MSE Standardization and Emerging Applications

Ad Hoc MSE Standardization Committee
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SPE/GCS Drilling Study Group
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Post-Presentation Clarification: The equations recommended in this presentation may already be loaded in your EDR vendor's pick list. But they may not have these names. You'll need to ask what their equivalent is to $MSE_{Downhole}$ and MSE_{Total}. If they don't have them. Most EDR vendors will allow you to write your own equations and display the curves on your own rigs.

Problems with Nomenclature <u>and</u> Equations

Example of names the driller must pick from in Electronic Data Recorders

- Mechanical Specific Energy
- MSE Adjusted (MSE x 0.30)
- Motor MSE
- Downhole MSE
- Surface MSE
- Relative MSE
- TTS Mechanical Specific Energy
- DAS MSE
- DAS Mechanical Specific Energy
- Hydraulic MSE
- MSE
- Numerous others in proprietary systems…..

What should the driller pick?
What does it represent physically?
Which is correct?

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Why fix MSE now?

- Some MSE equations are incorrect
- You can't use an MSE values if you don't know what they physically represent
- MSE's initial use was relativistic. Due to automation and big data analytics, it's becoming quantitative and it's calculation must be consistent
- Need a robust reference paper published to explain the physics of MSE, the standardization, and the effects of measurement and rig control uncertainties

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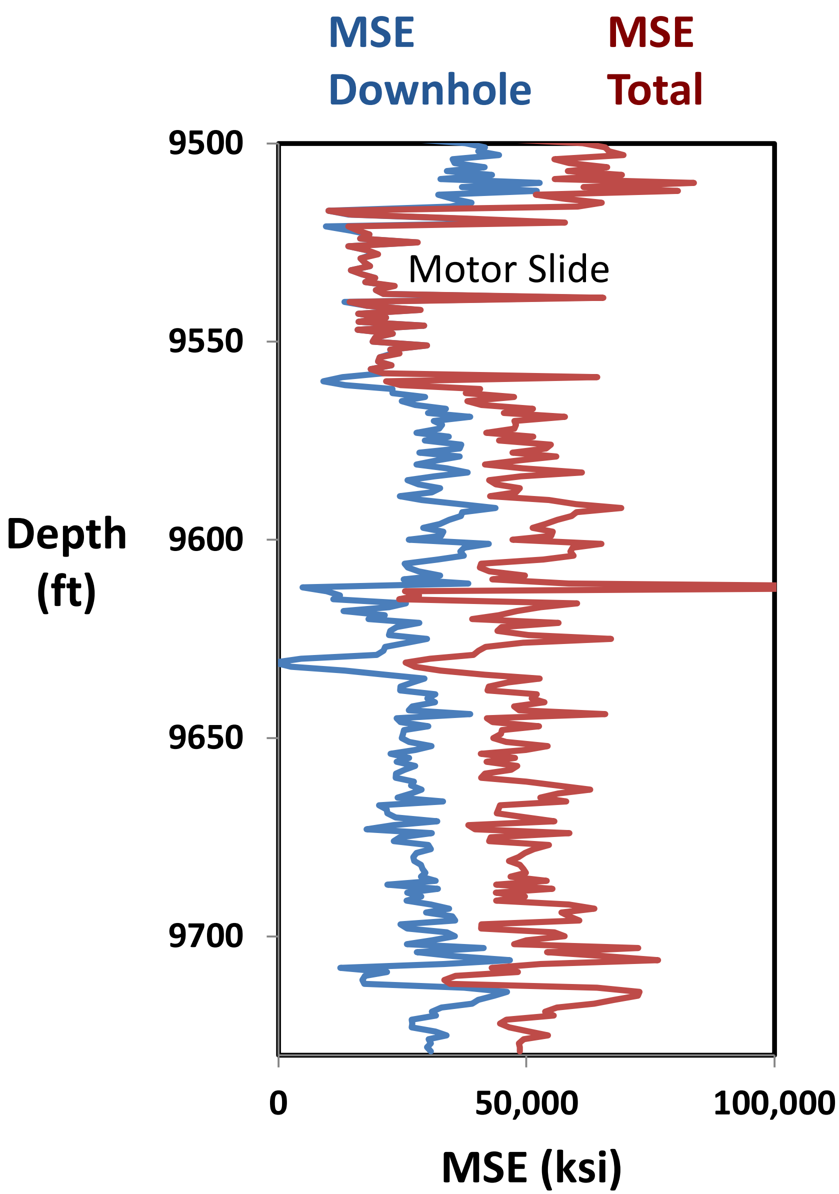
The purpose is to standardize names and equations, publish, and then encourage implementation.

