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Recent Work

Title
Acoustic signatures of a fracture during air injection

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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 satu-
ration, 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 esti-
mates are compared with available experimental data.

2aPA4. Resonance inversion for elastic moduli of anisotropic rocks.
Lawrence Berkeley Natl. Lab., 1 Cyclotron Rd., Berkeley, CA 94720, seijii@friction.lbl.gov)

In this research, acoustic resonance spectroscopy was applied to deter-
mine 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 mea-
sured 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 an-
isotropic 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 nonlinear (frictional) deformation of the rock specimen during the
static loading tests.

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 Riner, 1990; Datta-Gupta et al., 1994; Majer et al., 1997) that
ultimately led to its verification in core obtained from a 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 injec-
tion into the fracture. Zero-offset P-wave crosswell transmission and re-
fection measurements conducted during air injection showed a large de-
crease in the amplitude of the transmitted wave (approximately 10 times
reduction at 3 kHz), and a smaller increase in the amplitude of the re-
lected wave (approximately 1.5 to 5 times increase at 3 kHz). Measure-
ments 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.

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 64, 38(A) (1977)]. 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.

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 em-
pirically based models HWM-93 (for winds) and MSIS-90 (for tempera-
ture) 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.]

2aPA8. Spectral broadening of sound scattered by atmospheric turbulence.
George H. Goeddeke, Roy C. Wood (Dept. of Phys., New
Mexico State Univ., P.O. Box 30001, Las Cruces, NM 88003-8001),
Harry J. Auermann (U.S. Army Res. Lab., Adelphi, MD 20783-1155),
and Vladimir E. Otsaihev (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 dis-
plays 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 tur-
bulence. Several numerical results from this code are presented, including
one for a simulation of a recent experiment. The predicted spectral char-
acteristics are in very good agreement with the experimental ones. Some
possible extensions of the model for describing anisotropic and intermi-

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