Sound Propagation in Water-Saturated Sand

Friday, January 19, 1996 4:00 p.m.

Dr. Nicholas P. Chotiros
Applied Research Laboratories
The University of Texas at Austin

Wave propagation in water-saturated sand is modeled using Biot's theory. A unique feature of Biot's theory is the prediction of two compressional waves, in addition to the shear wave. The experimental data are reviewed. Measurements of the speeds and attenuations of both the fast and slow waves are presented. The results are compared with extant Biot model predictions for water-saturated sand, from which it is concluded that certain input parameter values need to be modified. The critical parameters are identified as the grain and frame bulk moduli. In the case of the grain bulk modulus, the value is obtained by direct laboratory measurement.The final result is a set of Biot input parameter values that give wave speeds and attenuations of both the fast and slow waves, in the 10-100 kHz band, that are consistent with experimental measurements.

Pattern Formation in Vibrated Granular Layers

Friday, January 26, 1996 4:00 p.m.

Paul B. Umbanhowar
Department of Physics
The University of Texas at Austin

Pattern formation in thin layers of vertically vibrated granular material has been investigated as a function of oscillation frequency, acceleration amplitude, and layer thickness. Above a critical acceleration of approximately 2.5g (where g is the acceleration due to gravity) the initially flat layer undergoes a hysteretic transition to subharmonic standing waves which are squares for low frequencies, and stripes for higher frequencies. Increasing the acceleration amplitude at fixed frequency reveals additional transitions to hexagons and more complicated patterns composed of domains with different relative phase. The associated critical accelerations are predicted by a simple model. For thicker layers (approximately 20 particles deep) a novel localized excitation has been observed for frequencies in the transition region between squares and stripes and accelerations below the lower stability boundary for standing waves. Localized excitations are stable, stationary, and interact to form more complicated structures.

Multiharmonic Plane Nonlinear Waves

Friday, February 9, 1996 4:00 p.m.

Dr. Claes Hedberg
Department of Mechanics
Royal Institute of Technology
Stockholm, Sweden

This seminar is dedicated to modulated, plane, weak shock waves where the nonlinear and dissipative effects are of the same order. Such waves are well described by the Burgers equation. In the first part of the seminar, two solutions for a biharmonic source condition are presented. Strengths and weaknesses in the use of the saddle point method are discussed. In the second part, high intensity plane wave propagation is investigated with theoretical results for an initially amplitude or phase modulated acoustic signal. An analytical model based upon the positions and amplitudes of the shocks is developed. A special situation occurs when the amplitude and frequency modulation cancel each other in such a way that the wave shape is constant once the full shock structure is developed.

Compression of Glass by Shock Waves

Friday, February 16, 1996 4:00 p.m.

Dr. Stephan J. Bless
Institute for Advanced Technology
The University of Texas at Austin

This lecture will start with a review of some basic principles of dynamic compression by shock waves, and then consider results for glass, which is a material of particular current interest, and which exhibits interesting anomalous behaviors including shock wave dispersion, sudden densification, loss of shear strength, dilatancy, explosive fracture and failure waves. The connection between these phenomena is just beginning to be understood, but there are still many unanswered questions.

Laser Generated Cavitation in Absorbing Liquid Induced by Acoustic Diffraction

Friday, February 23, 1996 4:00 p.m.

Dr. Martin Frenz
Biomedical Engineering
The University of Texas at Austin

Conversion of energy from a laser generated heat pulse to acoustic stress in an absorbing liquid is studied in detail. Pulses with a duration of 6ns created by an optical parametric oscillator (OPO) were used. The laser radiation was delivered via an optical fiber. Cavitation and propagation of stress waves were observed by use of time-resolved Schlieren imaging and piezoelectric pressure detectors. It is shown that tensile stress and cavitation is induced in front of the fiber tip. Depending on the absorption coefficient of the sample these cavitation effects are either produced inside (at low absorption) or clearly outside (at high absorption) the laser heated volume. The occurrence of tensile stress, so far only described by reflection of compressive waves at impedance mismatched boundaries, is explained by acoustic diffraction of the thermoelastic expansion wave. A good agreement between experimental results and theoretical calculation based on a three-dimensional model was found.

