Examining the ROP and Steerability of Drill Bits to Reduce Drilling Times and Achieve an Efficient Build Section

Aldo R. Gurmendi
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Efficient Build Section Topics

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- Assess how blade count, gauge length and size of cutters impact the ROP of different drill bits and enable day rate savings.
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- Discuss the steerability of drill bits and slide drilling motors to build to the lateral leg as quickly and smoothly as possible.
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- Assess the application of motor technology in relation to drill hole size to evaluate which motors can be used in small drill hole sizes to assess future drill bit investment

- Examining the durability of drill bits to prevent tearing up of bits and reduce time spent tripping to replace them as well as additional tool costs
Analyze ROP of Different Drill Bits to Understand Their Application in Different Formations and Maximizing Efficiency When Drilling
Define Well Objective

- What type of curve is needed to successfully complete our objective (TD & complete desired lateral)
- Operate with the highest probability of success
Well Design Criteria / Constraints of System

- BUR needed (short radius vs. long radius)
- 2D vs. 3D (build & turn) curves
- Geology: Compressive strengths / ratty formations / faulting (target changes)
- Desired length of lateral
- Mechanical system: rig, mud pumps, drill pipe
- Human Element – Directional Driller
From our system variables:

- What bit/bha will maximize our efficiency while drilling the curve...

Need bit/bha that will deliver best formation contact producing constant, consistent and efficient torque to effectively cut the formation for best ROP.
PDC and Roller Cone

**PDC** – higher torque / higher ROP

ROP is proportional to **POWER** at the bit

Power at the bit = SPEED x TORQUE

**Roller Cone** – low torque / lower ROP
PDC and Roller Cone

**PDC** – higher torque / TF control

**Roller Cone** – low torque

Drillpipe in the hole?
PDC and Roller Cone

–PDC / Fixed Cutter vs. Roller Cone

PDC – higher torque / higher ROP

➢ On average ~30+% increase in ROP

Whenever possible - PDC
PDC and Roller Cone

PDC / Fixed Cutter vs. Roller Cone

Roller cone when needed

- Ratty formation
- Faulting – change in BUR
  - Increased build & turn rates

If needed, take your medicine – wellbore quality!
Assessing How Blade Count, Gauge Length and Size of Cutters Impact The ROP of Different Drill Bits and Enable Day Rate Savings
Blade Count

- Higher blade count
- Better stability, directional control (TF control)
- Lower ROP
Gauge Length

- Smaller the gauge length better reaction to slide (sidetrack bits)
- Too small could cause poor hole quality – inconsistent BUR
Cutter Size

- Smaller cutter will generate less torque
- Smaller cutter will have lower ROP

- Smaller cutters will yield better TF control, better bit stability
Higher cutter count will generate less torque – cutters on shoulder/nose

Less torque less ROP
Limit depth of cut in cone. Do not limit depth of cut in shoulder – increased side cutting action.
Cutter Rake

Manage back rake, cutter size and placement for improved ROP – ‘depth of cut limiter’
Aggressive cutters on shoulders vs. cone for side cutting action
When drilling, the nose and shoulder of the bit remove the confining stresses in the formations.

Unconfined

Confined

Cutters located in the cone, nose, shoulder, and gage areas of the bit will react differently to a given drilling environment.
Discussing the Steerability of Drill Bits and Slide Drilling Motors to Build to the Lateral Leg as Quickly and as Smoothly as Possible

Step 1
Drill vertically until the wellbore reaches a point above the targeted reservoir.

Step 2
"Kick off" and begin to drill at an increasing angle until the wellbore runs horizontally through the targeted reservoir.

Step 3
Drill horizontally to desired length.

Horizontal Well
Matching Mud Motor to Drill Bit

- Three Point Geometry
- Motor Build up Rate (BUR)

- Motor Efficiency
- Torque output
Three Point Geometry

Motor BUR Capability

$$BUR = \frac{200 \times \Phi}{L1 + L2}$$

- **L1** = Length from bend to drill bit
- **L2** = Length from bend to top motor
- **Φ** = Motor Bend
Three Point Geometry

- Motors with smaller L1, increased BUR
- Higher build capacity with ability to rotate

<table>
<thead>
<tr>
<th>Performance</th>
<th>475</th>
<th>650</th>
<th>675</th>
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<tbody>
<tr>
<td>64” - 76”</td>
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<td></td>
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<tr>
<td>SBTB with fixed bent housing</td>
<td>44”</td>
<td>46”</td>
<td>48”</td>
</tr>
<tr>
<td>SBTB with adjustable bent housing</td>
<td>52”</td>
<td>56”</td>
<td>54”</td>
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<tr>
<td>Ultra Short</td>
<td>/</td>
<td>/</td>
<td>25”</td>
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Standard bit to bend for 6 3/4”
Motor is 6+’

New bearing packs allow for 4’ bit to bend
Three Point Geometry

- Motors with smaller L1, increased BUR
- Higher build capacity with ability to rotate

\[ BUR = \frac{200 \Phi}{L1 + L2} \]
Motor Efficiency

- Motor Torque and Speed
Motor Efficiency

- Improved Power Sections for Higher Horsepower

- Conventional Stator
- Steel

- Even Wall / Hard Rubber
- Elastomer
Motor Efficiency

Increase bit speed at higher operating Diff psi.

