Particle Size Distribution Measurement Techniques and Their Relevance or Irrelevance to Sand Control Design

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SPE 168152-MS

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Outline

• Literature Review

• Current Work
  – Calibration
  – Effect of sampling and particle shape; crossover of PSD
  – Generating samples for sand retention test
  – Sand retention test result and comparison with model prediction

• Conclusions
# Dry Sieve Analysis

![8” Diameter Test Sieve](image)

## U.S. Mesh Size

<table>
<thead>
<tr>
<th>U.S. Series Mesh Sizes</th>
<th>Sieve Opening (in)</th>
<th>Sieve Opening (mm)</th>
<th>U.S. Series Mesh Sizes</th>
<th>Sieve Opening (in)</th>
<th>Sieve Opening (mm)</th>
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</thead>
<tbody>
<tr>
<td>2.5</td>
<td>0.315</td>
<td>8.000</td>
<td>35</td>
<td>0.0197</td>
<td>0.500</td>
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<td>3</td>
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<td>6.730</td>
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<td>3.5</td>
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<td>200</td>
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<td>18</td>
<td>0.0394</td>
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<td>230</td>
<td>0.0024</td>
<td>0.062</td>
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<td>20</td>
<td>0.0331</td>
<td>0.840</td>
<td>270</td>
<td>0.0021</td>
<td>0.053</td>
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<tr>
<td>25</td>
<td>0.0280</td>
<td>0.710</td>
<td>325</td>
<td>0.0017</td>
<td>0.044</td>
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<tr>
<td>30</td>
<td>0.0232</td>
<td>0.589</td>
<td>400</td>
<td>0.0015</td>
<td>0.037</td>
</tr>
</tbody>
</table>
Laser Particle Size Analysis (LPSA)
# Dry Sieve Analysis vs. LPSA

<table>
<thead>
<tr>
<th>Dry Sieve Analysis</th>
<th>LPSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical separation of particles</td>
<td>Measurement of degree of scatter of laser</td>
</tr>
<tr>
<td>A minimum of ~ 20 gram of sample</td>
<td>&lt; 1 gram of sample</td>
</tr>
<tr>
<td>Particle size down to 37 µm</td>
<td>Particle size over a range of 0.5 µm to 2000 µm</td>
</tr>
<tr>
<td>Measures the second smallest dimension</td>
<td>Estimates the equivalent diameter of sphere of same volume</td>
</tr>
</tbody>
</table>
Differences in PSDs from Sieve and Laser Analyses

SPE 54745
Possible Causes of Differences in PSDs from Sieve and Laser Analyses

• Particle Shape
  – Sieve and LPSA tend to report different sizes for non-spherical particles

• Sample Size
  – LPSA uses < 1 g of sample
    • Representative enough compared to sample size in sieve analysis?

• Clay Content/Type
  – In LPSA, results are sensitive to the fluid used for reactive shales

• Fine Particles
  – In sieve analysis, fine particles can adhere to the surface of larger particles
    • Could this result in crossover of sieve and laser PSDs?
Glass Beads PSD

- Synthetic glass beads
- Perfect spheres
- Particles not too big (< ~ 1 mm)
- Particles not too small (> 32 µm)
- Inert particles (not swelling/reactive, etc.)
Effect of Sampling: Sample Splitter Can Produce Representative LPSA Fraction

PSD of Random LPSA Sample

- Cumulative % Retained
- Particle Size, μm

PSD of Split LPSA Sample

- Cumulative % Retained
- Particle Size, μm

Sample Splitter
Effect of Particle Shape on PDS

Prolate Spheroid

\[ a = b < c \]

LPSA always predicts larger particle size than sieve

Tri-axial Ellipsoid

\[ a < b < c \]

- If \( b < \sqrt{ac} \)
  - LPSA gives a larger size
- If \( b > \sqrt{ac} \)
  - Sieve gives a larger size
- If \( b = \sqrt{ac} \)
  - Sieve and LPSA give the same size
Effect of Particle Shape on PSD

