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U.S. DEPARTMENT OF ENERGY

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Rotary Piston Motor for High-Temperature Directional Drilling
GTO EDGE Community of Practice
July 24, 2019

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with US Synthetic, National Oilwell Varco, Marathon Oil and Radigan Engineering
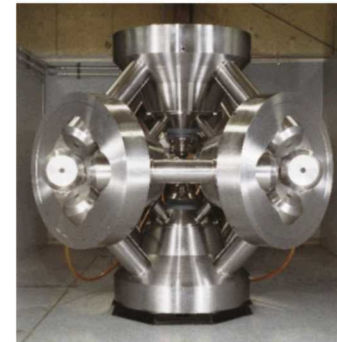
Image: Calpine

Project Summary

Description

Develop new downhole motor concept to replicate/improve torque and rotary speed profiles for geothermal drilling with: 1) Reduced lateral vibrations, and 2) Elevated temperature compatibility to 572F (300C) and maintain compatibility with conventional drill bits.

Scientific/Technical Approach

- Conceptual Design for Rotary Piston Motor Prototype
- Specify fluid power conversion to rotary shaft power
- Computational modeling using multi-body dynamics
- Computer-aided design and manufacturing
- Contact stress analysis & management
- Advanced synthetic diamond for low-friction bearings and drilling fluid compatibility
- Advanced materials and alloys
- Preload method and hardware specification
- Test & Evaluation in simulated drilling environment
- Intellectual Property Protection and Licensing

Project Objectives

Specific Objectives:

- Extend downhole motor technology temperature envelope

- Improve drilling vibration control

- Increase steering efficiency to improve directional responsiveness

Relationship to DOE EDGE FOA's goals:

1. **Reduce Non-Drilling Time by >50%**
   - ✓ Improve the amount drilled per BHA to reduce tripping

2. **Increasing drilling ROP to 25+ feet/hour**
   - ✓ Innovative drilling methods, materials, and/or technologies that are tailored to increase ROP in geothermal conditions
   - ✓ Improvements in vibration control and/or use of mechanical specific energy to increased bit durability while maintaining or improving ROP
   - ✓ Advancements in steering efficiency that improve directional responsiveness.

Current Progress

Important technical objectives and milestones (Overall Project)

Year	Key Milestones & Deliverables
Year 1	• Proof of Concept (POC) test of Prototype Power Section on Hydraulic Fluid on Sandia Dynamometer • POC Test of Prototype Power Section with Diamond Bearings on water-based drilling fluid on Sandia Dyno
Year 2	• POC Test of Prototype Power Section integrated into Motor Housing on WBDF on NOV Dynamometer • POC Test of Prototype Motor on WBDF drilling representative rock in NOV Horizontal Drill Rig

SOPO Important Milestones (for FY19/Q4, thru 09/30/19)

- M1.2.1: Execute multi-party CRADA agreement (7/31/19)

- M1.3.1: Routine project meetings

- M2.1.1: Develop requirements for RPM prototype module for Sandia test (4/30/19)

- M3.1.1: RPM module hardware developed and assembled (4/30/19)

- M3.2.1: Produce net-shape diamond for Sandia power section test (7/31/19)

- M4.1.1: Computational model developed for RPM configuration (4/30/19)

- M4.2.1: Multiple-stage computational model developed for RPM config (7/31/19)

Current Progress (cont.)

Progress Summary (overall and FY19/Q4):

- Project Start: 02/01/2019
- Team-wide Technical Interchange Meetings hosted monthly by Sandia via Skype (Feb 19, Mar 5, Apr 2, May 7, Jun 18 & Jul 2)
- Multi-party NDA drafted; circulated for execution
- CRADA-SOW prepared; CRADA documents distributed; acceptance pending
- Sandia visit to US Synthetic April 2019; address diamond integration needs
- Net shape diamond design & fabrication demonstrated by USS
- Diamond bearing design integration underway; progress continues
- Computational model developed
  – Fluid power to shaft power performance predictions
  – Multi-body dynamics interfacial load characterizations
- Prototype module fabrication pending comprehensive analysis/review
- Dynamometer Test Station upgrades underway
  – Improved hydraulic features & controls
  – H20/WBDF compatibility

Deep Dive into Data

Help to provide insights into common themes in data for geothermal drilling R&D by answering the following:

- **How does your project use data?**

  Q: What types of data are the most important?

  - Motor Requirements: Torque, speed, power, efficiency, …
  - Manufacturer's performance/dimensional specifications for existing PDMs/Turbines.
  - Drilling Configuration/Parameters: BHA specifications wrt well construction requirements.
  - Formation Properties/Parameters: Rock UCS, temperature, abrasivity, …
  - Operating Conditions/Parameters: Drilling fluid flowrates, standpipe pressure, …
  - Drilling Fluid Properties/Parameters: Density, Bulk Modulus, pH, filtration/grain size, …
  - Engineered Material Properties: HSS, PCD, WC, alloy steels, …

  Q Which types are less valuable?