\[ Hp_{out} = \frac{Trq \times RPM}{5252} \]

\[ Hp_{in} = \frac{Dpsi \times GPM}{1714} \]

Motor Efficiency = \( \frac{Hp_{out}}{Hp_{in}} \)
Motor Efficiency

Operating the 7/8_5 power section @ 520 Diff psi will generate ~ 4800 ft-lbs Torque

Operating the 4/5_7 power section @ 520 Diff psi will generate ~ 3000 ft-lbs Torque
60% reduction in torque at same operating parameters will reduce shearing capacity

Does our formation require the additional torque for efficient drilling...
Motor Efficiency

- The Human Element
- Other Factors - rig, drillpipe, pumps, driller,..

**Graph:**
- **Power Section Diff Pressure (kPa)**
- **Torque** (ft-lb / Nm)
- **RPM**

- **Maximum Recommended Diff Pressure**

**Legend:**
- NBR-1A, HSN-38
- NBR-HR

- **4/5_7.0 Power**

[Image of a trophy]
Assessing the application of motor technology in relation to drill hole size to evaluate which motors can be used in small drill hole sizes to assess future drill bit investment.
Three Point Geometry

- Motors with smaller L1, increased BUR
- Higher build capacity with ability to rotate

Standard bit to bend for 6 ¾” Motor is 6+’

New bearing packs allow for 4’ bit to bend – 15% increase in build capacity.
BHA Jamming in Curve Applications

\[ L = 2 \left[ Rc^2 - (R - (D - d))^2 \right]^{1/2} \]

Where:
- \( L \) = Maximum tool length (in), (mm)
- \( Rc \) = Radius of the curved borehole (in), (mm)
- \( D \) = Diameter of borehole (in), (mm)
- \( d \) = Diameter of tubular (in), (mm)
Motor Jam Calculations

**DATA ENTRY**

<table>
<thead>
<tr>
<th>PLANNED BUR (°/100')</th>
<th>17.00</th>
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<tbody>
<tr>
<td>HOLE SIZE (inches)</td>
<td>6 1/8</td>
</tr>
<tr>
<td>COLLAR O.D. (inches)</td>
<td>4 3/4</td>
</tr>
<tr>
<td>MOTOR LENGTH (STAB TO STAB)</td>
<td>18.0</td>
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\[ Rc = \text{Radius of curved borehole} \]
\[ D = \text{Diameter of Borhole} \]
\[ d = \text{Diameter of Tubular} \]
\[ L = \text{Maximum Length of Tool} \]

*Assumes no bending in member L.*

**COLLAR SIZE STIFF LENGTH MATRIX**

<table>
<thead>
<tr>
<th>( \text{delta OD} )</th>
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<tr>
<td>( \text{BUR} )</td>
<td>5 3/4</td>
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<tr>
<td>17.0</td>
<td>9.18</td>
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<td>18.0</td>
<td>8.92</td>
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**NYSE: HK**

HALCÓN RESOURCES
Motor Jam Calculations

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* ASSUMES NO BENDING IN MEMBER \( L \).
Examining the durability of drill bits to prevent tearing up of bits and reduce time spent tripping to replace them as well as additional tool costs
The PDC Cutter

**Polycrystalline Diamond Compact:**

Individual, synthetically grown diamond crystals (diamond grit) *mechanically* bonded through sintering process at 1 Million PSI and 1,500°C.

Cobalt acts as a catalyst.

The PCD is pressed onto a substrate composed of a tungsten carbide matrix.

The Non-Planar Interface manages the residual stresses left over from the sintering process.

The interface also plays a significant role in absorbing impact.

* The mechanical bond is quite strong and can, in some cases, approach the strength of the diamond grains.
Polycrystalline Diamond

Cobalt in substrate melts and infiltrates the diamond powder upon application of heat and pressure.

Cobalt acts as a catalyst.
What causes cutter failure?

- Thermal-degradation
- Mechanical Wear
- Impact
Thermal-degradation

The expansion of the cobalt within the diamond causes the mechanical bonds to fail.

Mechanical Wear

Abrasive formations can break the diamond bonds mechanically.

Both types of wear generally happen coincidentally and yield the dull condition seen above. However, mechanical wear can occur without thermal-degradation.
PDC Failure - Impact

Axial, Lateral

Torsional

Whirl
As discussed earlier, the 3 main types of impact causing movements are Axial, Lateral, and Whirl.

**Axial impacts** come from up and down movements along the drill string.

**Lateral movements** are generally due to instable drilling.

**Torsional impact** generally predicate from bit whirl is an extreme case of instability.
Latest Technology

• The latest improvements we are seeing in our test cutters is coming from changes in the pressure and temperatures of the sintering process. By varying one or both, the properties of the diamond table vary. This has had the biggest effect on the impact resistance, or toughness, of the cutters.

sintering process at 1 Million PSI and 1,500°C.