Primary funding is provided by

The SPE Foundation through member donations and a contribution from Offshore Europe

The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME

Society of Petroleum Engineers
Distinguished Lecturer Program
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How to Stabilize and Strengthen the Wellbore during Drilling Operations

Dr. Fred Growcock

Society of Petroleum Engineers
Distinguished Lecturer Program
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Presentation Outline

- The Lost Circulation Problem
- Strategy for Managing Lost Circulation
- Wellbore Strengthening
- Wellbore Stress Enhancement
- Application Strategies on the Rig
- Case History
- Summary
The Lost Circulation Problem: High-Risk Operations

Pressure Gradient / Mud Density

- Stable Wellbore
- Fractured Wellbore
- Collapsed Wellbore
- Depleted Zones
- Deep Water

Deviated Wellbores
The Lost Circulation Problem

- Estimated industry cost in the Gulf of Mexico: $1 billion/yr. Worldwide: ~ $2 to 4 billion/yr.
- On average, 10-20% of the total cost of drilling an HTHP well is expended on mud losses (U.S. Department of Energy).
- No consistent approach to manage lost circulation.
- Nearly 200 products offered by 50 drilling fluid companies to control lost circulation.

A comprehensive Lost Circulation mitigation and prevention program is required.
Managing Lost Circulation: A 4-Tiered Strategy

I - Best Drilling Practices

II - Drilling Fluid Selection

III - WSM

IV - LCM

Lost Circulation Materials
Wellbore Strengthening Materials
Tier I. Best Current or New Drilling Practices

- Accurate, precise Geomechanics Model, esp. Pore Pressure / Fracture Gradient
- Minimum and invariant Equivalent Circulating Density (ECD)
  - Accurate hydraulics profile for pre-drilling & at well site
  - Good hole-cleaning practices
  - Optimized solids control equipment
- Managed Pressure Drilling
- Casing While Drilling
- Expandable Casing/Liner
Managing Lost Circulation: A 4-Tiered Strategy

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Lost Circulation Materials

Wellbore Strengthening Materials
Tier II. **Drilling Fluids** which Minimize Losses:

WBM Form Thick, Tight Filter Cakes

WBM:
Full pressure shielded from tip by solids filter cake buildup.

OBM/SBM:
Full pressure at fracture tip.

Based on Morita et al, SPE 20409
Tier II. **Drilling Fluids** which Minimize Losses:

- High **Low-Shear-Rate Viscosity** (LSRV)
  - Reservoir Fluids
  - Underbalanced Fluids
  - Aphron and Mixed Metal Fluids
- **Minimum and Invariant ECD**
  - Soluble or Micronized Weighting Material
  - Temperature-Insensitive Rheology
- **Wellbore Isolation**
  - Silicate, Gilsonite Fluids
Managing Lost Circulation: A 4-Tiered Strategy

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Lost Circulation Materials

Wellbore Strengthening Materials
Tier IV. **LCM** in Pills or Whole Mud

Contingency: losses in high-perm zones/fractures

- Blends of materials of different sizes, shapes and properties;
- Particle size distribution matches distribution of openings in rock;
- Used in squeeze or sweep treatments;
- May be used one time or on regular basis while drilling ahead.
Managing Lost Circulation: A 4-Tiered Strategy

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Wellbore Strengthening Materials

Lost Circulation Materials
**WSM vs LCM**

Lost Circulation Materials - All materials that stop mud loss
Wellbore Strengthening Materials - tough, granular solids or sealants
Strategies for Strengthening the Wellbore

- **Physical**
  - Wellbore Isolation: Swellable or Reactive Materials
  - Fracture Tip Isolation (Fracture Propagation Resistance)
- **Chemical**
  - Decrease clay swelling pressure (inhibitors such as K+ and invert emulsions)
- **Thermal**
  - Increase temp of drilling fluid above bottom-hole static temp: stiff formations, high thermal expansion
- **Mechanical**
  - Fracture Closure Stress
  - Hoop Stress Enhancement (Stress Cage)
Extended Leak-Off Test – only FBP changes

- Leak-Off Pressure (LOP)
- Original Formation Breakdown Pressure (FBP)
- Fracture Propagation Pressure (FPP)
- Fracture Gradient (FG)
- Fracture Closure Pressure (FCP) (= Minimum Horizontal Stress, $S_{hmin}$)

Time or Volume Pumped (constant pump rate)
Fracture Closure Stress

• High-fluid-loss treatment for **existing** fractures
• Applied as high-fluid-loss pills or whole mud treatment (Drill-n-Stress)
• Pill may be water-based in a non-aqueous system
• May follow with cross-linked polymer plugs or cement
Fracture Closure Stress

As existing fracture is widened, particles are forced deep within the fracture.