  Biased performance specifications.

  Q Are there techniques you use to improve a data set's value?
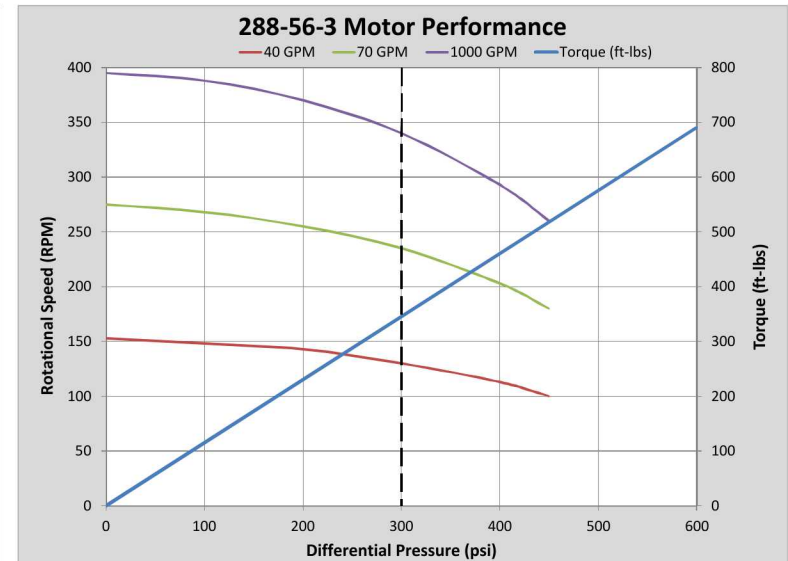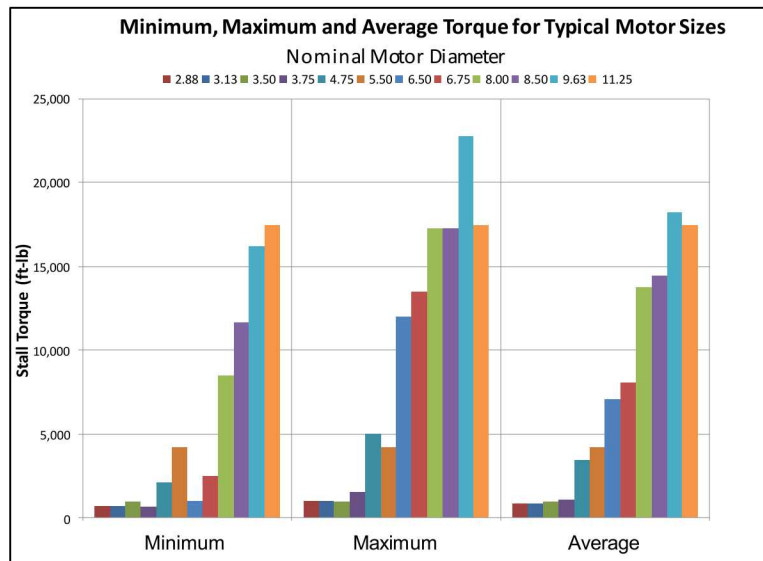
  Validation via computational modeling using first principles.

  Q What does your project do about data gaps?

  Engineering judgment, experience, etc., to reduce uncertainties.

Deep Dive into Data (cont'd)

- **Requirements Definition Example:** Manufacturer's Performance Specifications

Minimum, Maximum and Average Torque for Typical Motor Sizes

288-56-3 Motor Performance

PDM per Toro Downhole Tools

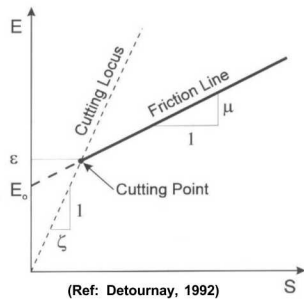# Deep Dive into Data (cont'd)