Development of Nonlinear Acoustics: From Euler to Lord Rayleigh

Friday, March 1, 1996 4:00 p.m.

Dr. David T. Blackstock
Mechanical Engineering Department
The University of Texas at Austin and
Applied Research Laboratories

The history of developments in nonlinear acoustics, from Euler (1755) to Lord Rayleigh (1910) is described. Results that are taken for granted today, such as the propagation speed for a finite-amplitude wave and the formation of shock waves, took nearly a century to be formulated and properly interpreted. Many famous scientists and mathematicians- Euler, Lagrange, Poisson, Stokes, Riemann, Rankine, and Rayleigh- and also some not so well known -Challis, Airy, Blake, and Earnshaw- are players in the story. Some were heroes, others goats, but all contributed to the clear understanding we now have today.

Theoretical Modeling of Nonlinear Surface Waves

Thursday, March 7, 1996 4:00 p.m.

Dr. Mark F. Hamilton
Mechanical Engineering Department
The University of Texas at Austin

Nonlinear effects in surface waves, like those in bulk elastic waves, are enhanced dramatically by micro-inhomogeneous features such as cracks and grains that are common in rocks. Since surface waves experience less geometrical spreading loss than bulk waves, nonlinearity can be even more pronounced than in bulk waves. A brief review of theoretical models for studying nonlinear surface wave propagation will be presented. The models are based on the theory developed at UT by Zabolotskaya for nonlinear Rayleigh waves in isotropic solids. In subsequent articles the theory was used to study harmonic generation, waveform distortion, and shock formation in plane waves, cylindrical waves, and diffracting surface wave beams. Radiation from both time harmonic and pulsed sources was investigated. Reported values for second and third order elastic moduli were used to calculate coefficients of nonlinearity for a number of rock-like materials. The theoretical model was recently extended to encompass nonlinear Stoneley, Scholte, and Lamb waves, and to include effects of anisotropy and piezoelectricity. Most experiments reported on nonlinear surface waves are associated with the development of nonlinear SAW devices in the 1970s. Several of these experiments will be revisited, and new interpretations of the measurements will be offered.

Effects of Frequency Dependent Absorption on the Propagation and Attenuation of High Intensity Acoustic Waves Containing Shocks

Tuesday, March 19, 1996 4:00 p.m.

Dr. Vera A. Khokhlova
Department of Acoustics
Physics Faculty
Moscow State University
Moscow, Russia

Shock waves used in medicine and other applications of intense ultrasound are greatly influenced by the thermoviscous losses in the propagation medium. The effect of the frequency dependence of the absorption and dispersion coefficient on nonlinear wave distortion, shock front structure and energy attenuation has not been investigated in detail up to date. For absorption frequency dependence other than quadratic, the corresponding nonlinear evolution equation is often complicated and thus frequency domain methods of solution are more effective. The presence of the shock, however, makes this analysis time consuming due to the large number of spectral components needed in numerical calculation. To avoid this complexity a semi-analytical method that enables calculations with relatively few harmonic components is used in this work. Propagation of an initially harmonic wave in various media with frequency dependent absorption is investigated.

Excitation of Shear Waves within Rubber-like Material by Focused Longitudinal Waves

Friday, March 22, 1996 4:00 p.m.

Dr. Oleg A. Sapozhnikov
Department of Acoustics
Physics Faculty
Moscow State University
Moscow, Russia

Propagating in an absorbing medium, acoustic waves lose not only energy, but also momentum. The latter effect is associated with acoustic radiation pressure. In liquids it gives rise to acoustic streaming. In solids the result of radiation pressure differs from that in liquids. Shear elasticity exists here, resulting, on the one hand, in damping of the hydrodynamic flows and, on the other, in generation of shear stresses and corresponding shear waves. In this work an experiment will be described on observation of shear waves radiated from the focal region of a focused ultrasonic beam. The measurements will be compared with a corresponding theoretical model.