Apache Corp: Michael Behounek
Ensign Drilling: Trevor Warren
ExxonMobil: Paul Pastusek
K&M Technologies: Chris Cutts
Marathon Oil: Dennis Moore
Contractor: Wendell Bassarath
NOV Totco: Bryan Cook
Oxy Petroleum: Jarred Collins
Pason Services: Bob Best, Stephen Lai
Pioneer Resources: Austin Jeske, JJ Wilson
Texas A&M: Fred Dupriest

We Need Two MSE Equations: 1) Downhole and 2) Total



The visual difference between the $MSE_{Downhole}$ and MSE_{Total} should be the energy being lost in the drill string. This may be a useful diagnostic for loss of weight or torque transfer.

Some current equations do not yield correct values

1) $MSE_{Downhole}$ (MSE_{bit} or MSE_{motor})

Teal's 1965 Lab Equation

$$MSE = \underbrace{\frac{4WOB}{\pi D^2}}_{\text{Axial Work}} + \underbrace{\frac{480\, TOR\, RPM}{D^2\, ROP}}_{\text{Rotational Work}} \qquad \text{Eq. 1}$$

$MSE_{Downhole}$ should reflect the bit efficiency alone. Uses downhole data from a motor or an MWD tool. Virtually all EDR vendors use the equations below. While the equation is relatively standardized, the name isn't. You might see something similar as MSE_{bit} or MSE_{motor}

With Motor Data:

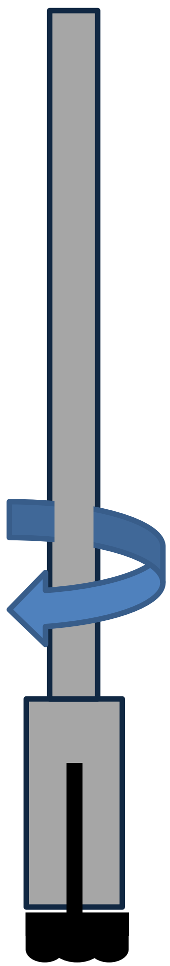
$$MSE_{Downhole} = \underbrace{\frac{4WOB_{Surf}}{\pi D^2}}_{\text{Axial Work}} + \underbrace{\frac{480\,(K_t\, \Delta P)(RPM_{Surf} + K_n Q)}{D^2\, ROP}}_{\text{Rotational Work}} \qquad \text{Eq. 2}$$

With MWD Data:

$$MSE_{Downhole} = \underbrace{\frac{4WOB_{MWD}}{\pi D^2}}_{\text{Axial Work}} + \underbrace{\frac{480\, TOR_{MWD}\, RPM_{MWD}}{D^2\, ROP}}_{\text{Rotational Work}} \qquad \text{Eq. 3}$$

2) MSE_{Total} (May see this called MSE_{system} or $MSE_{surface}$)

Incorrect MSE_{Total} Calculation w/Motor



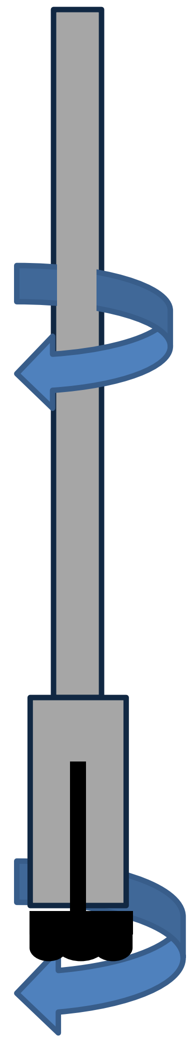
Common and Incorrect

TOR_{Surf} x RPM_{Bit}

Or

TOR_{Surf} x RPM_{String}

Correct MSE_{Total} Calculation w/Motor



String Work

TOR_{String} x RPM_{String}

Bit Work

TOR_{Bit} x RPM_{Bit}

2) MSE Total

MSE_{Total} is the energy (work) being done by both the bit and string combined. If there is no motor the correct calculation of work is simply to input the surface torque and RPM in the Teale equation. However, if a motor is in use the string and bit work must be calculated independently because each does work over a different distance (RPM), and with a different force (Torque)