- ## Validation Example: Downhole Drill Motor Requirements

$$E_s = \frac{Rotary\ Energy\ Expended\ Drilling}{Unit\ Rock\ Volume\ Removed} = \frac{\int T\,d\theta}{V_r} = \frac{2\pi T}{\pi\,r_b^2\,\delta} = \frac{2T}{r_b^2\,\delta} = \frac{8T}{d_b^2\,\delta}$$

$$T = \left(\frac{d_b^2}{8}\,\varepsilon\right)\delta$$

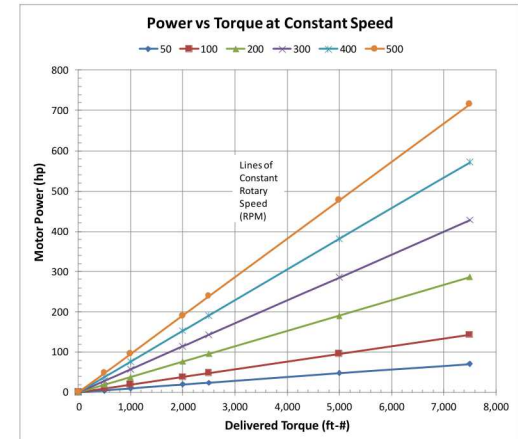$$P_m = \frac{2\pi\,T\,N_m}{(60*550)}$$
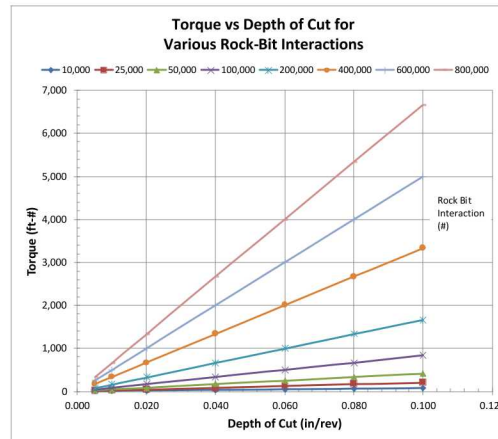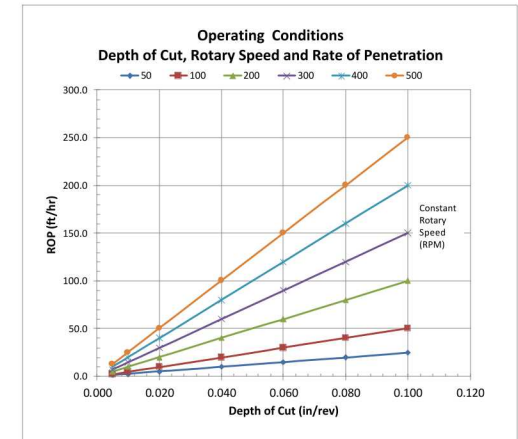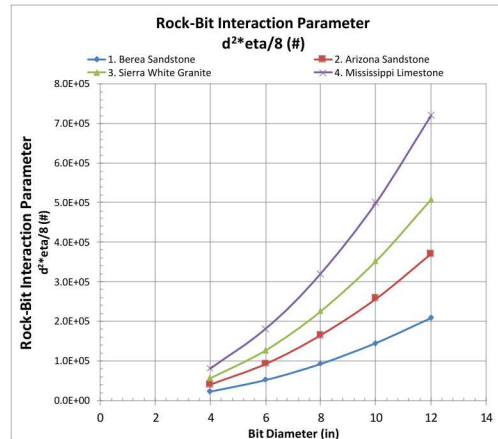

(Ref: Detournay, 1992)

$$E = \frac{2T}{r^2\delta} \qquad S = \frac{W}{r\delta}$$

NOV/Sandia Test Bit, Dec 2011

Reference: Development of a Downhole Piston Motor Power Section For Improved Directional Drilling: Part I – Design, Modeling & Analysis, D. Raymond, GRC Transactions, Vol. 42, 2018.

Deep Dive into Data (cont'd)

- **Do you have drilling data that you are willing to share with the Community of Practice (or more widely) that can be helpful to the FOA's goals?**

  Q: Does this data need to be sanitized before sharing, and if so please describe your standard procedures to remove sensitive information while keeping the data's value.

  Data is subject to internal classification review; Unclassified Unlimited Release (UUR) required for open distribution.

  Q: Are there current methods that you already use to share data (can be drilling specific or for other data types)?

  Sandia-hosted External Collaboration Network (ECN) for proprietary information.

  Q: Does your organization have general concerns and/or specific limitations about sharing this kind of data?

  Access authorizations are needed.

Deep Dive into Data (cont'd)

- **Do you have any issues with curating your own data internally?**
  - Do you host your data on site or subscribe to a service like AWS? Internal.
  - Are there bandwidth limitations (either on the up- or down-load side) and if so how do you deal with these limitations? Data set specific.
  - Do you, as a researcher, have to deal with security concerns for your data? Yes.
- **Do you subscribe to any data service providers?** No.
  - If so, which service(s)?
  - Are these services worth their costs/fees?
  - Are there shortcomings in the current services providers available?
  - Can data from the EDGE COP augment/replace data service providers?
- **Are there current data standards or templates used in the drilling community?** Yes.
  - Are there shortfalls in these standards?
  - Would you propose any new standards that would help the EDGE projects?
- **Is there anything worth discussing about data that wasn't asked above; if so, what? Please discuss.**