Reading Spark Signatures and Educational Activities of the Acoustical Society of America

Friday, May 3, 1996 4:00 p.m.

Dr. Wayne M. Wright
Applied Research Laboratories
The University of Texas at Austin
and
Department of Physics
Kalamazoo College
Kalamazoo, Michigan

This presentation will be composed of two parts. The first part will be an illustrated review of opportunities that are provided by modest sparks in air to learn about diffraction, focusing, and other acoustical phenomena. Availability of reliable theoretical expectations, when a short-duration impulsive signal propagates through a non-dispersive medium, permits one to deduce features of the system through which the wave propagates, and of the receiving system, with considerable confidence. The second portion of the presentation will be based on several years of activity on behalf of the Acoustical Society's Committee on Education in Acoustics, as well as on recent service as ASA representative to the Education Advisory Committee of the American Institute of Physics. It will include discussion of the background and intent of the ASA Directory of Graduate Education in Acoustics and, in particular, changes associated with the anticipated 1996 revision.

Presentations for the 131st Meeting of the Acoustical Society of America

Monday, May 6, 1996 3:30 p.m.

Michael R. Bailey
"Intensified cavitation produced with pressure release and rigid ellipsoidal reflectors"

E. A. Zabolotskaya
"Nonlinear surface wave propagation in crystals"

David T. Blackstock
"R. T. Beyer's contributions to nonlinear acoustics"

Frank A. Boyle
"Mapping acoustic echosounder data to human color vision"

Penelope Menounou
"Propagation of finite-amplitude broadband noise"

B. J. Landsberger
"Second harmonic generation in a sound beam incident on a liquid-solid interface near the Rayleigh angle"

Nonlinear Acoustic Nondestructive Testing

Thursday, May 9, 1996 4:00 p.m.

Dr. Alexander Sutin
Institute of Applied Physics
Russian Academy of Science
Nizhny Novgorod, Russia

Acoustic imaging and NDT methods are widely used in various technical fields. Conventional methods are based on the principles of linear acoustics; nonlinear distortion is ignored. The strength of the distortion can drastically increase due to the compliant features of the cracks. Such distortion can be observed by using different nonlinear effects such as higher harmonic generation, modulation of sound by vibrations, and generation of subharmonics. Nonlinear acoustic methods are based on these effects, and many examples of its experimental verification are presented. First we studied nonlinear detection of bubbles for applications such as bubble diagnostics in seawater and in blood. A similar method was developed to test the glue quality of thermoprotective covers of the Russian Buran space shuttle. Using the nonlinear effect of high frequency sound modulation by vibrations we have experimentally demonstrated an enormous increase of acoustic nonlinear parameter in steel that has been fatigued. Single microcracks in metal construction were detected as well. The method based on second harmonic generation due to cracks was tested for crack detection in big carbon electrodes (3.5m length). The sensitivity of new nonlinear methods to detect the appearance of fatigue damage to a material is much larger than that of conventional methods of NDT. Another application of the nonlinear method is detection of bubbles. For example, a gas bubble insonified at two frequencies will produce sound at the difference frequency. Bubble motion will produce a difference frequency doppler shift that can the linear doppler shift. Our experimental observations reveal that the nonlinear doppler shift is 50 times more than the linear one. Experimental observations of nonlinear effects due to bubbles at sea and in sediments are presented, and their theoretical interpretation will be described. Theoretical work, as well as experiments, both at sea and in the laboratory, will be described. Nonlinear methods may also play an important role in industrial defect detection; for example, in safety inspection of aircraft and spacecraft, and to make more reliable the operation of nuclear power station equipment, as well as inspection of fatigue damage in buildings, bridges, tunnels, gas and oil pipelines, etc.

Trends in Electromechanical Transduction

Wednesday, September 11, 1996 4:00 p.m.

