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Distinguished Lecturer Program
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Lost Circulation- A Challenge We Must Address

Salim Taoutaou

Schlumberger
Agenda

- Lost circulation definition
- Lost circulation risk identification
- Prevention and Mitigation
- Case Histories
- Ongoing Research
- Conclusion
The impact of Lost Circulation

- Lost circulation occurs in 25% of wells* worldwide
- Costly and time consuming
- Global footprint
- Impact on downhole Well Integrity and production

## Type of Losses

<table>
<thead>
<tr>
<th>Seepage</th>
<th>Partial</th>
<th>Severe</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconsolidated Sand Sandstone, Silt formation</td>
<td>High permeable zones, small natural fractures; induced fractures</td>
<td>High unconsolidated zones, large natural fractures; induced fractures &amp; vugs</td>
<td>High unconsolidated zones, large natural fractures; induced fractures &amp; vugs</td>
</tr>
<tr>
<td>Loss Rate &lt;10bbl/hr</td>
<td>Loss Rate 10-200bbl/hr</td>
<td>200-500bbl/hr</td>
<td>500 bbl/hr</td>
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</tbody>
</table>

- **Induced losses**: due to drilling practices (surge & swab) downhole conditions (depletion)
- **Natural fractures**: pre-existing fractures (carbonates)
Consequences of Loss Circulation

Drilling & Completion

- Mud loss to the formation
- Operational concerns
- Lost time and Money
- Compromise of well working envelop
- Reservoir damage

Well Integrity & Production

- Isolation not achieved
- Casing protection
- Remedial work
- Environmental impact (fluid migration)
- Production impairment
Lost Circulation in Numbers... An Example

- 37 wells drilled
- Loss of 6700 bbl of mud/well—250,000 bbl mud
- USD 29 million in mud cost
- USD 6 million in rig-time cost
- Average cost USD 940,000/well

A real waste of money!
Addressing Lost Circulation

- While drilling
- Casing running
- While cementing
- Post-cement placement

Prevention vs. Mitigation!
## Addressing the Lost Circulation

### Prevention vs. Mitigation!

<table>
<thead>
<tr>
<th>Losses</th>
<th>Prevention</th>
<th>Mitigation</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Drilling</td>
<td>Casing Running</td>
</tr>
<tr>
<td>Induced</td>
<td>Managed pressure Drilling/Cementing</td>
<td>Special tools to manage Surge and swab (Auto fill up equipment)</td>
</tr>
<tr>
<td></td>
<td>Casing while Drilling</td>
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<tr>
<td></td>
<td>Solid Expandable Tubulars</td>
<td></td>
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<tr>
<td>Natural Fractures</td>
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</tbody>
</table>
Prevention - Managed Pressure Drilling & Cementing

- Control annular pressure profile
- Control of surface backpressure
- Avoid influx and Loss Circulation

IPTC-17749-MS
Prevention- Casing While Drilling

- Simultaneously drilling and casing the well
- Vertical and directional wells
- Helps reduce the mud losses
Prevention - Expandable Tubulars

- Liner ran, cemented and expanded mechanically
- Temporary solution to cover the troublesome zone
- Cement testing considerations
Lost Circulation Characterization

Real Time Surface Data
- Weight-On-Bit (WOB)
- Pump Pressure
- Rotary Torque
- Flow-in/Flow-out Rate
- Depth Sensor
- Tank level
- Cuttings & Lithology

Real Time Downhole Data
- Annular Pressure While Drilling
- Formation resistivity
- Natural Gamma Ray
- Wellbore image
- Ultrasonic caliper
- Sonic
- Photoelectric Factor

Characterization

Decision tree

Models/Software
Lost Circulation Characterization

Lost Circulation Decision Tree

- **Seepage** (to 9.5 bbl/hr)
  - Drill ahead adding LCM
  - Pump LCM pill
  - Drill ahead if wellbore integrity is reestablished

- **Partial** (9.5 to 63 bbl/hr)
  - Reduce rheology and circulating rate (reduce ECD)
  - Treat losses
  - Pump plug-and-seal additive

- **Severe** (>63 bbl/hr)
  - Stop drilling
  - Check for static losses
  - Pump plug-and-seal additive

- **No returns** (dynamic)
  - Stop drilling
  - Discuss options with offsite experts
  - Pump LCM pill
  - Static losses
  - Run contingency liner casing

- **Static**
  - No returns: Drill ahead only with approval and only to find a competent casing seat
<table>
<thead>
<tr>
<th>Year</th>
<th>Dyke</th>
<th>Verga et al</th>
<th>Majidi</th>
<th>Lavrov</th>
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</thead>
<tbody>
<tr>
<td>1996-97</td>
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<tr>
<td>2013</td>
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</tbody>
</table>

