arthroplasty (THA). In this work, the authors conducted fatigue tests of two sets of cemented femoral stem constructs. One set of the specimen, Spectron (Smith Newphew, Inc. Memphis, TN), had favorable records of successful rate in clinical practice, the other, Precoat (Zimmer, Inc. Warsaw, IN), had relatively poor records. Using the real time information, the formation and progression of microcrack activities were quantitatively measured. Apparently, the findings were consistent with the clinical performance of the specimens. Although further tests are needed to provide more statistical support, the current data showed that AE technique has the potential of being a preclinical tool to evaluate the fatigue performance of the cemented femoral stem construct in a much more clinically relevant environment.