MSE_{Total} = Axial Work + String Rotational Work + Bit Rotational Work

$$MSE_{Total} = \frac{4WOB}{\pi D^2} + \frac{480\,(\boldsymbol{TOR_{Surf}} - \boldsymbol{TOR_{mm}})\,RPM_{Surf}}{D^2(ROP)} + \frac{480\,TOR_{mm}\,RPM_{mm}}{D^2(ROP)} \qquad \text{Eq. 4}$$

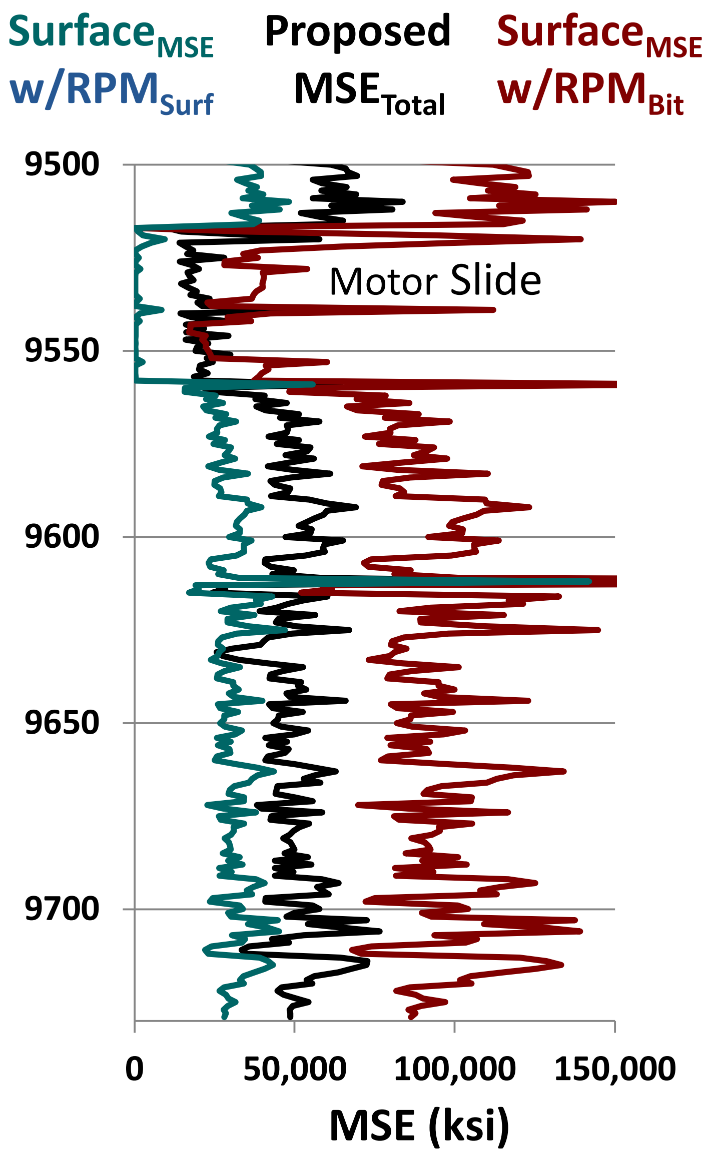
For motor applications this simplifies to:

$$MSE_{Total} = \frac{4WOB_{Surf}}{\pi D^2} + \frac{480\,TOR_{Surf}\,RPM_{Surf}}{D^2(ROP)} + \frac{480\;(K_t\,\Delta P)(Kn\;Q)}{D^2(ROP)} \qquad \text{Eq. 5}$$