Dr. Ilene Busch- Vishniac
Department of Mechanical Engineering

In recent years there has been a growing interest in electromechanical transducers, i.e., sensors and actuators. This increase in interest has been prompted by a number of trends, including: the growing pervasiveness of sensors and intelligence in devices, the increasingly challenging requirements being applied to sensors and actuators, the emergence of new applications, the push for miniaturization, the growing emphasis on actuators, and the rapidity with which the technologies associated with transduction are changing. These trends will be examined in more detail, with examples from the research projects conducted by the speaker over the past few years.

Techniques for “Collecting Relevant Information Electronically”

Friday, September 20, 1996 4:00 p.m.

Susan Ardis
Head, McKinney Engineering Library

The purpose of this talk is to give students and faculty the scoop (the truth) about libraries and information so that you can get what you want when you want it with grace and ease. This talk will answer several exciting questions including:

1. Why is information arranged in such a peculiar way?

2. When will it all be online?

3. So, how do I get what I need?

4. “Why is everything always checked out?”

5. You mean students and faculty are charged fines?

And then the best part (demonstration), which will include:

1. Helpful hints.

2. Shortcuts

3. Words of wisdom

4. You can ask questions

Lithotripsy: The Breaking of Kidney Stones by Acoustic Shock Waves

Friday, October 4, 1996 4:00 p.m.

Dr. Robin Cleveland
Applied Physics Laboratory
University of Washington at Seattle

The use of shock waves to destroy kidney stones has found wide acceptance in hospitals throughout the world. Although over two million successful lithotripsy treatments have occurred, there is still much to be learned about the physical mechanisms of stone destruction and tissue damage. The principal mechanisms proposed for stone comminution are: compressive fracture, spallation (tensile failure), and cavitation (violent collapse of microbubbles). These mechanisms probably also play a role in damage to healthy kidney tissue. In this talk the basic principles of lithotripsy are discussed. We report on the results of research carried out at Applied Physics Laboratory and Indiana University Medical School as part of a collaborative NIH grant. We shall present measurements of lithotripter shock waves in vivo (using pig models), methods for detecting cavitation in vivo during lithotripsy, and evidence of damage to kidneys being treated with lithotripsy.

Modeling and Measurement of Nonlinear Surface Waves*

Monday, October 14, 1996 3:30 p.m.

Doug Meegan
Applied Research Laboratories

The linear theory for small-signal surface waves (Rayleigh, Scholte, and Stoneley) will be reviewed, and conditions for the existence of these modes of propagation will be described. Next, a nonlinear theory for finite-amplitude Stoneley and Scholte waves will be presented. The theory generalizes an existing spectral model for nonlinear Rayleigh waves. Numerical solutions were obtained for Stoneley and Scholte waves propagating along interfaces formed by a variety of material pairs. Harmonic generation and shock formation for these two modes will be compared with the corresponding processes in Rayleigh waves. Finite-amplitude effects were found to be very similar for all three types of surface waves when the propagation distance is normalized by an approximate expression for the shock formation distance. Nonlinearity coefficients for Stoneley and Scholte waves were calculated for a variety of materials. Finally, piezoelectric transduction techniques used to produce focused Scholte waves will be described, along with the results of experiments conducted to study Scholte waves that propagate along an aluminum-water interface.

*Final oral defense of Ph.D. dissertation.

Acoustic Correlates to Speech Form the Basis for Perception

Friday, October 25, 1996 4:00 p.m.

Wendy A. Castleman
Department of Psychology

Speech is a fairly continuous stream of acoustical information. However, listeners do not hear speech as continuous. They perceive speech as a string of discrete words, syllables and phonemes. This poses the problem of how listeners are able to segment the stream into discrete units. There are no invariant acoustical features that delineate a specific phoneme. Phonemes are distinguished from one another by differences in frequency, amplitude and duration. The distinction between voiceless fricatives (like “sh” in “ship”) and voiceless affricates (like “ch” in “chip”) has long been presumed to be due to amplitude rise time at the onset of frication. Recent research has, however, brought this into question (Kluender and Walsh, 1992). Acoustical analysis reveals that duration cues are more effective at discriminating between fricatives and affricates. Silence and frication durations combined provide a qualitative difference between fricatives and affricates that is robust under a variety of conditions when amplitude rise time is not. Salient patterns of acoustical information such as this can provide the basis for speech perception.

