Numerical modeling of shear-wave splitting and azimuthal velocity analysis in fractured media

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Outline

- Introduction
- Numerical seismic modeling
- 3C-3D seismic data processing
- Results
- Conclusions
- Acknowledgements
Fracture effects from previous study:

1) Velocity decreases, $S$ velocity drops over 20%

2) P- and $S$-velocity anisotropy with aligned fractures
Objectives

1) Is fracture induced anisotropy detectable?
2) Can we see and use shear-wave splitting for fracture characterization?
3) Compare the sensitivity of P-waves and S-waves to fractures.
Blocked well logs and stratigraphic chart (after Fuzesy, 1982)
Rock properties of fractured layer

<table>
<thead>
<tr>
<th>Top</th>
<th>970.8 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>40.4 m</td>
</tr>
<tr>
<td>Crack parameters</td>
<td>1% penny-shape vertically aligned (along y axis of the survey) fractures, filled by brine with Vp 1430 m/s, density 1100 kg/m³.</td>
</tr>
<tr>
<td>Density</td>
<td>2603.9 kg/m³</td>
</tr>
<tr>
<td>Stiffness matrix</td>
<td>5.610 2.354 2.354 0 0 0</td>
</tr>
<tr>
<td>Vp</td>
<td>5184.7 m/s</td>
</tr>
<tr>
<td>Vs</td>
<td>2792.9 m/s</td>
</tr>
<tr>
<td>Survey design</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Survey size</td>
<td>4km x 4km</td>
</tr>
<tr>
<td>Receiver spacing</td>
<td>20 m</td>
</tr>
<tr>
<td>Receiver line spacing</td>
<td>20 m</td>
</tr>
<tr>
<td>Sample rate</td>
<td>2 ms</td>
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<tr>
<td>Record length</td>
<td>2048 ms</td>
</tr>
<tr>
<td>Source</td>
<td>Dynamite at the surface</td>
</tr>
<tr>
<td>Modeling frequency range</td>
<td>2 – 110 HZ</td>
</tr>
</tbody>
</table>

Fracture direction
Raw data (isotropic)
Raw data (HTI)
3C seismic data processing workflow

- Geometry
- Horizontal rotation for x & y components
- Spherical divergence compensation
- Deconvolution
- Velocity analysis and NMO
- Noise attenuation using FK filter
- Azimuth-offset gather
- Stack
- Shear-wave splitting analysis
Radial and transverse components of isotropic model (from horizontal rotation)
Radial and transverse components of HTI model
(from horizontal rotation)
Deconvolution

Before deconvolution

After deconvolution
Azimuthal velocity analysis
(vertical component, HTI)
Azimuthal velocity analysis (radial component, HTI)
offset-azimuth gathers of vertical component

offset

180  420  660  900

HTI
offset-azimuth gathers of radial component
azimuth bin stack of vertical component
azimuth bin stack of radial component
azimuth bin stack of transverse component
Shear-wave polarization analysis
Time and amplitude changes (vertical component)

1.1 ms

3.2%

12.2%
Time and amplitude changes (radial component)

ISO
HTI

3.75 ms

4.9 ms

2.2%

46%

30%
Conclusions

- Visible seismic velocity anisotropy on both vertical and horizontal components
- Stronger effects on horizontal component
- Distinct shear-wave splitting, and polarization of fast and slow shear waves is consistent with the crack orientation
- Apparent time-shift and amplitude changes by anisotropic layer on both vertical and radial components
- The time-shift on the radial component is up to 5ms, the amplitude change is up to 46%
Acknowledgements

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