Five Technologies in Development that can Make a Difference on your Future Well

Presented to IADC DEC
September 9, 2015

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Technologies Being Introduced

- Hybrid bit for Steerable Sections
- Automated Bit Selection Guide (response based selection of features based on customer input)
- Field Adjustable Depth of Cut Control
- Directional Drill Ahead Model
- Self-Adjusting Depth of Cut Control for Elimination of Stick Slip
What is the hybrid bit?

• Roller cone and PDC in one unit
• PDC provides aggressive cutting action
• Roller cone controls torque response for smooth drilling
**Hybrid| 8.75” Simulator Tests**

- Hybrid produces less torque per a given weight
- Lower torque fluctuation has better tool face
Hybrid | Field Performance in a curve

- PDC unable to achieve BUR due to erratic toolface
- Hybrid achieved smoother toolface and higher ROP
Hybrid| Field Performance while sliding

- Smoother drilling
- Able to maximize WOB & Motor Power
- Resulting in higher ROP & consistency
Hybrid | Bearing Improvement

- Implementing Precision Tapered Roller Bearing
- Reduces axial play
- Extends operating hours by 2x
Automated Drill Bit Selection Tool

Introduction to BitGenie™ drill bit selection tool:

- A data-driven, collaborative solution which optimizes the features
- Rapidly accelerates the PDC bit selection process
- The responsive algorithm takes performance priorities into account
- Quickly compare, modify, and evaluate results with confidence
- Check stock point inventory on the fly
  - Reduces need for delays in designing and building a new bit
Technical Background

Traditionally, we have designed, selected, and sold bits in terms of **Features**, not **Behaviors**.

**Features**
- Blade Count
- Cutter Size
- Back Rakes
- Chamfers
- Profile
- Junk Slot Area
- Gage Length
- Etc.

**Behaviors**
- Aggressiveness
- Cleaning Efficiency
- Lateral Stability
- Torsional Stability
- Side Cutting
- Durability
- Cutter Abrasion Resistance
- Cutter Impact Resistance

**Consequences:**
- Lack of focus on ultimate goals, subjective preferences may dominate
- Lack of understanding of how features affect behaviors
  - Designer adds a blade (+durability), but the bit balls up (-cleaning).
  - Designer removes a blade (+aggressiveness and -durability) and increases back rakes (-aggressiveness and +durability). In the end, the behaviors are unchanged.
  - Engineer requests RRT to change back rakes in shoulder by 1°. A new PN is created that has no significant behavior change from the reference bit.
What is a Bit Behavior?

- Fundamental technical property
- Quantifiable and measurable
- Relatable to a wide audience with range of expertise
- Non-dimensional
- Scaled 0–100
- Has a ±10 point uncertainty range for ~90% confidence
- Carefully derived and validated from over a decade of laboratory testing, field performance, and computer modeling:
  - >300 Simulator Rig Tests
  - >400 Surface Rig Tests
  - >500 Single Point Cutter Tests
  - >600 Field Runs
  - >1000 Computer Simulations
- Leveraged over 15 years of Drill Bit Advisor knowledge
- Utilized over 100 years of HCC and Oasis technical expertise
Use Case #1

Central Oklahoma, USA

“I’ve run several 8.75” bits in my application operating at ~110 ft/hr and 195 rpm. How do my bits compare to each other?”
Case Study #1

The differentiated behaviors of X18268 resulted in record field performance.

- X18268 has much higher Cleaning Efficiency
- X18268 has higher Lateral Stability than X17908
- Talon Stay Sharp cutters have higher Abrasion and Impact Resistance
- X18268 has lower Side Cutting

Surface Rig, Carthage, 120 rpm
Case Study #1: 8.75 in. Curve Mississippi Chat

Original Bit: X17908

Aggressiveness
Simulator, Carthage, 6000 psi, 30K wob, 120 rpm

Stability
Surface Rig, Carthage, 120 rpm

New Bit: X18268

Balling Resistance

Field Performance
“# short runs reduced from 18 to 3”, “better tool face”

Less Aggressive + More Stable + More Balling Resistance = Better Field Performance
Select Adjustable D.O.C.PDC Drill Bit

- Interchangeable ovoids in varying heights and materials
  - Refine bit aggressiveness and torque control between each run
  - Get to the best bit performance faster
  - Reduces inventory, bit delivery improved

![Bit Behavior Response vs Ovoid Height](image)
What is Select Depth of Cut Control?