- Prolate Spheroid Particles
- Cylindrical Particles
- Square Pyramid Shape Particles
- Conical Particles
Crossover of PSDs from Dry Sieve and Laser Analyses

Spheroid Particles: Aspect Ratio = 2

Square Pyramid Shape Particles: Aspect Ratio = 0.5

Spheroid + Square Pyramid Shape Particles

6th European Sand Management Forum (Aberdeen, UK) | March 26-27, 2014
PSD of CaCO$_3$ and Silica Particles

PSD of Calcium Carbonate Particles

- Dry Sieve
- LPSA

PSD of Silica Particles

- Dry Sieve
- LPSA

PSD of Calcium Carbonate and Silica Particles

- Dry Sieve
- LPSA
Large Difference between Dry Sieve and Laser Analyses in 200 to 400 microns

PSD of Calcium Carbonate, Larger Silica and Smaller (< 62 μm) Silica Particles

Cumulative % Retained

Particle Size, μm

- Dry Sieve
- LPSA
- Slot Size (250 μm)
Estimated vs. Measured PSDs of Mixture of CaCO3, Larger Silica and Smaller (< 62 microns) Silica Particles

Dry Sieve

LPSA

Cumulative % Retained

Particle Size, μm

1. Calculated
2. Measured

Cumulative % Retained

Particle Size, μm

1. Calculated
2. Measured
## Sand Retention Test: Slurry vs. Prepack Test

<table>
<thead>
<tr>
<th></th>
<th>Slurry Test</th>
<th>Prepack Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulates</td>
<td>Gradual Failure</td>
<td>Hole Collapse</td>
</tr>
<tr>
<td>Concentration</td>
<td>Low (&lt; 1%)</td>
<td>High (~ 50%)</td>
</tr>
<tr>
<td>Pack Forms</td>
<td>During Test</td>
<td>Start of Test</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Size Exclusion Only</td>
<td>Size Exclusion + Bridging</td>
</tr>
</tbody>
</table>

- Started with Slurry Test
  - Analytical model for sand production prediction
  - Laminar flow
  - Anticipate sieve analysis to give a more relevant result
### Estimated vs. Experimental Sand Production at 250 μm WWS

<table>
<thead>
<tr>
<th>PSD</th>
<th>Experimental Sand Production (lb/ft²)</th>
<th>Estimated Sand Production (lb/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spherical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Square Pyramid</td>
</tr>
<tr>
<td></td>
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<td>Conical</td>
</tr>
<tr>
<td>Sieve</td>
<td></td>
<td>0.210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.187</td>
</tr>
<tr>
<td></td>
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<td>0.147</td>
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<tr>
<td>LPSA</td>
<td>0.172</td>
<td>0.027</td>
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<tr>
<td></td>
<td>0.030</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Average Aspect Ratio = 1.39
Methodology of PSD Analysis: Slurry Test

Observe Under the Microscope

Particle Shape, Particle Size Range, Mineralogy

Preferred Technique: Sieve Analysis

Not Enough Sample & Good Sphericity

Dry Sieve PSD

LPSA PSD

Aspect Ratio

LPSA Fluid

Mineralogy

Dynamic Image Analysis

Simulation Model

Estimated Sand Production

X-Ray Diffraction

Simulation Model

Estimated Sand Production
Conclusions

• Possible causes for differences in PSDs from dry sieve and laser analyses
  – Aspherical shape
    • Crossover can occur strictly due to the shape of the particles
  – Particle sampling
  – LPSA fluid, different obscuration levels in LPSA, etc.
    • PSD crossover can be explained by reasons other than particle sticking
• For slurry tests, dry sieve is the relevant technique for PSD
• For prepack tests, more work needs to be done
• Initial evaluation of particle shape, size range and mineralogy using microscope is recommended before dry sieve or laser measurements
Thanks!
Questions?