Physical and Numerical Modeling of Acoustic Reflectivity from Elastic Anisotropic Media

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Introduction

Elastic anisotropy has a predominant effect on our understanding of the solid Earth. In this contribution, we have studied the effect of elastic anisotropy on acoustic reflection coefficient variation with incident angle and azimuth. Longitudinal reflection coefficients are collected from water boundaries with Phenolic CE and single crystal quartz which possess orthotropic and trigonal anisotropic symmetry, respectively. P-wave critical reflection angle variation with azimuthal direction and tilt angle of the phenolic samples clearly indicates the orientation of the fabrics inside the phenolic. We also have observed the double Schoch shift pattern with azimuth from the P-wave reflectivity of water-quartz crystal, which is clearly corresponding to the crystal symmetry of the α-quartz and the shear wave velocity. To better understand the Schoch shift effect, we have implemented a bounded pulse propagation algorithm to model the ultrasonic reflectivity from the liquid-solid interface. The algorithm enables us to predict the schoch shift from a water-solid interface that happens at the Rayleigh angle.

Physical Modeling of the Acoustic Reflectivity

To study the reflected wavefield from elastic anisotropic materials, we have used designed ultrasonic reflectometer by [1]. The relatively larger transmitter compared to the receiver, creates a scenario in which reflected wavefield is considered near plane-wave. No matter how large the transducer is, the diffraction patterns are observed from the edges of the transducer that would change the signal properties of the reflected wavefield. Phenolic CE is a standard synthetic sample with orthotropic symmetry that is being studied for it anisotropic behavior for decades [2-4]. Fig. 1 displays a block of phenolic CE, and its measured acoustic reflectivity variation with incidental (θ) and azimuthal (φ) direction from 30 degree tilted phenolic block with water. Note on the variation of the acoustic critical angle (θp) with azimuth. Study this pattern could clearly indicates the major fabric orientation within the samples, which are an analogue to the fractured medium.

Figure 1. (a) Measured and modeled reflectivity variation with incident angle (θ) and azimuth (φ) from 30 degree tilted phenolic samples and water interface, (b) displays the phenolic block.

In the next step, we used the z-cut α-quartz disc (single crystal) and studied its reflectivity variation with azimuthal direction. The double Schoch shift pattern that is observed from its Rayleigh angle (θR) is unique, Fig 2. This chain like pattern that is observed in AVOAz polar plot, shows collapses into single
shift at every 60 degrees in azimuthal angle. Further studies about the z-cut α-quartz disc revealed that it has similar rotational symmetry in the trigonal crystal structure [5], the double schoch shifts collapses into single shift from the reflections collected at its plane of symmetries ($V_{s1}=V_{s2}$), Fig 2.

Figure 2. Polar representation of the (right) water-quartz acoustic reflection variation with incident angle and azimuth (left) absolute shear-wave velocity difference ($|V_{s1} - V_{s2}|$) variation with azimuth and incident angle, (Solid red lines), indicates the planes of symmetry of z-cut α-quartz.

**Bounded pulse modeling**

To understand the effects around the P-wave critical angle and the null reflections at the Rayleigh angle, we developed a computer algorithm [6] to propagate the bounded pulse into the medium, then reflect its wavefield from the water-solid boundary into the receiving transmitter, where the reflected wavefield is measured, and compare its results with the simple plane-wave reflectivity solution ($R_{pp}$) and experimental values. Fig. 3, displays the algorithm modeling of reflectivity from water-Copper alloy boundary, which the bounded pulse modeled reflectivity ($B_{pp}$), predict the measured data ($M_{pp}$) with the great confidence than $R_{pp}$.

Figure 4. a) Acoustic reflectivity measured from water-aluminium, b) and its amplitude ($M_{pp}$) comparison with the plane-wave solution ($R_{pp}$) and bounded pulse solution ($B_{pp}$).

**Conclusion**

In this contribution, we demonstrated a reflectometer technique to study the acoustic reflectivity from the water-solid interface in a different direction, and results from phenolic CE and single crystal z-cut α-quartz with orthotropic and trigonal anisotropic symmetry are presented. To better understand the effect of the bounded pulse on the reflected wavefield from the water-solid boundary, we presented the algorithm that predicts the laboratory measured acoustic reflection around the Rayleigh and P-wave critical angles properly.

**References**