- Goal: change ovoids at the rig site
  - Optimized D.O.C.
  - Controlled Exposure
  - Simple
  - Reliable
  - Small footprint
  - Learn fast, immediate implementation
Full Bit Validation Testing

**Lab testing**
- 8.5" TD505S (X21088)
- Test multiple ovoid variations

**Field testing (27+ runs through 1Q2015)**
- South Texas
- Northeast
- Rockies
- Alaska
- Tests pending in Canada and China
South Texas Field Test Data

- 8.5” 16mm, 5 blades
- 3 sequential runs on same bit
  - “ROP on par or better than standard TD505S (X19719)”
  - “no issues reported during the repair process”

“31% faster, saving 21 hrs and $52,500”
Field Application

- Understand application issues
  - High stick-slip
  - Erratic torque
  - Poor toolface
  - Poor BUR

- Know the application target DOC
  \[
  \text{DOC (in/rev)} = \frac{\text{ROP (ft/hr)}}{5 \times \text{RPM}}
  \]

- Evaluate bit behavior trade-offs
  - Torsional stability vs. aggressiveness
  - *Aggressiveness does NOT = ROP
  - *Torsional Stability does NOT = BUR

- Select ovoid height
  - Application specific
  - Work with customer to tune in height on subsequent runs as driller gains confidence
  - Or use best estimate from experience and offsets
Case Study, Record Setting ROP, Curve - Lateral Section

- All runs in 2015 within a 5 mile radius, 4 suppliers products included.
- Bottom line: Take time to review the past performance, select optimum DOC, apply to the bit; put money in your pocket by cutting drilling time.
Directional Drill Ahead Simulator

Overview of Directional Drill Ahead Simulator

**Description**

- Software tool that simulates the directional drilling process.

- The Bit and BHA designs are analyzed simultaneously as a system.

- The Simulator uses an iterative process to create detailed, digital wellbores. BUR and local DLS are easily viewed.

**Benefits**

- Improved BUR success rate in the curve sections and hole quality in the lateral.

- Reduces risk of failure when trying new BHA or bit designs, or when drilling in a new area.

- Visualizes the directional drilling process (contact force locations and magnitudes, deflection, bending moment).

**Current Success Highlights**

- Simulator results compare favorably to multiple AT Curve runs in Canada, the Utica

- The Simulator predicts correct behavior types for the given drilling parameters, lithology, BHA and Bit design (i.e. smooth BUR for longer gauge bits, hole spiraling for very short gauge bits).
What is a Drill Ahead Model?

- Predicts Directional Trajectory
  - BHA Model
  - Bit Model(s)
  - Steering Model

- Past and Present Models
  - Brett et al., 1986 (FEA BHA + analytic bit model based on lab data)
  - Ho, 1987 (bit anisotropy calculated from past well data)
  - Rafie, 1988 (beam + bit anisotropy calculated from past)
  - Dahl & Schmalhorst, 1991 (FEA BHA + bit anisotropy assumed)
  - Downton, 2011 (Beam BHA + bit anisotropy assumed)
  - Perneder, 2012 (Beam BHA + bit anisotropy assumed)

- The DDAS
  - It is the only one that models the detailed bit geometry.
Software Interface

![Software Interface Diagram]

- **LITHOLOGY**
  - Bit: X1066
  - 8.75 in.
  - TD: 2065 ft
  - Taper:
  - 0.625 in. Cutting Diameter
  - 22 Face Cutters
  - 0 Baskets
  - Gage Length:
  - Gage Module (inner), in.
  - Gage Relief Angle, deg.: 0.29

- **OPERATION**
  - Mud Wt.: 12.0

- **BHA**
  - AX_K_Complex.xml

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Value Proposition

- The Directional Drill Ahead Simulator allows us to ensure that a given well plan can actually be achieved.
- It will aid in optimizing the well planning and drilling process.
- High-dollar off-shore jobs have asked for this type of analysis now.
In 2013, Baker Hughes introduced a company-wide innovation contest based on open innovation concepts and sought ideas for “breakthrough product or service”