For MWD applications this simplifies to:

$$MSE_{Total} = \frac{4WOB_{MWD}}{\pi D^2} + \frac{480\,TOR_{Surf}\,RPM_{Surf}}{D^2(ROP)} + \frac{480\,TOR_{MWD}\,RPM_{MWD}}{D^2(ROP)} \qquad \text{Eq. 6}$$

Comparison of Different MSE_{Total} Calculations w/Motor



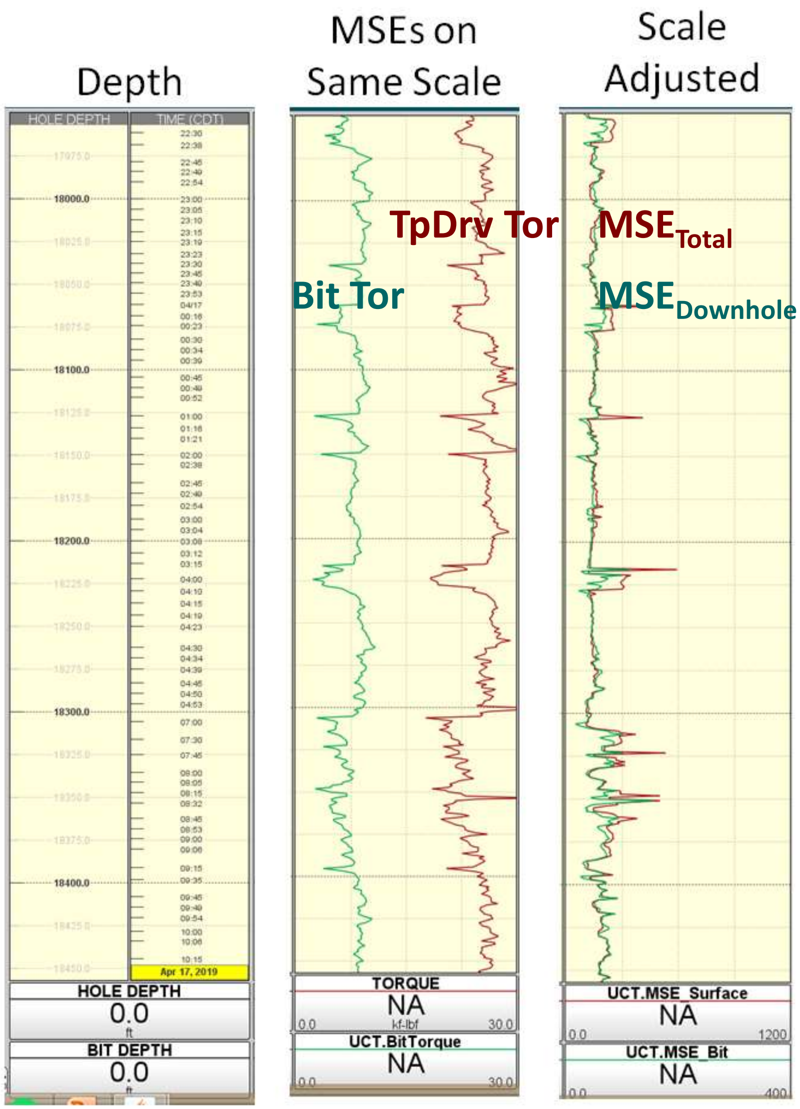
A Surface MSE has historically been calculated when using a motor by multiplying the Surface Torque times either the string speed or bit speed

When calculated with string speed the resultant value is lower than the correct $MSE_{Total.}$ With only bit speed, it's too high

Definition of Units and Variables

MSE	Mechanical Specific Energy (psi)
WOB	Weight on bit based on surface hook load measurement (lbs)
TOP	Torque based on top drive amperage conversion (ft-lbs)
RPM	Top drive rotational speed (rpm)
WOB_{Surf}	WOB Based on hook load slack off (lbs)
Tor_{Surf}	Toque based on top drive amperage conversion (ft-lbs)
Kt	Motor torque factor provided by vendor (ft-lbs/psi)
ΔP	Differential pressure across motor (psi).
Kn	Motor rpm factor provided by vendor (rounds per gal)
Q	Flow rate through motor (gpm)
D	Diameter of bit (inches)
ROP	Rate of penitration (ft/hr)
WOB_{MWD}	WOB measued by downhole subs (lbs)
RPM_{MWD}	Rotational speed measured by downhole subs (rpm)
TOR_{MWD}	Torque measured by downhole subs (ft-lbs)
TOR_{MM}	Torque generated by mud motor (ft-lbs)
RPM_{MM}	Rotational speed of mud motor rotor (rpm)

Total vs Downhole MSE



Virtually all variation in surface MSE is due to changes in bit MSE, not string energy

If simply scaling can make surface MSE look like Downhole MSE, what are implications for self tuning and analytics?

