## Science-ing Up Deep Earth Drill Bit Design With MATLAB Production Server

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# Reed Hycalog NOV

### Deep Earth Drill Bits

Roller Cone vs PDC



#### **ROLLER CONE**

- 1909 (Hughes)
- Rotating cutting structures
- 19% market share in 2019<sup>1</sup>



#### POLYCRYSTALLINE DIAMOND COMPACT (PDC)

- 1971 (GE)
- Fixed blades
- Cutters brazed on blade
  - Diamond cutting surface
  - Fine control over placement
- 81% market share in 2019<sup>1</sup>

## Average Rate of Penetration (ft/h)





## Average Depth Drilled per Bit (ft)



#### Average Depth Out (ft) USA 2010-2020



### Well Types USA 2010-2020



### Design Objectives for PDC Bits

#### **Rate of Penetration**

- Less rig time = savings
- Efficient transfer of forces from surface to bit

#### Durability

- Fewer bits to drill a section = savings
- Cutter wear

#### Steering

- Predictable tool face (torque)
- Minimize walk

## PreCut (Pressurized Cutter Testing) 4D shaped cutter vs planar



## Data Driven Bit Design



### **ReedHycalog Digital Experience Team**



### **ReedHycalog Digital Experience Team**



### **Orbit Architecture**



### **Orbit Client**

Orbit 2020.2 File	,				Custom Mode Off 🏾 🌣
Cutting Structure     He       &        &        Cutter     Cut       Analysis     Shapes	at Generation A at Generation A ata Parametric DOCC Evaluation	DU WRA OBF SRA DUI WRA OBF SRA	RF W08 & OBF		BitClass: Concentric Approach: Standard
Steady State Respose	Drilling Response	Performance Indices	Bit - Reamer Matching	0	Run Analysis   C Override  Lock  Parameter Evaluation  Run Analysis
Concentric	300           250           Signature           200           150           100	0 1250 1500 1750 WOB lbf	<ul> <li>Torque-Pilot(</li> <li>Torque-Pilot(</li> <li>Torque-Pilot(</li> <li>Torque-Pilot(</li> <li>Torque-Pilot(</li> </ul>	X Axis WOB ✓ Y Axis Torque ✓	Data Input     Model Specification

#### Upload Design

- Schematic File
- Link to CAD

#### Run Analysis

- KPIs
- Simulations

#### Iterate

• Design Objectives

#### Export

- Design Review
- Sales

### Why MATLAB Production Server?

### Separation of concerns

- Intellectual property
- Engineers "own" code
- Performance

### Rapid deployment

- Easy to use API
- Few modifications to R&D code
- Automated management of runtime
- Update in place



### **Orbit Pipeline**



MATLAB Code

- R&D
- Source Control

MPS Template

- Build Script
- Standard API
- .NET / Yeoman

### CI/CD

- Automate
  - Build
  - Test
  - Deploy

#### UAT/Production

- Integration
- Validation
- Release

## **Case Studies**



### Predicting wear

Cutter wear is costly

- Decreased efficiency
- Bits replaced mid section
- Health and Safety

What drives cutter wear?

- Mechanical wear? Abrasion?
- Thermal conditions downhole
  - Substrate-to-diamond table bond degrades
  - Diamond degrades

#### **Extreme temperatures accelerate cutter wear**







### Mitigating Thermal Wear



- Cutter Technology
  - Materials
  - Manufacturing Process
- Heat generation
  - Friction
  - Propagation
  - Cutter placement
- Heat transfer
  - Drilling fluid
  - Nozzle placement

### A Solution

- Thermal load model
  - R&D Team (Babaie Aghdam)
  - Friction & heat propagation
  - Finite element analysis
  - Validated in the field (dulls)
  - Algorithm implemented in MATLAB
- Orbit
  - Pipeline
  - New visualization
  - Integration with computational fluid dynamics (nozzle placement)

### **Thermal Analysis Chart**

Thermal load vs cooling efficiency



- Cutters ordered by radius
- Top axis: increase in cutter temperature
  - MATLAB model
- Bottom axis: heat transfer (drilling fluid)
  - Computational Fluid Dynamics (CFD)

#### Workflow:

- Run thermal load analysis (Orbit)
- Export to CFD
- Upload CFD output to Orbit

### A better physics model

Extrapolate cutter forces to whole bit.

• Originally based on experiments run at surface.

#### Material properties of rock change under pressure

– Brittle at surface, ductile at depth

#### A new standard

- Pressurized drilling lab
- Discrete element analysis
- AMBAR Model (Rahmani)

### The Prototype

File Home Ins	ert Page Layout	Formulas Da	ata Review	View	Develop	er H	elp	Team	Q	Search												ßS	hare	🖓 Con	nment
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2	Browse Primary bdt										1											•			
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4 Run Batch Analysis	Browse Hybrid bdt										0.5														
6	Hybrid Contact Area										0.8														
Parametric Evaluation	- Hybrid contact Area	-									0.7														
8	Orbit CSV			_						[sq	0.6														
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12 Chamfer type	100	Depth of cut (mm)									0.3														
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- Excel spreadsheet
- Extensive VBA routines
- Calculation performed on hidden sheets

#### Limitations:

- Hard to maintain, distribute
- User manages artifacts

### AMBAR in Orbit

- Integration
  - Rewritten in MATLAB
  - Pipeline
  - Automated
    - No need to manage artifacts
- Continuous improvement
  - Multiple iterations pushed since release
- Reception
  - Engineers have greater confidence in output
    - Better usage
    - Sales support
  - New Analyses

### **Torque Control**



Torque variation makes steering harder

- Hooke's law
- Weight on bit fluctuation
- Torque control components (TCC)

AMBAR

- Better model for TCC
- Better model downhole
- Enables finer analysis like DOCC