Acoustical Aspects of the Planar Jet Instability

Friday, November 1, 1996 4:00 p.m.

Dr. A. Wilson Nolle
Department of Physics

The spatial growth of the sinuous instability of planar jets has received much attention as the amplification mechanism involved in edge-tone oscillation and in flute-like instruments. Early “temporal” theoretical treatments, used in most discussions of these systems, dealt with an unrealistic oscillation growing in time but fixed in space, and proved incorrect when attempts were made to convert the results to spatial amplification and phase velocity. Some features of preferable, more recent spatial-propagation calculations are verified by hot-wire studies described here. In one set of these studies, the jet is excited by an acoustical cross-current localized at the nozzle, allowing study of propagation parameters of an effectively free oscillating jet in a downstream region. In another set, the acoustical cross-current driving the jet is as uniform over the entire observable region of jet travel, as it would be in an organ pipe. The greatly changed apparent amplification in this situation may be understood from the basic free-jet results by assuming that the observed jet displacement (zero at the nozzle) is the sum of the particle displacement in the lateral exciting signal and the growing instability-wave displacement, as suggested in various ways by Powell, Fletcher, and Elder. The contiguous acoustic field of the oscillating jet, which must be considered as a self-excitation mechanism, is also investigated.

Localization and Delocalization in One-Dimensional Dynamic Systems

Wednesday, November 6, 1996 4:00 p.m.

Joe Dickey
The Johns Hopkins University

Mechanical structures with reasonably periodic variations in impedance may exhibit wave localization similar to Anderson localization in atomic systems. Several such systems have been investigated by the authors: a beaded string, membranes and plates with periodic stiffeners attached, and a “jungle gym” All these exhibit pass and stop bands in the propagation of vibration in the structure and the related spatial localization and delocalization when the periodicity of the impedance discontinuities is disturbed. When the strict periodicity is perturbed, localization and delocalization occur in the pass and stop bands, respectively. It is demonstrated that these effects depend on the interactions between discontinuities.

Point-Source Reciprocity Relations in Elastodynamics and Acoustics

Monday, November 11, 1996 4:00 p.m.

Professor C. L. Morfey
Institute of Sound and Vibration Research
Southampton, United Kingdom

The fields of linear elastodynamics and linear acoustics employ somewhat different reciprocity relations for the limiting case of point sources. In acoustics, the volume-velocity source is regarded as basic: The appropriate reciprocity relation is well-known and it is shown by Landau and Lifshitz (Fluid Mechanics) to be valid for inviscid fluid media with arbitrary spatial variations of density and sound speed. In elastodynamics the point force is the basic singularity; again a well-known reciprocity relation applies, and remains valid regardless of spatial inhomogeneity or even anisotropy of the medium. The only restriction is that if the medium is a fluid, restrictions apply to the manner in which the force is applied. A synthesis of these two viewpoints is presented here. The new approach leads to an apparently new result for point spherical sources in locally-isotropic media.

Propagation of Acoustic Pulses in a Turbulent Medium

Friday, November 15, 1996 4:00 p.m.

