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Simultaneous Ultrasonic Measurement of Compressional and Two Directional Shear Wave Velocities With A Single Pair of Transducers

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Introduction

In field of Ultrasonic Testing, piezoelectric crystal transducers are often used to generate waves in elastic solids. The choice of ceramic transducers is favored compared to quartz transducers due to their greater electromechanical conversion and convenience of fabrication and use. Since the mid-20th century, different experimental techniques have been developed to measure compressional (P) and/or shear (S) waves velocities. Early workers such as Van Steveninck (1967) developed the concept of stacking ceramic transducers to produce both P- and S-waves in solids. Hemsing (2007) brought some modifications in the stacked system concept such as the building of damping material on the top of the ceramic transducers. Following the method developed by Hemsing (2007), our work introduces a new set of transducers able to simultaneously generate P wave and two orthogonal directional S waves in a solid media. One application of the new device is in the field of rock anisotropy studies. The new setup enables the measurement of fast and slow shear waves velocities in anisotropic media subject to external pressure from a single pair of transducers.

Transducer design

Commercially available piezoelectric (PZT) ceramics from Omega Piezo Technologies Inc. have been used for the building of the transducers. The PZT ceramic is a polarized material that converts the electrical pulse into mechanical vibration (source mode) and converts the mechanical vibration into electrical signal (receiver mode). The vibration mode and the desired frequency are determined by the polarization (axial or lateral) and the thickness of the PZT ceramic, respectively. For our experiments, P-wave crystals were circular disks with a diameter of 25 mm and a thickness of 2 mm while the S-wave crystals were square plates with side lengths of 15 mm and a thickness of 1 mm. Both P- and S-wave PZT ceramics were made with resonant frequencies centered around 1 MHz.

The technique used by Hemsing (2007) consisted of gluing a P-wave PZT ceramic on top of the S-wave PZT ceramic using silver conductive epoxy. Two copper foils, acting as electrodes, were used in the stacked set: (i) one separating the two ceramics and acting as negative side of the P-wave PZT ceramic and as the positive side of the S-wave ceramic, and (ii) the other glued on the top of the P-wave PZT ceramic acting as its positive side. For our study, the same stacking system was built and a second S-wave ceramic with a copper piece on its top was glued at the base of the first S-wave ceramic, the polarization axes of the two S wave PZT ceramics making an angle of 90° with each other (figure 1a). Orthogonal polarized shear waves could thus be generated using the set of stacked transducers. By means of a suitable switching arrangement, an electric pulse was applied to either the compressional or the shear transducers and the corresponding wave velocities measured consecutively.

Some preliminary experimental results

A pair of the new transducers has been used to make velocities measurements on a weakly layered carbonate rock under different conditions of confining pressure. A calibration run was done beforehand and consisted of measuring waves speeds within the metal end caps attached to the transducers and within which the rock sample were later inserted (figure 1b). Figure 2 shows P- and S- waveforms obtained under a confining pressure of 10 MPa. Shear waves polarized parallel to the rock layering are observed to propagate slightly faster than those polarized perpendicular to it.

Conclusion

Following earlier workers, we have developed a stacked ultrasonic transducer system that allows for simultaneous measurement of one P and 2 orthogonally polarized shear wave velocities on a cylindrical core sample. Full characterization of the material under the assumption that it is transversely isotropic requires that measurements are made on three differently oriented cores from a given rock sample. Initial tests of the transducer show strong waveforms in the different polarizations. These transducers will be applied to a number of shale samples to better characterize their anisotropy following the work of Hemsing (2007).

