SPE Workshop

Extended Reach and Horizontal Wells – Challenges and Solutions

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Keys to Proper Application of MSE in Horizontal/ER Wells

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Outline

• MSE Refresher
  – History
  – What it tells us
• Mechanics of Torque Generation
• Implications for Horizontal / ERD Wells
• Case Study Example
What is Mechanical Specific Energy (MSE)?

- Measure of energy used to destroy rock
- For a known rock strength, efficiency can be inferred

\[ MSE = \frac{WOB}{A_B} + \frac{120 \times \pi \times RPM \times T}{A_B \times ROP} \]

Origins?

- Developed by Teale in 1965 (Int. J. Rock Mech. Mining Sci. Vo.2)
- Evolved / validated by Pessier in the 1992 (SPE 24584)
- Applied by Waughman in 2002 (SPE 74520)
- Popularized by Dupriest in the 2005 (SPE 92194)

Why use MSE?

- **While Drilling:** Optimize parameters for maximum performance
- **While Planning:** Identify performance bottlenecks
MSE, ERD, and other TLAs

What we are talking about today…

ERD Plot

MSE's Early Use / Proof of Concept
MSE Refresher

• Increasing trends may indicate a problem
  – Lateral Vibration
  – Balling
  – Bit Damage / Dulling

• Experimenting from one well to another reveals improvements
  – Better designs result in lower and/or more consistent MSE
The Problem with Surface Torque

- Torque is the most dangerous variable in the MSE equation
  - Need to know torque near bit (not at surface)
  - Surface torque is mostly due to drill string friction in ER wells
Drill String Generated Torque

• Torque = N × μ × R_{eff}

• Normal Force (N) can be generated in 4 ways
  1. “Low Side” – Gravity pulling pipe to the low side of the hole
  2. “Brake Drum” – Tension across a dogleg forces pipe into the side of the hole
  3. Buckling – Forces the pipe into the sides of the hole as compression increases
  4. Lateral Vibration

• Mechanisms 1-3 can be easily predicted-modeled
• Mechanism 4 can be inferred
<table>
<thead>
<tr>
<th>Method</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>On Bottom Torque</td>
<td>Easy</td>
<td>Wrong. Leads to over-estimated MSE and apparent dulling trend. Can’t compare MSE for wells with different trajectories</td>
</tr>
<tr>
<td>On Bottom – Off Bottom</td>
<td>Fairly Easy</td>
<td>Wrong, may lead to over or under estimation of MSE. Can’t compare MSE for wells with different trajectories</td>
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<tr>
<td>Motor ΔP</td>
<td>Fairly easy.</td>
<td>Need a motor in the hole. Actual performance vs. handbook varies and degrades with time.</td>
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<tr>
<td>Down hole WOB/Torque</td>
<td>Can be accurate and close to the bit.</td>
<td>Measurements can drift if not frequently calibrated. By itself, can not differentiate between bit dysfunction and lower BHA dysfunction.</td>
</tr>
<tr>
<td>Calculate using T&amp;D Engine</td>
<td>Accurate (if surface measurements are good). Can compare wells of different trajectories. Can reveal certain phenomenon* when combined with other methods</td>
<td>Complicated. Need special procedures, software, and resources.</td>
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* For example, when used with ΔP can identify bit balling. When used with DWOB/DTOR placed below an under reamer can differentiate between bit/reamer dysfunction.
How to Infer Bit Torque

1. Record off bottom torque each stand at drilling
2. Back-calculate the TQFF using T&D Model
3. Calculate the string-generated torque at each data point;
   – Actual surveys
   – Current WOB
   – Most recent TQFF
4. “Down hole” torque is the difference between surface torque and string-generated torque

* Can verify with DWOB/DTOR sensors or motor ΔP
Consider this ER well

- Very long (>22,000’) and shallow (<4,000’)
- Tapered 5”x4½” drill string
- Highly variable WOB, Torque, RPM, ROP
- T&D engine used to normalize string generated torque and attempt to estimated bit torque
Concept Validation

Formation CCS: 2-4 ksi

Conventional Interpretation:
• MSE is increasing, bit may be dulling
• Shift at 20,500’ – Whirl?

“Inferred Downhole Torque” Interpretation:
• MSE and torque are fairly constant
• MSE is similar to CCS
• Everything is normal

Down hole measurements agree with calculated torque

- Reduce ROP from 300-150 ft/hr (for logging)
Summary

1. MSE is a great tool when used properly
2. Directional wells skew MSE results / interpretation
3. Modeling should be used to remove string torque
4. Combining inferred down hole MSE from different sources can reveal interesting phenomenon
Backup Slides
Cumulative Savings: >400 days and >$30MM
Consider These 3 Wells:

- Deep KOP Horizontal (12°/100’ BUR)
- Shallow KOP B&H (3°/100’)
- Complex Horizontal (3°/100’ BUR’s)

All Configured with:

- 20,000’ Long
- 5” drill pipe
- 10.0 ppg MW
- 40 kips WOB
All wells with 0 WOB:
Each has a different off-bottom torque trend

Horizontal well with 40 kips WOB
String torque is 4 k ft-lbs (28%) higher

B&H well with 40 kips WOB
String torque is 3 k ft-lbs (10%) lower

Complex well with 40 kips WOB
String torque is 1 k ft-lbs (4%) higher
Wellpath Effects

S-Path Well in Colorado

- **Surface MSE** trend had been fairly constant to 11,600’ MD
- Increasing trend below 11,600’ suggests dulling trend
- Operator pulls bit, but is “green” at surface
- Why...?

**Down hole MSE** trend (accounting for string torque) shows everything was “business as usual” (improving, if anything).