MSE: A Valuable Trending Tool for Drillers and Engineers

Overview
Mechanical Specific Energy (MSE) is not a new idea: both the original concept and formula were introduced by R. Teale in 1964. MSE is defined as the amount of energy required per unit volume of rock drilled. The Pason Electronic Drilling Recorder (EDR) uses drilling data collected from the rig to calculate an MSE value in ksi (kilo-pound force per square inch) units. Users can also set up an alarmed MSE trace in the EDR. Once set up, the drilling engineer, driller, or geologist can analyze MSE trends to identify possible drilling inefficiencies and make adjustments to drilling parameters. In the hands of qualified analysts, a properly set up MSE trace is a powerful trending tool.

Why MSE is Valuable
MSE is valuable because it helps identify inefficiencies in the drilling process. Drillers should strive to keep MSE as low as possible and Rate Of Penetration (ROP) as high as possible, by varying Weight On Bit (WOB), rotary speed, and mud flow within normal operating limits. Drilling engineers want to hold MSE as close as possible to a formation’s true compressive strength. Unexpected changes in MSE may indicate changes in rock properties, or drilling inefficiency, or both.

In an ideal drilling process, there is a 1:1 relationship between input energy and a formation’s true compressive strength. However, this 1:1 relationship does not hold for comparisons to Unconfined Compressive Strength (UCS), due to the impact of hydrostatic pressure from the mud column at depth.

Actual versus Relative MSE
The Pason EDR offers a choice of two MSE traces: actual MSE and relative MSE (rMSE). The actual MSE trace requires that users enter values and perform calibrations, but produces a very accurate trace. Conversely, the relative MSE trace requires fewer user inputs, but produces a much less accurate trace. rMSE trends can still be used to optimize drilling operations, but these trends cannot be compared to a formation’s compressive strength the way an MSE trend can.

Informed Drilling with MSE
Analysis of MSE can help to:
- Recognize dull or damaged bits
- Select an appropriate bit for a rock type
- Select an appropriate WOB for a bit and rock type
- Select an appropriate RPM for a bit and rock type
- Adjust to avoid poor mud circulation
Using MSE

The MSE calculation depends on torque, RPM, hole diameter, ROP, and WOB. Also, if a mud motor is used, the speed-to-flow ratio, maximum-rated torque, and maximum-rated differential pressure are required as inputs. For actual MSE to be used, one of the following two conditions must be met:

1. The Pason torque trace must be set up in real torque units (N-m or ft lbs),
2. A mud motor must be in use with values entered for maximum-rated torque and differential pressure.

If torque can’t be accurately calibrated in real units, or if only the speed-to-flow ratio is known for the mud motor, then only relative MSE is available. In either case, the MSE value produced is only as good as the calibration of the inputs.

Pason’s MSE Formulae

The Pason EDR, versions 3.4.x and higher, uses these formulae to calculate MSE:

When torque is calibrated, and a mud motor is not in use (Canada):

\[
MSE = \left[ \frac{40,000 \cdot WOB}{\pi D^2} + \frac{480,000}{D^2} \cdot \frac{N \cdot T}{ROP} \right] \times 0.14504
\]

When a mud motor is in use (Canada):

\[
MSE[ksi] = \left[ \frac{40,000 \cdot WOB}{\pi D^2} + \frac{480,000}{D^2} \cdot \left( N + K_N \cdot Q \cdot 1000 \right) \cdot \left( \frac{T_{MAX}}{\Delta P_{MAX}} \right) \cdot \frac{\Delta P / 1000}{ROP} \right] \times 0.14504
\]

When torque is calibrated, and a mud motor is not in use (US):

\[
MSE = \frac{4 \cdot WOB}{\pi D^2} + \frac{480 \cdot N \cdot T}{D^2} \cdot \frac{ROP}{ROP}
\]

When a mud motor is in use (US):

\[
MSE[ksi] = \frac{4 \cdot WOB}{\pi D^2} + \frac{480 \left( N + K_N \cdot Q \right) \cdot \left( \frac{T_{MAX}}{\Delta P_{MAX}} \right) \cdot \frac{\Delta P / 1000}{ROP}}{ROP}
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>CDN EDR</th>
<th>US EDR</th>
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<tbody>
<tr>
<td>MSE</td>
<td>Mechanical specific energy</td>
<td>ksi</td>
<td>ksi</td>
</tr>
<tr>
<td>WOB</td>
<td>Weight on bit</td>
<td>kdaN</td>
<td>klbs</td>
</tr>
<tr>
<td>D</td>
<td>Bit diameter</td>
<td>mm</td>
<td>inches</td>
</tr>
<tr>
<td>N</td>
<td>Rotary speed</td>
<td>RPM</td>
<td>RPM</td>
</tr>
<tr>
<td>T</td>
<td>Rotary torque (units may be different)</td>
<td>kN-m</td>
<td>kFT-lb</td>
</tr>
<tr>
<td>ROP</td>
<td>Rate of penetration</td>
<td>m/hr</td>
<td>ft/hr</td>
</tr>
<tr>
<td>K_N</td>
<td>Mud motor speed to flow ratio</td>
<td>rev/L</td>
<td>rev/gal</td>
</tr>
<tr>
<td>Q</td>
<td>Total mud flow rate</td>
<td>m³/min</td>
<td>gal/min</td>
</tr>
<tr>
<td>T_{MAX}</td>
<td>Mud motor maximum-rated torque</td>
<td>N-m</td>
<td>ft-lb</td>
</tr>
<tr>
<td>ΔP_{MAX}</td>
<td>Mud motor maximum-rated differential pressure</td>
<td>kPa</td>
<td>psi</td>
</tr>
<tr>
<td>ΔP</td>
<td>Differential pressure</td>
<td>kPa</td>
<td>psi</td>
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Summary
The Pason EDR can calculate either actual or relative MSE, as well as display MSE as an alarmed trace. By doing so, Pason provides drilling engineers with a powerful trending tool to help evaluate the efficiency of the drilling process.

For More Information
For more information about MSE in the US, please contact USSalesReps@pason.com. In Canada, please contact CSales@pason.com.