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References

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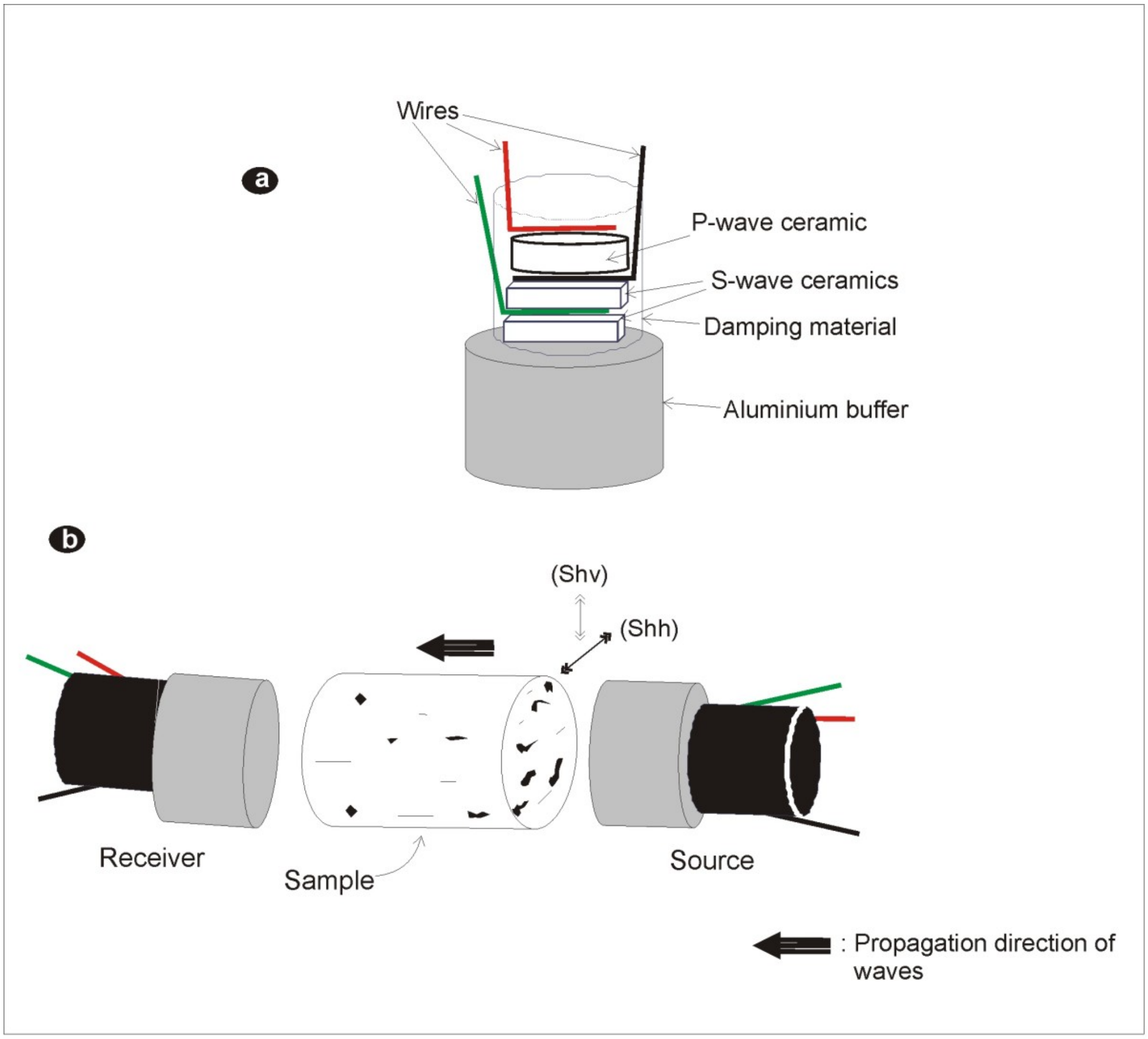

Figure 1: (a) Source/receiver transducer. (b) Assemblage Sample + Transducers. Arrow (Shh): Shear wave propagating horizontally with particles vibrating in horizontal direction (that means parallel to the rock layering); Arrow (Shv): Shear wave propagating horizontally with particles vibrating in vertical direction.