**Lietard/Sanfillippo**
- Bingham Plastic, model based on Darcy’s law, constant aperture
- Newtonian Fluids in non-deformable fracture, constant aperture, impermeable walls

**Lavrov & Tronvoll**
- Mud loss into a single isolated deformable fracture
- Fracture opening/closing
- Power Law Fluids

**Shahri**
- Effect of Natural Fracture geometry on fluid loss
- Yield Power Law/Herchel Bulkley

SPE 25022; 63266; 103564; 114630; 168123
New Generation Models

- Qualification: identify Loss Type and Loss Location using Surface Data
- Quantification: identify Natural Fractures attributes (aperture, number and spacing) based on primarily Mud Loss Data
- Placement: recommendation on the most suitable treatment.
New Generation Models - Example

Diagnostic and Characterization Results

Recommended Treatment
Laboratory Qualification

Plugging Efficiency Test Result

- Differential Pressure (psi)
- Filtrate Volume (ml)

Time (minutes):
- 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Differential Pressure (psi):
- 0 50 100 150 200 250 300 350 400 450 500

Filtrate Volume (ml):
- 0 50 100 150 200 250 300 350 400 450 500
Solutions-Plugging mechanism

Leaf effect

- LCM is deposited at the mouth of the fracture
- Temporarily stops the losses

Wedging effect (stress caging)

- Different particle size distribution to reach the fracture tip
- Strengthens wellbore by redistributing the hoop stress

High Permeability

Block fracture with mud solids

Block fracture with sized particles

Increase the hoop stress
Mitigation- Fluids

- **Time activated**
  - Lost circulations gels

- **Temperature activated**
  - Acid soluble cement
  - Fibrous cellulose, crosslinking agents, and fibrous LC materials

- **Pressure activated**
  - Emulsion

- **Inert bridging material (Granular, Flaked, Fibrous)**
  - Fibers LC materials
  - Sized particulates
Engineered Treatment

- Engineered Treatment based on the characterization results
- Inert materials used in Treatment
- Solid package - any, available on the rig
- Can be pumped through the drilling assembly
- Compatible with the drilling and cementing fluids
Case History 1: Induced Fractures

Challenges

- Induced losses due to depletion
- 250-400 well drilled per year
- 2% success & 75 hours NPT
- Remedial jobs with Workover rig

Solution

- In depth Characterization
- 100bbls of Engineered treatment

Results

- Improved success rate 62%
- More than 48 wells treated
Case History 2: Natural Fractures

Challenge

- While drilling 8 ½” OH losses 150 bbl/hr at 17,448ft in a fractured limestone formation
- Drilling was stalled for 7 days total losses
- Conventional LCM solutions unsuccessful

Solution

- 70 bbl of 12.5 lbm/gal Engineered pill based on diagnostics/Characterization model
- Pill pumped through a side sub
Case History 2: Natural Fractures

Results

- Complete returns were observed
- Applied Squeeze pressure equivalent to the ECD expected during the drilling
- Section drilled to final depth without losses

<table>
<thead>
<tr>
<th>Well</th>
<th>Depth (ft)</th>
<th>Loss rate before treatment bbl/hr</th>
<th>Pill volume (bbl)</th>
<th>Loss rate after treatment bbl/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16448</td>
<td>150</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>16521</td>
<td>100</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>7875</td>
<td>Total</td>
<td>90</td>
<td>5</td>
</tr>
</tbody>
</table>

JOBS PERFORMED DURING DRILLING
A Glimpse at the future-
Ongoing Research

- Extensive experimental work has shown that filtercake blocks mouth of growing fracture,
- Filtercake prevents flow of wellbore fluid into fracture and inhibits hydraulic fracture growth
- Filtercake is self-healing, always present and easy to characterize

Patent EP 16305237.5; US patent 8215155; SPE 178799
Ongoing Research - Drilling Fluids

Fractures at around 10.4 MPa (1095 sec), 50% higher than A.

Effect of filtercake strength
Patent EP 16305237.5; US patent 8215155; SPE 178799

EFFECT OF CAKE THICKNESS
Borehole pressure v. pumping time for two small block tests using oil-based mud in sandstone
Ongoing Research-Cementing

- 71 well sections from four offshore areas
- 40 well sections with losses
- Losses occurrence & At what stage of well construction
90% of loss events initiated while running casing/liner or during pre-job circulation

Only 5% of losses initiated during cementing despite higher cementing ECD’s

If losses were severe or total, the cement reduced the loss rate in more than 50% of the cases

Cement was not able to reduce the loss rate when losses were partial or seepage
Conclusion

- Lost circulation is detrimental for the life of the well
- Use Managed Pressure Drilling, Casing While Drilling and Solid Expandable Tubulars to prevent the losses
- Use characterization software and engineered lost circulation treatments to mitigate the losses
- Continue research and collaboration efforts to bring better, easier and faster solutions
Your Feedback is Important

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