Fracture Properties from Seismic Waves

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The goal of my project is to determine if seismic waves can be used to delineate the dominant flow path in a rock fracture.

My rock sample is a 4”x4”x4” Lucite mold of a single fracture in Austin Chalk limestone.

The dominant flow path between the two rough surfaces will depend on aperture size and contact area.

Predictions will be made using image and waveform analysis.
Procedure

- The Lucite sample has two halves; a front and a back.
- For a control, the rough surface of each half is scanned with a laser, and an image is formed that maps the highs and lows of the sample half.
- For further control, each half is seismically scanned separately and wave data is collected of the fracture halves when there is no contact between the surfaces.
- For these experiments the reflected seismic waves were recorded for analysis, and transmitted waves were not collected.
• With the control data collected, the fracture is assembled and sealed so that no water can leak into the fracture during the experiment.
• The assembled sample is again secured and clamped in the tank and immersed in water.
• Reflection data is collected of each half while the fracture is assembled, sealed, and clamped so that the affect of contact area can be seen.
• Transmitted seismic waves through the entire sample are collected with the use of a second transducer for comparison with reflected data.
• Analyze data and make a prediction about the dominant flow path in the fracture by looking at the arrival times, amplitude, and frequency ranges of the collected wave forms. The arrival times will provide a good indication of contact area, aperture size and overall geometry.

• Verify the predicted flow path by recording the flow of fluorescent beads.

• Determine if the observed path matches the predicted path.
Experimental Setup for Surface Roughness

- Surface roughness scans use a laser and a moving platform so that a signal can be acquired every 0.25 mm over the area of the sample.
- For a given scan, one half of the sample is secured rough side up facing the laser.
- The laser is “zeroed” on the lower left corner of the sample.
- A Labview program controls the moving platform and records data for every point on the area of the sample half.
Experimental setup for seismic scans

- The sample is secured and clamped in a tank and immersed in water.
- Underwater, ultrasonic transducers are mounted to overhead actuators, and hang down facing the sample.
- The actuators are controlled by computer input and the transducers return either a reflected or transmitted signal to an oscilloscope.
- The waveforms from the oscilloscope are recorded by a computer program.
The sealed, assembled sample is submerged in a tank of water with the same orientation as the seismic scans.

A green laser illuminates the fracture plane.

A syringe pump is programmed to deliver desired amounts of a fluorescent bead swarm through a needle placed directly above the fracture.

A video camera records the path of the fluorescent beads as they fall through the fracture under gravity.
Data Analysis

Surface Roughness Front
<table>
<thead>
<tr>
<th>Back half reflection</th>
<th>Back reflection with fracture</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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Waveform back half reflection

Waveform back reflection with fracture
Front half reflection

Front reflection with fracture
Waveform front half reflection

Waveform front reflection with fracture
Transmission

Waveform Transmission
Waveform comparison
Amplitude Comparison
Swarm Movies

Swarm in tight fracture

Swarm in tight fracture
<table>
<thead>
<tr>
<th>Swarm with wall 10 mm apart</th>
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<tbody>
<tr>
<td><img src="image1" alt="Image of swarm with wall 10 mm apart" /></td>
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<table>
<thead>
<tr>
<th>Swarm with walls 5 mm apart</th>
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<tbody>
<tr>
<td><img src="image2" alt="Image of swarm with walls 5 mm apart" /></td>
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</tbody>
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Swarm in 3 mm gap

Swarm in 3 mm gap
Conclusion

- Determining the dominant flow path was difficult from the amplitude data. First arrival data gave a reasonable image of the geometry of the fracture.
- Need more transmission data and further analysis of reflection data to make the best prediction.
- The swarm experiment was modified because the wall separation was too small.
- New procedure is to perform the swarm experiment first, then acquire seismic data of the sample.