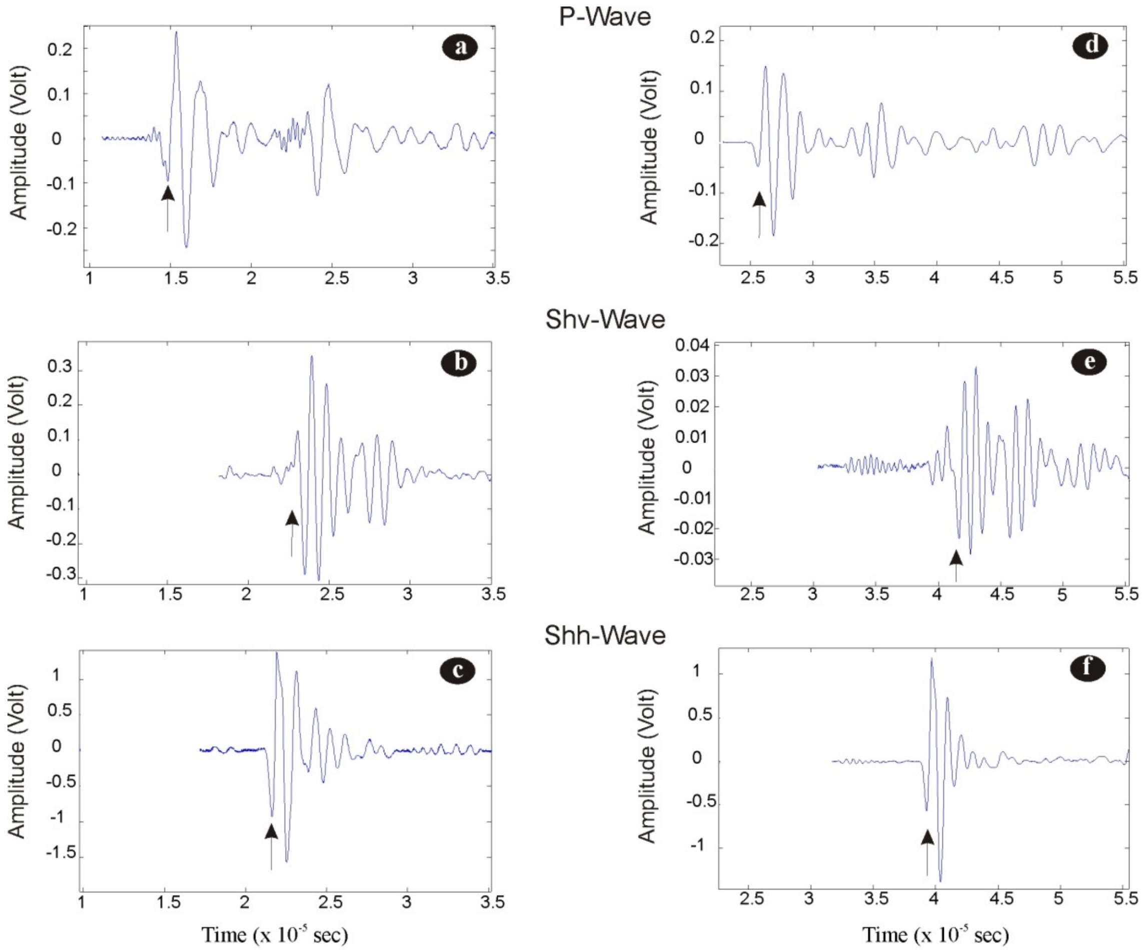

Figure 2: P- and S- waveforms under a confining pressure of 10 MPa. (a), (b), and (c): Signals through the aluminium buffer in the absence of sample. (d), (e), and (f): Signals through the buffer and the sample. The travel times is usually picked at the first extremum, marked by arrows. Shv-and Shh-waves were generated by the top and bottom S-wave ceramics in the transducer system, respectively (see figure 1a, b). The polarization axis of the bottom S-wave ceramic (Shh-wave) was parallel to the weakly developed rock layering.