Investigation of Ultrasonic Wave Interaction with Fluid-Saturated Porous Rocks

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We have no objection from a patent standpoint to the publication or dissemination of this material.

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Summary

During the period of this grant we have conducted an investigation of ultrasonic wave propagation in fluid-filled porous materials. The acoustical properties of fluid-saturated porous media are of interest to the geophysical community because measurements of the various wave velocities (fast and slow compressional waves, shear wave, surface waves, Lamb wave, etc.) and attenuation can lead to important parameters of fluid-filled rocks, e.g. elastic properties, tortuosity, permeability, internal damping, porosity, etc. Several of these parameters are especially related to the so-called slow wave velocity and attenuation, and one of our major efforts was to develop techniques to measure slow wave parameters.

First we studied the feasibility of using different surface modes to characterize both synthetic and natural rocks. We introduced several new techniques: corrugated surface wave technique, and direct generation of surface waves by edge excitation. We have reported the first observation of the so-called “true” surface wave on the free surface of fluid-saturated rocks. We have developed analytical solutions to the reflection and transmission of ultrasonic waves at boundaries between fluid and fluid-saturated porous solids. An experimental system was also developed to verify analytical predictions. These analytical treatments led to the development of a general solution for thin fluid-saturated porous plates and the dispersion curves of Lamb modes. Additional dispersion curves were predicted due to the presence of slow waves. Based on theoretical prediction, a new method was developed to detect slow waves in the frequency domain by measuring the Lamb wave spectrum.

In addition to the investigation of guided acoustic waves (surface waves, Lamb waves) in water-saturated porous media, we also studied bulk wave propagation in air-saturated specimens. We developed an experimental technique, which is based on the transmission of airborne ultrasonic waves through air filled porous plates. This technique provided irrefutable evidence of slow wave propagation in natural rocks and lends itself quite easily to tortuosity measurements in such materials. This technique was further developed to a high-resolution slow wave imaging system, to study the inhomogeneous pore structure of permeable formation.

Our research efforts — supported through this grant — should find application to the geophysical evaluation of fluid-bearing rocks where conventional techniques are difficult to apply. During this period thirty-four (34) research papers were published on the subject of this work supported by the Department of Energy. In addition two Ph.D. dissertations and one M.Sc. thesis covered this subject.

A list of publication and copies of published manuscripts will be given in this report.
Publications


