

Hole Cleaning in Deviated Wellbores

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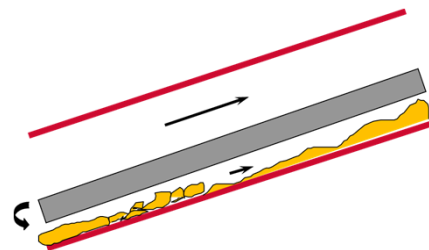
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AADE Fluids Management Group
27 February 2014

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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?



The general scenario

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

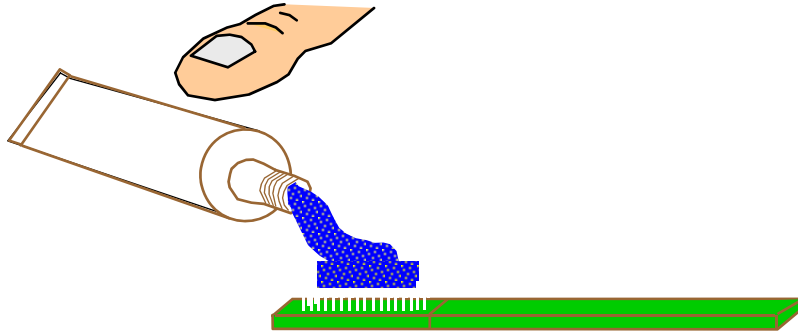
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Herschel-Bulkley Rheological Model

- Governing equation:
$$\tau = \tau_0 + K \cdot \gamma^n$$
- Model parameters:
 - 1) Flow behavior index (n)
 - 2) Consistency index (K)
 - 3) Yield stress (τ_0)

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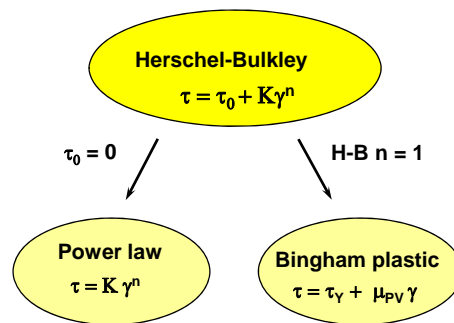
What Is Yield Stress / Tau Zero?



A shear stress is required to initiate flow.

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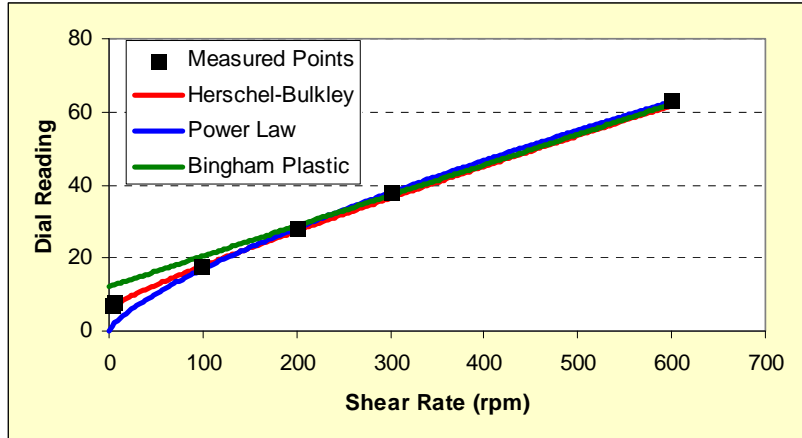
Herschel-Bulkley Rheological Model Is the ‘Mother’ Model for Pseudoplastic Fluids



The Herschel-Bulkley rheological model fits Bingham plastic fluids, power law fluids, and everything else in between.

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Accuracy of 3 Common Industry Rheological Models

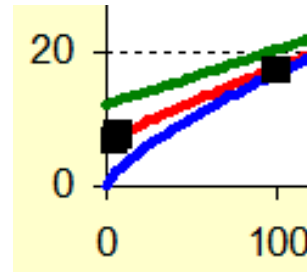


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Benefits of Improved Mapping of Low Shear Zone

Improved accuracy of calculations

- Pressure drop
- Hole cleaning efficiency
- Particle settling velocity
- Cuttings transport efficiencies
- Fluid suspension properties



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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)

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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

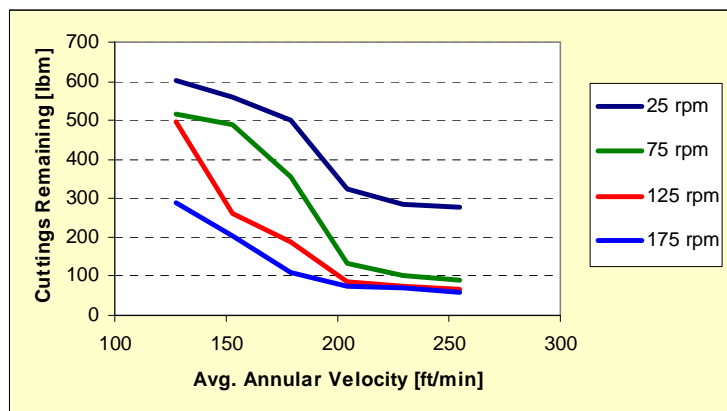
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Effect of DP Rotation on Cleaning