Surface MSE needs to be accurate

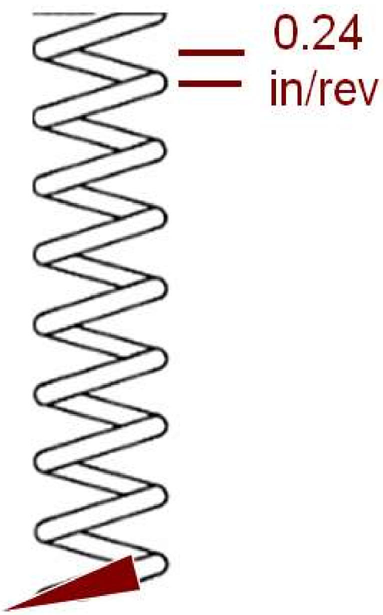
Example Use

High WOB, In Itself, Does Not Wear the Bit Faster

Force per area on a cutter cannot exceed rocks strength (load the rock can hold without breaking). As you increase WOB the contact area grows so the force per area stays the same. Cutter wear occurs at the tip as it slides, much like chalk on a blackboard. Wear of an efficient bit depends on sliding distance. Higher depth of cut (WOB) reduces cutter sliding distance, so it reduces wear per foot drilled.

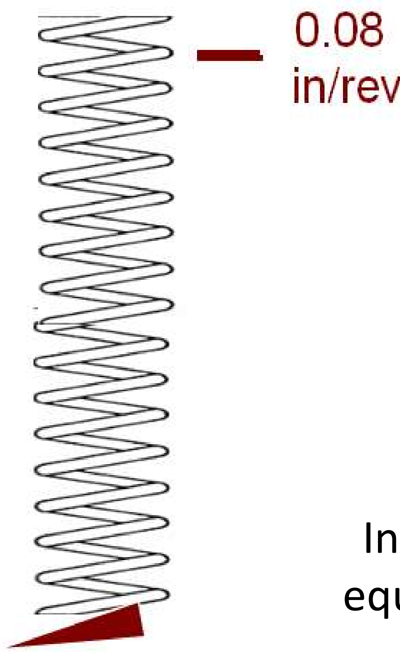
@ 150 fph

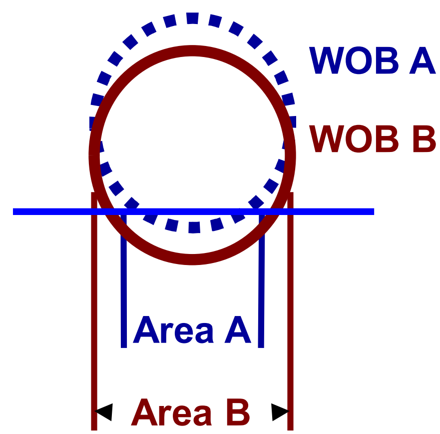
10,679 ft of sliding



@ 50 fph

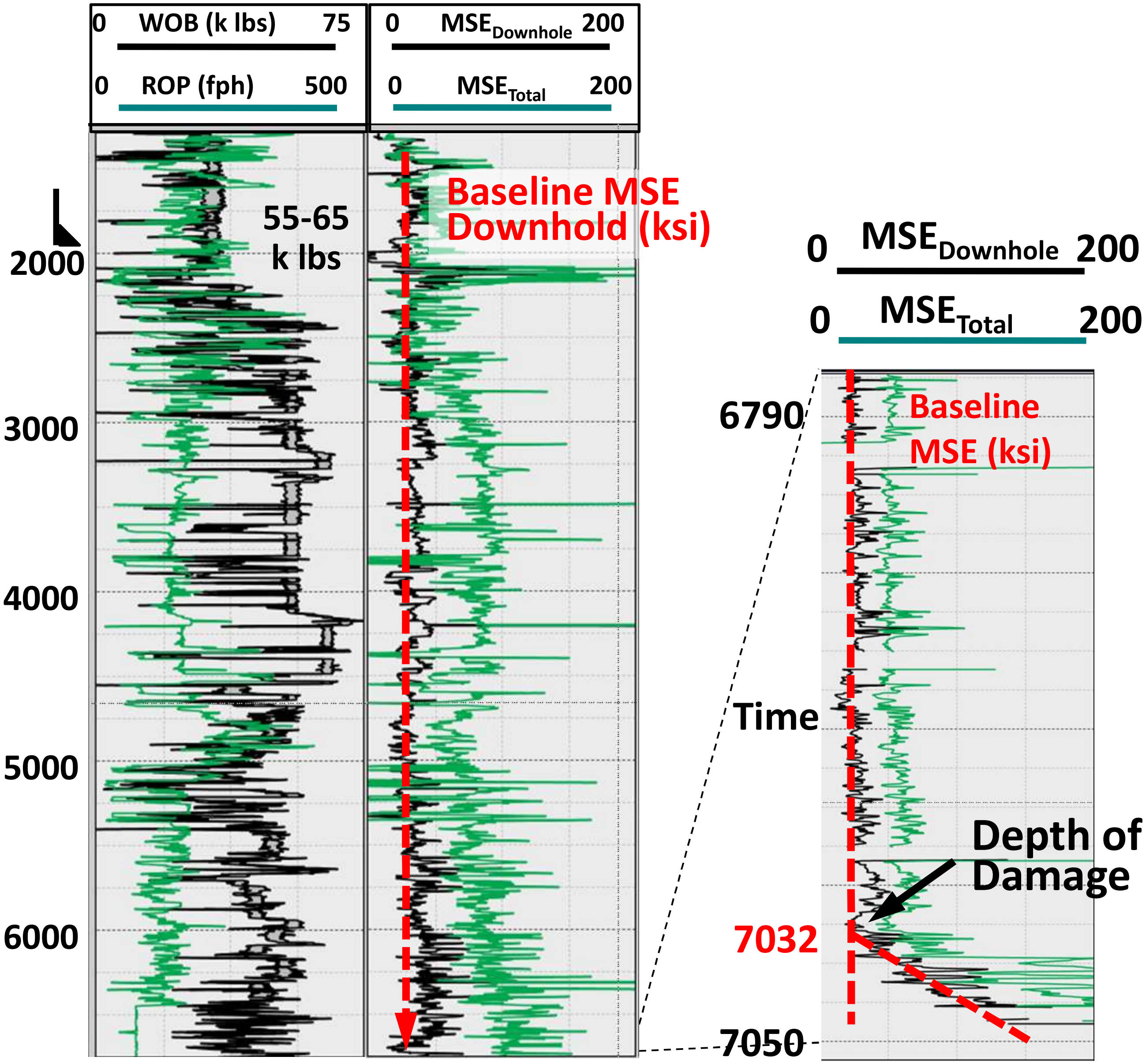
32,038 ft of sliding





Indents until force per area equals rock strength per area

MSE Baseline Surveillance: Bit Wear



If the Downhole MSE periodically returns to its Baseline value, the cutters cannot have wear flats. The bit is green

Key Takeaways

1. **Uniform nomenclature and MSE equations are needed to implement the quantitative uses emerging in automation and data analytics**
2. **All EDRs should contain MSE_{Total} and $MSE_{Downhole}$ in their pick list, including proprietary company systems**
3. **The $MSE_{Downhole}$ for motors is likely to be the same equation you are already using, but the name needs to be changed**
4. **MSE_{Total} is likely to be a different equation than you're using that more accurately reflects the loss of energy in the string**
5. **There are significant issues in the measurement of the values that are input at the rig. These will be discussed in the technical paper.**
6. **As much as possible, MSE should be used to in deterministic analysis and decisions, not stochastic. This requires we teach rig crews more physics (how things really work)**