Title
Acoustic signatures of a fracture during air injection

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9:15

2aPA3. Notes on nonlinear elasticity of rocks. Lev A. Ostrovsky (Univ. of Colorado/NOAA Environ. Technol. Lab., 325 Broadway, Boulder, CO 80303)

Recent experiments with samples of Earth materials such as sandstone have shown that they possess a strong nonlinearity, and that water saturation, even in small amounts, may strongly affect nonlinear properties of the material. Here, a theoretical model is considered which represents the rock as a conglomerate of "large" grains (of order 100 μm) with two types of contacts: hard ones which determine the basic elastic matrix, and soft contacts, due to much smaller contacting grains which can create strong nonlinearity. Also, the effect of capillary and Van der Waals forces in thin liquid layers between grains is considered. The theoretical estimates are compared with available experimental data.

9:30

2aPA4. Resonance inversion for elastic moduli of anisotropic rocks. Seiji Nakagawa, Kurt T. Nihei, and Larry R. Myer (Earth Sci. Div., E. O. Lawrence Berkeley Natl. Lab., 1 Cyclotron Rd., Berkeley, CA 94720, seiji@friction.lbl.gov)

In this research, acoustic resonance spectroscopy was applied to determine the dynamic elastic constants of isotropic glass and transversely isotropic rock cubes. This technique consists of resonating the specimen over a broad range of frequencies, measuring the resonance frequencies, and computing the elastic constants by nonlinear inversion of the measured resonance frequencies. Specimens were tested under unconfined, traction free conditions. Resulting surface vibrations were measured using a miniature accelerometer and their spectral characteristics were analyzed. The inversion was performed using a numerical algorithm based on the Rayleigh–Ritz method that minimized the difference between measured and computed resonance frequencies iteratively. Mode shapes of the anisotropic specimens were also measured using a laser Doppler vibrometer and compared with the prediction of the numerical model. Comparison between the elastic moduli of rock specimens determined by static loading tests, resonance inversion, and ultrasonic transmission tests showed good agreement between the ultrasonic and resonance results but the moduli determined from ultrasonic measurements were consistently higher than the resonance inversion. Such results may be due to the frequency-dependence of the wave velocity in microscopically heterogeneous rock and nonelastic (frictional) deformation of the rock specimen during the static loading tests.

9:45

2aPA5. Acoustic signatures of a fracture during air injection. Kurt T. Nihei, John E. Peterson, Jr., Larry R. Myer, and Ernest L. Majer (Earth Sci. Div., Lawrence Berkeley Natl. Lab., 1 Cyclotron Rd., M.S. 90-1116, Berkeley, CA 94720)

This study examines the acoustic signatures of transmitted, reflected, and guided waves during air injection into a single, natural, water-saturated fracture in limestone. The presence and location of the fracture were established in a series of geologic, hydrologic, and seismic studies (Queen and Rizer, 1990; Datta-Gupta *et al.*, 1994; Majer *et al.*, 1997) that ultimately led to its verification in core obtained from a slanted well. This work describes the results of a follow-up high frequency (1 to 10 kHz) crosswell survey that was designed to illuminate the fracture by air injection into the fracture. Zero-offset *P*-wave crosswell transmission and reflection measurements conducted during air injection showed a large decrease in the amplitude of the transmitted wave (approximately 10 times reduction at 3 kHz), and a smaller increase in the amplitude of the reflected wave (approximately 1.5 to 5 times increase at 3 kHz). Measurements of the *P*-wave and an interface wave propagating along the fracture also show a small increase in amplitude during air injection. Analyses of these measurements using numerical boundary element and finite-difference simulations and the importance of including fracture stiffness heterogeneity arising from irregular distributions of air inside the fracture will be presented.

10:00

2aPA6. Wind generated sound in standing corn. David G. Browning (Dept. of Phys., East Hall, Univ. of Rhode Island, Kingston, RI 02881)

The "sound of corn growing" in farming folklore appears to be due to wind puffs, during otherwise calm conditions (especially at night), causing isolated audible popping sounds due to leaf striking leaf [D. G. Browning, Am. J. Botany **84**, 38(A) (1997)]. When the wind becomes steady, the number of events greatly increases, resulting in a rustling sound with a smoothed, broad spectrum between 1 and 5 kHz, and a peak at 2.5 kHz. For a windspeed of 20 mph the peak level is 20 dB above ambient. As the corn matures, the increased weight of the corn ears causes greater stalk sway at a given windspeed; also the leaves tend to become more brittle due to reduced moisture content. Both of these changes appear to alter the measured sound spectra, offering a means for evaluation.

10:15

2aPA7. Seasonal variability in the atmosphere and its effect on infrasonic propagation. David E. Norris and Robert Gibson (BBN Technologies, 1300 N. 17th St., Arlington, VA 22209)

Infrasonic waves can propagate thousands of kilometers in range and sample regions of the atmosphere from the ground up to and including the thermosphere. In this study, seasonal changes in the atmosphere and their effect on infrasonic propagation are characterized. The NASA/NRL empirically based models HWM-93 (for winds) and MSIS-90 (for temperature) are used. Three-dimensional ray traces are computed through the modeled atmosphere for several representative scenarios. Seasonal trends in both ray arrival times and ray azimuth bias are computed, and limited comparisons with data are made where possible. [Sponsored by Defense Threat Reduction Agency, Contract No. DSWA01-97-C-0160.]

10:30–10:45 Break

10:45

2aPA8. Spectral broadening of sound scattered by atmospheric turbulence. George H. Goedecke, Roy C. Wood (Dept. of Phys., New Mexico State Univ., P.O. Box 30001, Las Cruces, NM 88003-8001), Harry J. Auvermann (U.S. Army Res. Lab., Adelphi, MD 20783-1155), and Vladimir E. Ostashev (Environ. Technol. Lab., Boulder, CO 80303)

Scattering of a monochromatic sound wave by atmospheric turbulent eddies that are moving with the mean wind is described. The source and detector have wide radiation patterns and are at rest in a ground fixed frame. For eddies that make the dominant contribution to the detector signal, scattering angles change substantially with time, so the signal displays a time-dependent frequency which may include the full longitudinal Doppler width. A computer code is developed that calculates the time-dependent detector response and its Fourier spectrum due to one or many eddies, including a steady-state collection of eddies of many different scale lengths that models homogeneous and isotropic atmospheric turbulence. Several numerical results from this code are presented, including one for a simulation of a recent experiment. The predicted spectral characteristics are in very good agreement with the experimental ones. Some possible extensions of the model for describing anisotropic and intermit-