Directional Dependency of Reflectivity in Anisotropic Media: a Laboratory Case Study

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Summary

In this contribution, we experimentally test the effects of azimuth and tilt angle on the acoustic reflectivity of a liquid-anisotropic solid interface. For this study, we are using a large source transducer, and acquired data for samples with different tilt angles. We use Phenolic CE material, which is known to have weakly orthorhombic symmetry. Our results show that changes of the tilt angle produce important variations on the reflectivity that are larger as the tilt increases. The most remarkable feature is the change of the critical angle with the azimuth, which shows a larger spread for larger tilts. The spectral components of the acquired waveforms also show characteristic features linked to the location of the critical angle, we particularly observed a drop in the peak frequency. These observations suggest that care must be taken about the interpretation and inversion of observed incidence and azimuth dependent seismic reflectivities and critical angles in obtaining information on a formation's anisotropy.

Introduction

In this work, we experimentally test the effects of azimuth and tilt angle on the acoustic reflectivity of a liquid-anisotropic solid interface. We use Phenolic CE material, which is known to have weakly orthorhombic symmetry. For this study we are using a large source transducer, and acquired data for samples with four different tilt angles, which are 0°, 30°, 45°, and 90°. Our result show that changes of the tilt angle produce important variations on the reflectivity that is larger as the tilt increases. The most remarkable feature is the change of the critical angle with the azimuth, which shows a larger spread for larger tilts. The general trend of the azimuthal reflectivity curves for tilts of 30° and 45°, resemble those of 90°. The spectral components of the acquired waveforms also show characteristic features linked to the location of the critical angle, we particularly observed a drop in the peak frequency. These observations suggest that care must be taken with regards to the interpretation and inversion of observed incidence and azimuth dependent seismic reflectivities and critical angles in obtaining information on a formation's anisotropy.

Experimental Method

The ultrasonic lab setup includes one large rectangular source and one small point receiver set in the goniometer immersed into the water tank, which allows us to read azimuthal and scattering angles. Figure 1, displays lab setup for ultrasonic lab for physical modeling of wave propagation in anisotropic media. Large rectangular ultrasonic source and small point ultrasonic receiver facilitates practicing plane-wave modeling. We leveled samples with the laser precision to avoid apparent angles. Electrical instruments are assembled in National Instrument power source and oscilloscope, which enables us to create a pulse source with dominant frequency of 2.2 MHz and record it with up to 150 million samples per minute. Figure 2, Shows the waveform that is recorded by point receiver directly from source inside the water tank and its corresponding frequency spectrum. To calibrate and test the ultrasonic system, we
modeled water-aluminum interface, and compared it with Zoeppritz (1919) solution. Because of the geometry of the acquisition, we were able to measure reflectivity from 20° to 60° incident angle.

Figure 1. Lab setup for ultrasonic physical modeling of plane-wave propagation in anisotropic media, and measuring reflectivity and transmissivity from water-sample interface, after Bouzidi and Schmitt (2009).

The large ultrasonic ceramic allows us to physically model plane-wave propagation and avoid correction for spherical wave. Figure 2 displays the source signature generated from the power ceramic in direct measurement inside the water, accompanied by frequency spectrum with dominant frequency of 2.2 MHz. For the purpose of calibration, we measured reflectivity from the water and Aluminum cube and compared it with Zoeppritz solution. Figure 3 shows wiggle representation of the reflectivity data from this interface, the phase rotation, which occurs right after the P-wave critical reflection is known as Schoch Shift, Bouzidi and Schmitt (2009).

Figure 2. Source wavelet recorded directly from source inside the water tank (left) and corresponding amplitude spectrum with the dominant frequency of 2.2 MHz (right).

Results
To better understand the reflectivity from anisotropic media, we used Phenolic CE sample, which represents a very weak orthorhombic anisotropy. Figure 4 shows Phenolic cubic samples with different alignment.
Amplitude envelope from water- PhTi30 in four azimuthal directions of 0°, 30°, 60° and 90° is displayed in figure 5. We observed that P-wave critical angle varies with azimuth of measurement and the pattern of PP-reflection varies drastically with azimuth.

Figure 3. Wiggle trace representation of the reflected wave from the water-Aluminum interface.

Figure 4. Phenolic CE cubic samples with rotation angles of 0°, 30°, 45° and 90°. PP reflectivity in various azimuthal direction and scattering angles are measured from the water and phenolic interface.

**Conclusion**

We have shown that the suggested ultrasonic set-up can be used to accurately determine the reflectivity, including the critical angle of incidence, as well as the spectral components of a liquid-anisotropic solid contact. Although, in principle, the set-up is limited to the liquid-solid interface, a stack of different materials can be used to study other type of contacts. The use of the large source transducer eliminates the necessity of spherical corrections. Results from isotropic samples (e.g. Aluminum) perfectly matches trusted Zoeppritz solutions. However measured PP reflectivity from Phenolic CE samples with various rotation angles show complex amplitude variation with azimuth and scattering direction. Future work will be dedicated to invert this reflectivity data to estimate elastic coefficients of the unknown samples.

Future works will be dedicated to better understand the Schoch shift and create a computer model to understand the wave propagation from the ultrasonic source.
Figure 5. Amplitude envelope representation of reflected wave from water-PhTl30 interface in a) 0°, b) 30°, c) 60° and d) 90° azimuthal directions. The P-wave critical angle varies with azimuth of measurements, which is a result of azimuthal dependency of velocity, the faster, the velocity inside the Phenolic sample, the smaller the critical angle will be.

Figure 6. Polar representation of PP reflectivity measured from a) water-PhT00 and b) water-PhTI45 interfaces. Reflectivity from the tilted transverse anisotropy shows complex variation azimuth where as it stays the same in all azimuthal directions from water-VTI interface.

Reference