- The contest was open to 60,000 employees, had over 7,000 participants & 1,075 ideas

- “Self-Adjusting PDC Bit” was one of the four winning ideas, and was awarded USD 1 Million and 1 year to bring the idea to life

- The idea develops an innovative PDC bit that can self-adjust its DOC control characteristics to the constantly-changing drilling environment and mitigate vibrations while delivering improved ROP.
Wildcat Challenge project delivers ‘self-adapting’ drill bit.

Wildcat Challenge: Open competition for independent research. Budget, resources, and senior technical and management mentors.
Self-Adjusting PDC Bit

- 8 ¾” 405 single-piece steel body bit with standard shank
- Three self-contained cartridges secured by threaded cap with preload
- The cartridges encapsulate a passive hydro-mechanical feedback mechanism with rate sensitive strokes
- Blade strength qualified for field conditions
- Failure of individual units does not fail the bit.
Dynamically Adjusted DOC Control

During normal steady state drilling, the elements gradually adjust their exposure to enable fast and efficient drilling.

During unfavorable dynamic events, the elements engage with the formation and mitigate dysfunctions.
Field Tests in Research Wells at BETA

- Test Objective:
  - Compare stick-slip tendencies of standard and self-adjusting PDC bits

- Identify and compare the stick-slip zone boundary

- Tests at 2600’-3100’ with 3 ½” DP
Logs from Wilcox Sandstone

- The logs show surface and downhole measurements in Wilcox Sandstone
- Fixed PDC Bit exhibited stick/slip
- Self-adjusting bit mitigated stick/slip and expanded stable operating zone, resulting in higher ROP
Power Curves from Arbuckle Dolomite

- Significant improvement in “stick-slip free ROP”

![Graphs showing Power Curves from Arbuckle Dolomite](image)
Summary

- **Steerable Hybrid**
  - Based on solid fundamental design
  - Based on solid understanding of drilling mechanics
  - Features added to address behavior in build sections
  - New stronger bearing package
  - Very low vibration signature-BHA reliability increased

- Field proven, available, ready to solve your drilling issues.
Summary

- **Bit Selection Software**
  - Data driven analysis + very experienced applications engineers input
    - Single point cutter, Atmospheric runs, Simulator runs, DBA, Beta, Oasis, and senior experts
    - Customer requirements can be added as a constraint
  - Behavior based decision tree
  - Qualification test showed high degree of effectiveness
  - Frequently finds an active design that meets the optimization plan
- Ready for customer to challenge the common wisdom.
Summary

- **Field Adjustable Depth of Cut control**
  - Takes a proven concept and gives it flexibility
  - Ability to optimize between runs
  - Cost effective in many applications
  - Bit Representative can help make the decision on doc.
  - Initial designs tweaked, more robust now.
  - Provide custom solution quickly where stability is important

- Ready to be applied to optimize your bit-BHA performance.
Summary

- **Drill Ahead Model**
  - Incorporates BHA, bit geometry and steering models
  - Only model to incorporate all of the above
  - BETA tested and verified predictions in Utica and Canada
  - Service that can assure your hitting the target with minimal risk

- Ready to help customers with any variety of steerable BHAs
- Assistance with predictive model to minimize sliding?
Summary

- **Self-adjusting Depth-of-Cut Control**
  - Chosen by senior technical personnel as a Wildcat Challenge winner
  - Plan given resources and freedom
  - Passed Laboratory and BETA test.
    - Systems performed as designed.
    - Stick-slip eliminated except in soft shale
    - Re-engineering now for robust commercial product
- **Q1-2016 targeted for field trials**
  - Anyone interested in being the first to run this?
New and unknown often has the classic reaction popularized in the 1960’s cereal commercial.

“Let Mikey Eat It.”

“Hey Mikey Likes it.”

Any “Mikey’s” Here Today? Willing to try it before others?
Thank You for your Attention.
Thank You for Opportunity to Show Bit Technology Nearing Commercialization.

Questions?