Dr. Philippe Blanc-Benon
Laboratoire de M’ecanique des Fluides et d’Acoustique
Ecole Central de Lyon
Lyon, France

An acoustic wave propagating through a turbulent atmosphere is significantly affected by the variation in the value of the refractive index along the propagation path. The influence of temperature and wind velocity fluctuations has been demonstrated in many experimental studies. In recent years the turbulence has been taken into account in the numerical simulations of realistic cases of sound propagation. As an example, for sound propagation over long distances when strong negative vertical sound-speed gradients refract sound upward, it has been confirmed that the increase of the mean sound-pressure level in the shadow zone is due to the scattering of sound by turbulence. Because of the turbulent fluctuations, each frequency component of an acoustic source will be scattered in a different way. As a consequence an acoustic pulse propagating in a turbulent atmosphere will be distorted. In addition, when there exists a mean sound-speed gradient echoes will appear due to multi-path propagation. Exploration of the coupling effect between turbulence and mean sound-speed gradient on acoustic propagation is an important issue in the use of impulse responses for outdoor sound propagation investigation. In our numerical model a time independent turbulent medium is represented by a set of realizations of random fields composed of a series of Fourier modes. The propagation of an acoustic pulse with a Gaussian time dependence is calculated using Fourier synthesis. In a first step each frequency component of the pressure signal is propagated using a wide angle parabolic equation; in a second step the acoustic pressure in the time-domain is obtained via an inverse Fourier transform. Results are presented for the case of a sound speed profile decreasing with height and a turbulent medium with Gaussian temperature fluctuations. The spatial variability of the time signatures in the shadow zone is illustrated and energetic aspects are discussed for individual realizations of the turbulent field.

Presentations for the Third Joint ASA Meeting Honolulu, Hawaii

Monday, November 25, 1996 4:00 p.m.

Frank Boyle
Applied Research Laboratories:
A Generalized Acoustic Model for Marine Sediments

Matias Budhiantho
Department of Electrical Engineering:
Acoustic Velocity Related Statistical Distributions

B. J. Landsberger
Department of Mechanical Engineering:
Second Harmonic Generation in a Sound Beam Transmitted Through an Isotropic Solid

Zhenia Zabolotskaya
Department of Mechanical Engineering:
Nonlinear Surface Wave Propagation in a Piezoelectric Material

Control of Acoustic Cavitation with Application to Lithotripsy*

Wednesday, December 18, 1996 3:00 p.m.

Mike Bailey
Department of Mechanical Engineering

Control of acoustic cavitation, which is sound-induced growth and collapse of bubbles, is the subject of this dissertation. Application is to extracorporeal shock wave lithotripsy (ESWL), used to treat kidney stones. Cavitation is thought to help comminute stones yet may damage tissue. Can cavitation be controlled? The acoustic source in a widely used clinical lithotripter is an electrical spark at the near focus of an underwater ellipsoidal reflector. To control cavitation, we used rigid reflectors, pressure release reflectors, and pairs of reflectors aligned to have a common focus and a controlled delay between sparks. Cavitation was measured with aluminum foil, which was placed along the axis at the far focus of the reflector(s). Collapsing bubbles pitted the foil. Pit depth measured with a profilometer provided a relative measure of cavitation intensity. Cavitation was also measured with a focused hydrophone, which detected the pressure pulse radiated in bubble collapse. Acoustic pressure signals produced by the reflectors were measured with a PVdF membrane hydrophone, digitally recorded, and input into a numerical version of the Gilmore equation [Caltech, 1952]. Maximum pressure produced in a spherical bubble was calculated and employed as a relative measure of collapse intensity. Experimental and numerical results demonstrate cavitation can be controlled by an appropriately delayed auxiliary pressure pulse. When two rigid-reflector pulses are used, along interpulse delay (150-200 μs) of the second pulse “kicks” the collapsing bubble and intensifies cavitation. Foil pit depth and computed pressure three times single pulse values were obtained. Conversely, a short delay (< 90 μs) “stifles” bubble growth and weakens cavitation. A single pressure release reflector time-reverses the rigid-reflector waveform – a positive pressure spike follows a shallow negative phase – and thus inherently stifles cavitation. Additional configurations and waveforms were explored, and localization of an intensified cavitation region surrounded by a tempered cavitation region was realized. The general methods of control and their specific implementations provide tools for assessment of cavitation’s role in, and for improvement of, ESWL.

*Final oral defense of Ph.D. dissertation.