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Lost Circulation, an Old Challenge in need of New Solutions!

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Technology Manager, Wellbore Services
Agenda

• Overview & Significance of Lost Circulation
• Solutions to Various Lost Circulation Scenarios
• Lost Circulation Solutions Design & Planning
• Laboratory Performance Testing
• Novel Approaches
Overview

- Lost Circulation: the loss of whole fluid into a subterranean rock while drilling, cementing, completing or running tubulars in a well
- Lost Circulation Materials (LCM) are not covered under API 13A standards
- Regional experience and sourcing varies
- LCMs have different HSE profiles depending on size, source and chemistry
The Impact of Lost Circulation

- Loss of Well
- Well Control
- Poor Zonal Isolation
- Formation Damage
- Loss of Formation Evaluation
- Financial Losses
- Non-Productive Time (NPT)
- Added logistics Complexity
- Additional Casing String
- Wellbore Instability
- Tool Plugging
Lost Circulation Scenarios

- Matrix Permeability
- Natural Fractures
- Induced Fractures
- Faults
- Vugs & Caverns
### Classification vs Severity of Loss

<table>
<thead>
<tr>
<th>Type of Loss</th>
<th>Typical Loss Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seepage</td>
<td>10 - 20 bbl/hr</td>
</tr>
<tr>
<td>Partial</td>
<td>20 – 50 bbl/hr</td>
</tr>
<tr>
<td>Severe</td>
<td>50 – 150 bbl/hr</td>
</tr>
<tr>
<td>Total</td>
<td>&gt; 150 bbl/hr</td>
</tr>
</tbody>
</table>

- **Natural Fracture**
- **Induced Fracture**
- **Matrix Por/Per**
- **Mud Losses**
Lost Circulation Material Classification

Type

- Fibers
- Flakes
- Granules
- Settable Fluids
Granular Lost Circulation Material Lifecycle

- Raw Material
- Grinding
- Sizing
- Mixing
- Pumping
- Sealing
## Typical Lost Circulation Solutions

<table>
<thead>
<tr>
<th>Matrix Permeability</th>
<th>Fluid Engineering</th>
<th>Particulate Based</th>
<th>Chemical Based</th>
<th>Well Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Fractures</td>
<td>Low Equivalent Circulating Density Fluids</td>
<td>Plugging</td>
<td>Thixotropic Fluids</td>
<td>Drilling &amp; Tripping Practices</td>
</tr>
<tr>
<td>Induced Fractures</td>
<td>Hydraulics Modeling</td>
<td>Sealing</td>
<td>Settable Fluids</td>
<td>Managed Pressure Drilling, Casing Drilling, etc.</td>
</tr>
<tr>
<td>Faults</td>
<td></td>
<td>Bridging</td>
<td>Swellable Additives</td>
<td>Geo-Steering</td>
</tr>
<tr>
<td>Vugs &amp; Caverns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lost Circulation Prevention Planning

• Prevention
  • Low ECD Fluids
  • Hydraulics Modeling
  • Drilling Practices
• Mitigation
  • Induced fracture
    • Fit to Aperture Size
  • Natural Fractures
    • Fit to loss rate

Solution Development
• Material Type
• Concentration Limits
• Treatment Type

Validation
• Lab Tests
• QA/QC
• Plan Development

Execution
• ECD Management
• LCM Deployment
• Degradation Effects
• Tool Limitations
## Theories & Assumptions

### Diverse Views

<table>
<thead>
<tr>
<th>Method</th>
<th>Material Type Important?</th>
<th>Material Size Important?</th>
<th>Rock Stress</th>
<th>Location of Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress Cage (2004)</td>
<td>Yes</td>
<td>Yes</td>
<td>Increases</td>
<td></td>
</tr>
<tr>
<td>Fracture Closure Stress (2005)</td>
<td>No</td>
<td>No</td>
<td>Increases</td>
<td></td>
</tr>
<tr>
<td>Fracture Propagation Resistance (2009)</td>
<td>Yes</td>
<td>Yes</td>
<td>Not Changing</td>
<td></td>
</tr>
</tbody>
</table>
From Theory to Practice

Fracture Width Prediction – Albery (SPE-180296)

Fracture Width

Distance from wellbore wall (in)

Fracture width (mm)

Y (mm)  Analytical

Courtesy of TUDRP
Fluid Performance & Modeling

Safety Margins Breached
Test Equipment & Results

Unidirectional flow
Radial flow
Radial flow/Tri-axial stress
# WBS Application – Decision Matrix

<table>
<thead>
<tr>
<th>Loss Rate</th>
<th>50-100 bbl/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Mechanism</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Loss Zone</td>
<td>Known</td>
</tr>
<tr>
<td>Carrier Fluids</td>
<td>Base Oil/Water/Drilling Fluid</td>
</tr>
<tr>
<td>Bypass Sub / Through Bit</td>
<td>(verify with downhole tools provider)</td>
</tr>
<tr>
<td>Product Treatment Level (lb/bbl)</td>
<td>Product A 14 ppb Product B 16 ppb Product C 20 ppb</td>
</tr>
<tr>
<td>Application Method</td>
<td>Spot Pill</td>
</tr>
<tr>
<td>Placement Method</td>
<td>Pump then pull</td>
</tr>
</tbody>
</table>
What about Current Industry Trends?

Cost Discipline
- Drill “Advantaged Oil” Fields
- Leverage Commodity Market
- Reduce R&D Spending

Data Science
- Transform Operations
- Drive Efficiencies
- Minimize Risk
- Optimize Production & Reserves

ESG Awareness
- Geo-thermal
- Department of Energy
- More Regulations
- Sustainable Products
Novel Approaches

- Shape factor/blending algorithm
- Data Science Tools
- Novel Chemistries

Novel Blending Algorithms

• Current models assume spherical particle for simplicity in calculations
• There are numerous shape factors that come in play (Sphericity, Aspect Ratio)
• Computational Fluid Dynamics (CFD) can address these issues
Data Science Applications

- Data Gathering
- Data Analysis
- Model Development
- Predictive Algorithms
- Artificial Neural Networks

Pre-predictive models
- Success: 71%
- Fail: 29%

Post Predictive models
- Success: 92%
- Fail: 8%

Blue = Success
Red = Failure
Novel Chemistries

– Settable Water-Based Fluids
  • Polysaccharides
  • Di-valent Mixed Metal Oxide

– Settable Non-Aqueous Fluids
  • Expandable Silicates
  • Geo-Polymers

– Novel Solutions
  • Eutectic Metals
  • Shape Memory Polymers
  • Nano-technology based additives
Summary

• The Future
  – Collaboration is key to success
  – Data Science can have a significant impact on predicting losses
  – Novel chemistries offer new solutions where particles application are limited due to size
  – Lost Circulation should be explored as an opportunity to inject cuttings and fluids to subsurface formation within the regulatory and engineering limits.
Additional Resources

Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation
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