T&D Implications of Using MSE in Horizontal/ERD Wells
Brandon M. Foster

IADC DCTZ Conference
Galveston, TX October 23-25th
Outline

• MSE Refresher
  – History
  – What it tells us
• Mechanics of Torque Generation
• Implications on Horizontal / ERD Wells
• Case Study Example
MSE Refresher

• 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?
  – 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:** Trends can reveal problems down hole
  – **While Planning:** Can pinpoint what is bottlenecking performance
• Increasing trends may indicate a problem
  – Lateral Vibration
  – Balling
  – Bit Damage / Dulling

• Experimenting from one well to another should reveal improvements
  – Better designs should result in lower and/or more consistent MSE
• Torque is the most important (and dangerous) variable in the MSE equation
  – Need to know torque at (or near) the cutting surface (bit and/or reamer)
  – We usually only measure torque at surface
  – Most surface torque is due to drill string friction
  – Simply subtracting “off-bottom” from “on-bottom” isn’t good enough

Looks green to me...

“But the MSE trend told me we needed to trip…”
The Simple Physics of Torque

• Torque = N x μ x 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 and modeled
• Mechanism 4 can be inferred (in the absence of measurement)
Bit Torque: Not What it Looks Like...

- On-Bottom Torque
- Off-Bottom Torque
- “Perceived” Bit Torque
- Actual Bit Torque
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
Well Path Effects

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
...Which Fouls Interpretation

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).
## Bit Torque Inference Options

<table>
<thead>
<tr>
<th>Method</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<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>
</tr>
<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>
</tr>
<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>
</tr>
</tbody>
</table>

* For example, when used with DP 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 on every stand at drilling RPM/flow
2. Back-calculate the torque friction factor
3. Recalculate the string-generated torque at every d-point using;
   – Actual surveys
   – Current WOB
   – Current TQFF
4. “Down hole” torque* is the difference between surface torque and string-generated torque
   * Can verify/cross check with DWOB/DTOR sensors or motor ΔP
Validation: Extreme ERD Well

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
Does The Technique Work?

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
   – Must remove the string generated torque component
3. T&D modeling should be used to remove string torque
   – Doing so produces a much more accurate estimate of down hole MSE
   – The next bottleneck is surface measurement accuracy
4. Combining inferred down hole MSE from different sources can reveal interesting phenomenon