Laboratory Measurements of P-wave and S-wave Anisotropy in Synthetic Sandstones with Controlled Fracture Density

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SUMMARY

We present ultrasonic laboratory measurements on synthetic sandstones containing controlled fracture density and geometry. New construction methods can provide more realistic synthetic sandstones. We build a set of sandstones containing different fracture densities and grind these rock samples into octagonal prisms with about 50mm wide faces at increments of 45° to the fracture normal. These rock samples contain different fracture densities; the fracture diameter is about 4mm and fracture thickness is about 0.06mm. P-wave and S-wave velocities in each propagation direction of these samples were measured in an ultrasonic measurement system. The laboratory results show the influence of fracture density on P-wave and S-wave velocity and anisotropy. More laboratory experiments will be performed on these rock samples.
Introduction

A major cause of seismic anisotropy is thought to be fractures. Fractured reservoirs always induce significant anisotropy and fracture parameters are required if we want to evaluate these fractured reservoirs. Equivalent medium theories are used to describe rock physics parameters and elastic wave propagation in media containing fractures. The most important parameter in these equivalent medium theories is the fracture density.

In this study, we used a new construction method to build a set of synthetic fracture samples with different fracture densities. The fracture geometry is so-called “penny-shaped voids”; the fracture diameter is about 4mm and the fracture thickness is about 0.06mm. The measurement results show that the fracture density has an obvious influence on P-wave and S-wave velocity and anisotropy.

Construction of the fractured samples

We use a new production process to construct synthetic sandstones containing controlled fracture density and distribution. In the production process we ensure that the different samples have the same background anisotropy due to layering that is often inevitable due to the construction process.

To create the fracture samples with different fracture densities, we used a 100×100mm mould. When laying the sand mixture in the mould each time, high molecular material discs were spread out on the surface of each layer. The surface of each layer was divided into 4 parts, and the number of high molecular material discs spread out on each part was 0, 20, 40 and 60. When the sample had been prepared in the mould, it was left to dry in a constant temperature oven for weeks. At last, the sample was sintered in a furnace and the high molecular material discs were then decomposed and drained out, leaving voids as fractures. The fracture number in each part is different, so the four parts have different fracture densities but with the same background anisotropy. The sample was cut into four blocks and these were ground into octagonal prisms with about 50mm wide faces at increments of 45° to the fracture normal. Figure 1 shows the construction process of the fracture samples.

Figure 1 Construction process of the samples with different fracture densities
Laboratory results

The P-wave and S-wave velocities of these blocks were measured in an ultrasonic experimental system. We measured the P-wave velocity and S-wave velocity in propagation directions 0°, 45°, 90° and 135°, respectively to the symmetry axis.

Figures 2a, 2b, 2c and 2d show the P-wave velocities in the four propagation directions for the four samples, respectively. The P-wave velocity parallel to the fractures (the 90° direction) decreases slightly as the fracture density increases. In contrast, the P-wave velocity perpendicular to the fractures (the 0° direction) decreases sharply as the fracture density increases. Therefore, the P-wave anisotropy parameter ε increases as the fracture density increases (Figure 5a).

Figures 3a, 3b, 3c and 3d show the S-wave velocities in the four propagation directions of the four samples respectively. The S1 wave (fast shear wave) velocity parallel to the fractures decreases slightly while its velocity perpendicular to the fractures decreases sharply as the fracture density increases. The S2 wave (slow shear wave) velocity parallel to the fractures decreases sharply as the fracture density increases. Shear wave splitting in the fracture-parallel direction (90° direction) increases as the fracture density increases, however shear wave splitting is not influenced by fracture density in the direction perpendicular to the fractures (0° direction) (Figure 4). S-wave velocity and anisotropy are more sensitive to fracture density than the P-wave velocity and anisotropy. S-wave anisotropy and shear wave splitting in the 90° direction increase sharply as the fracture density increases (Figure 4 and 5b).

![Figure 2 P-wave velocities of the four samples](image-url)
Figure 3 S-wave velocities of the four samples

Figure 4 Shear wave splitting of the four samples
Note that in this experiment, the samples have strong background transverse anisotropy due to layering. The effects of the background anisotropy can be compensated for by using the background samples containing no fractures (Chapman, Maultzsch, Liu, & Li, 2003).

Conclusions

The four samples presented in this paper show significant anisotropy caused by fractures. Here, we focus on the changes of P-wave and S-wave velocity anisotropy with fracture density. The results reveal that the P-wave anisotropy parameter ($\varepsilon$) and S-wave anisotropy parameter ($\gamma$) show seemingly linear increases with the fracture density. S-wave anisotropy is more sensitive to fracture density than P-wave anisotropy. Note that the #1 sample is a blank sample without fractures, and the anisotropy in this sample is due to layering. Therefore the constructed samples reveal strong anisotropy with orthorhombic symmetry.

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References