- 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

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Effect of AV and DP Rotation on Hole Cleaning Data ex-Tulsa Univ. Flow Loop (1995)



65 degrees deviation, 0.25-in limestone cuttings

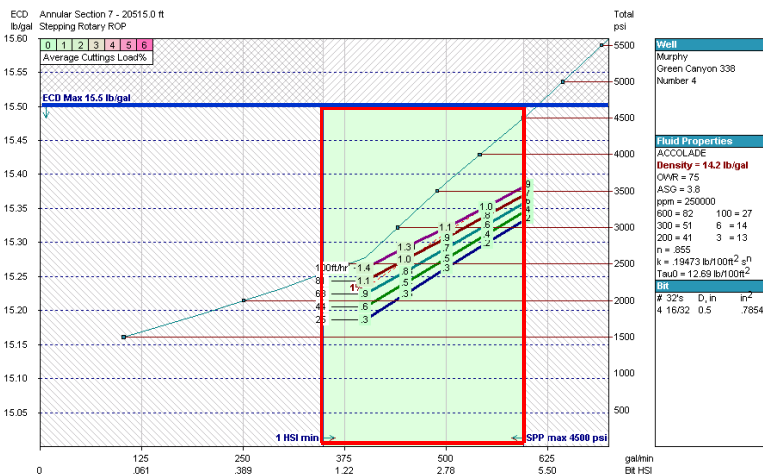
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Effect of ROP at High Angles

At constant pump rate, DP rpm, etc:

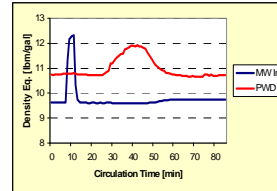
- Increased ROP reduces hole cleaning efficiency
- Cuttings accumulation increases → pressure drop increase → ECD increase
- Increased bed heights when circulation stopped
- ROPs can be optimized using hydraulics and ECD / standpipe pressure boundaries

ROP Optimization Using Hydraulics and SPP



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



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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

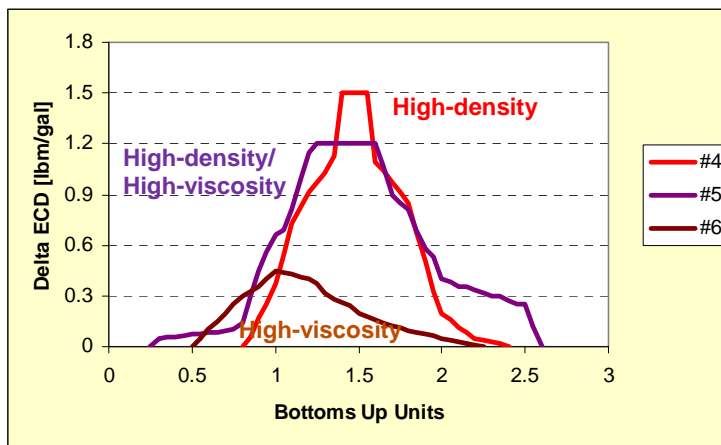
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Results of Sweep Study in Deviated Wellbores (2004)

- 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

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ECD Changes While Pumping Sweeps (in Units of Bottoms-Up)



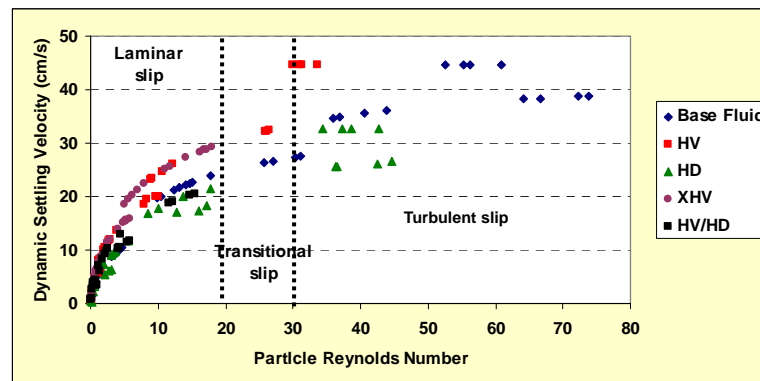
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Results of Sweep Study in Vertical Wellbores (2010)

- 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

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Dynamic Settling Velocity vs. Particle Reynolds Number All Data in Study



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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

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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

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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)

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Thank you for your time and attention.

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