Hole Cleaning in Deviated Wellbores

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Key Topics for Consideration

- Using the right rheological model
- Key parameters for cleaning in vertical wellbores
- Key parameters for cleaning in deviated wellbores
- Drilling practices and hole cleaning
  - Pump rate
  - Rate of penetration (ROP)
  - Drill pipe rotation speed
- Best practices
  - Drilling fluid sweeps
  - Backreaming, tripping practices
  - Hole cleaning and/or wellbore instability?
Major Rheological Models in Oilfield Use Today

- Bingham plastic
- Power law
- **Herschel-Bulkley**
  - Baroid’s standard for hydraulic and hole cleaning calculations since 1994
  - New API 13D Recommended Standard, June, 2006

Herschel-Bulkley Rheological Model

- Governing equation:
  \[ \tau = \tau_0 + K \cdot \gamma^n \]

- Model parameters:
  1) Flow behavior index (n)
  2) Consistency index (K)
  3) Yield stress (\( \tau_0 \))
What Is Yield Stress / Tau Zero?

A shear stress is required to initiate flow.

Herschel-Bulkley Rheological Model Is the ‘Mother’ Model for Pseudoplastic Fluids

Herschel-Bulkley
\[ \tau = \tau_0 + K\gamma^n \]

\( \tau_0 = 0 \)  \( \text{H-B } n = 1 \)

Power law
\[ \tau = K\gamma^n \]

Bingham plastic
\[ \tau = \tau_Y + \mu \gamma \]

The Herschel-Bulkley rheological model fits Bingham plastic fluids, power law fluids, and everything else in between.
Accuracy of 3 Common Industry Rheological Models

![Graph showing shear rate versus dial reading for Measured Points, Herschel-Bulkley, Power Law, and Bingham Plastic models.]

Benefits of Improved Mapping of Low Shear Zone

- Improved accuracy of calculations
  - Pressure drop
  - Hole cleaning efficiency
  - Particle settling velocity
  - Cuttings transport efficiencies
  - Fluid suspension properties
Key Parameters in Hole Cleaning Modeling - Vertical Wells

- Fluid rheological properties
- Pump output
- Hole and pipe geometry
- Mud density
- Particle size and shape
- Rate of penetration (ROP)

Key Parameters in Hole Cleaning Modeling - Deviated Wells

- Fluid rheological properties
- Pump output
- Hole and pipe geometry
- Mud density
- Particle size and shape
- Rate of Penetration (ROP)
- Hole angle
- Drill pipe eccentricity
- Drill pipe rotation
Effect of DP Rotation on Cleaning

- DP rotation mechanically disturbs cuttings beds
- DP rotation increases annular pressure drop
- DP rotation enhances cleaning
- Degree of improvement in cleaning dependent upon annular velocities, hole angle and rpm speed

Effect of AV and DP Rotation on Hole Cleaning

65 degrees deviation, 0.25-in limestone cuttings
Effect of ROP at High Angles

At constant pump rate, DP rpm, etc:

- Increased ROP reduces hole cleaning efficiency
- Cuttings accumulation increases pressure drop increase ECD increase
- Increased bed heights when circulation stopped
- ROPs can be optimized using hydraulics and ECD / standpipe pressure boundaries
Hole Cleaning Best Practices: Drilling Fluid Sweeps

- Best hole cleaning tool is flow rate/velocity
- Sweeps are secondary cleaning tools, not primary tools
- DP rotation enhances sweep performance, but there are limits

Typical Drilling Fluid Sweeps

- Single function sweeps
  - High-density (HD)
  - High-viscosity (HV)
  - Low-viscosity (LV)
- High-density / high-viscosity (HD + HV)
- Tandem (one type followed by another)
- Fiber sweeps
Results of Sweep Study in Deviated Wellbores (2004)

- Numerical method developed to evaluate sweep efficiency
- High-density sweeps most efficient type for high angles
- ECD increases dependent upon quantity of cuttings brought out by sweep
- Up to 3 “bottoms up” intervals needed to remove sweeps from hole
- Sweep volume important to effectiveness of sweep

ECD Changes While Pumping Sweeps (in Units of Bottoms-Up)
Results of Sweep Study in Vertical Wellbores (2010)

- Theoretical modeling used
- Particle sizes up to 0.75-in diameter modeled
- High-density and high-viscosity/high-density mixed together gives best performance
- Moderate- to high-viscosity sweeps have highest particle settling rates
- Fast rotation of drill string while pumping viscous sweeps reduces their effectiveness

Dynamic Settling Velocity vs. Particle Reynolds Number
All Data in Study
Hole Cleaning Best Practices: Drilling High-Angle Wells

- Avoid backreaming as hole cleaning tool
  - Excessive pressures on wellbore wall
  - Damage to filter cake on borehole wall
  - Increases incidents of pack-offs and stuck pipe

- Should be used only as a temporary ‘fix’
  - Repeated use can lead to wellbore instability

Hole Cleaning Best Practices: Wellbore Stability

- Maintain sufficient density while drilling
  - Adequate mud weight (static and dynamic density) to control pore pressures and hole collapse pressures
  - No fracturing of the wellbore
  - Wellbore stability modeling to determine densities vs hole angle and azimuth

- Efficient cleaning of an unstable wellbore nearly impossible task – keep wellbore stable

- At equal cleaning efficiencies, hole cleaning in 1000-ft lateral similar to cleaning in 5,000-ft lateral
Hole Cleaning Key References

- Herschel-Bulkley rheological model solution: O&GJ, August 23, 1993
- SPE 35099 (cleaning in deviated wellbores)
- SPE 37610 (cleaning in ERD wells)
- SPE 71362 (ROP optimization using hydraulics)
- SPE 77448 (sweeps in deviated wellbores)
- SPE 134514 (sweeps in vertical wellbores)

Thank you for your time and attention.

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