Liquid leaks from the slurry through the fracture walls or tip.
Fracture Closure Stress

As the slurry deliquifies, it consolidates.

The residual solid plug supports the fracture and isolates the tip.
Hoop Stress Enhancement

• Wellbore is pre-fractured and sealed to prevent subsequent fracturing

• Mathematical models are used to design the WSM: calculate the required fracture width and particle size distribution of WSM

• WSM is added at moderate concentration while drilling (involves solids control management): Continuous addition is much more effective than pills

• The formation is pressured every stand to build hoop stress, or ECD is raised to desired level
Hoop Stress Enhancement

As fracture is widened, large particles are forced in and wedged in the fracture mouth to create bridge.

Smaller particles come in behind the bridge and seal the opening.
Hoop Stress Enhancement

Trapped fluid filters through permeable walls of fracture

The pressure drops and compressive forces are transferred to WSM
Hoop Stress Enhancement Application Cycle

- **Suitability of Treatment**
- **Data Collection**
- **Modeling of Fracture Creation and Filling**

**Output:**
- Fracture dimensions
- Formulation of Loss Prevention Material

- **Lessons Learned**
- **Data Collected & Analyzed**
- **Program Implementation**

**Fluids Program**
- Type of treatment:
  - Pills
  - Continuous
- Handling WSM
- Fluid property management
- Monitoring tools
  - Slot Tester
  - Sieves
- Mud Pump restrictions
- Downhole tools restriction
- Lost circulation contingency
Design of Hoop Stress Enhancement

- **Fracture Width** required to achieve desired wellbore pressure – elastic model:
  - Desired Equiv. Circ. Density, or Wellbore Pressure
  - Rock Properties – Poisson’s Ratio, Young’s Modulus, Minimum Horizontal Stress (or Fracture Gradient)
  - Well Geometry – Depth, Inclination, Hole Size

- Acceptable *types of WSM*

- **WSM particle size distribution (PSD) and concentration**
Acceptable **WSM**

Large, Tough and Granular

- Proprietary Graphitic Blend
- Marble
- Nut Husks
- Ground petroleum coke
- Graphite
- Proprietary Cellulosic Blend
Unacceptable WSM

- bagasse
- flake graphite
- proprietary cellulosic blend
- flake calcium carbonate
- spherical materials cokes, graphites, proppants
- mica
Continuous Addition of **WSM** to whole mud is best

- For short intervals, bypass the shale shakers
- For long intervals, screen out the WSM with the shakers
- **The most effective solution**: an **WSM Recovery System**

Screens out drilled cuttings

**Recovers and recycles WSM**

Screens out fines
Monitoring Hoop Stress Enhancement

• Techniques to be used at the rigsite:
  – Permeability Plugging Tests
  – Wet Sieve Analysis
  – Sand kit determination

• Techniques available at shore bases:
  – Laser Light-Scattering Particle Size Distribution
  – Fracture Sealing and Wellbore Strengthening tests
Case History – Deepwater Gulf of Mexico

Major challenges
- Mud losses…> 15,000 bbl/well on previous wells, especially in intervals below the salt!
- Wellbore stability

Solution
- Strengthen five intervals
  - One above the Salt
  - One in the Salt
  - Three below the Salt
- Shakers dressed with 14/20 mesh screens
- [WSM] ~ 15 to 30 lb/bbl
- WSM Design
  - Sized Marble
  - Granular Synthetic Carbons
Case History – Deepwater Gulf of Mexico

- No losses in 2900 ft sand section above salt
- No losses in 7500 ft salt section, screened up
- No losses in 9200 ft sand section below salt (where majority of losses occurred in offset wells)

Savings
- Total cost for the WSM ~ $0.7 MM. Previous mud losses ~ $2.7 MM. Net savings ~ $2.0 MM on materials alone.
- On subsequent 4 wells, similar net savings of ~ $2.0 MM on materials alone.
The 4-tier strategy for managing lost circulation must be an integral part of well planning.
Your Feedback is Important

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http://www.spe.org/events/dl/dl_evaluation_contest.php