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

CHRISTOPHER BREMER
SOFTWARE ENGINEERING LEAD
NOVEMBER 18, 2020

ReedHycalog | NOV
Deep Earth Drill Bits
Roller Cone vs PDC

ROLLER CONE
• 1909 (Hughes)
• Rotating cutting structures
• 19% market share in 2019

POLYCRYSTALLINE DIAMOND COMPACT (PDC)
• 1971 (GE)
• Fixed blades
• Cutters brazed on blade
  – Diamond cutting surface
  – Fine control over placement
• 81% market share in 2019
Average Rate of Penetration (ft/h)
USA 2010-2020
Average Depth Drilled per Bit (ft)
USA 2010-2020

- 2010-2012: 3,000 ft
- 2012-2014: 3,500 ft
- 2014-2016: 3,500 ft
- 2016-2018: 3,500 ft
- 2018-2020: 4,000 ft
Average Depth Out (ft)
USA 2010-2020

- 2010-2012
- 2012-2014
- 2014-2016
- 2016-2018
- 2018-2020
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

Planar PreCut Front View  4D PreCut Front View
Data Driven Bit Design
ReedHycalog Digital Experience Team

- Physics Models
- Design Verification

Orbit

- CAD Software
- Drill Bit Design

creo®

- Field data
- Drill string analysis

Spectra
drilling analysis software
ReedHycalog Digital Experience Team
Orbit Architecture

Client App

Power BI

Web Service

MATLAB Production Server

Orbit Database

Resource
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

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

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

- 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