Use of elastomers in an oil-filled drilling tool

13th December 2019 – Daniel Minett-Smith C. Eng
Introduction 1

• Rockatek Limited
  • SME Engineering Consultancy based in Gloucester, UK
  • Specialist areas – downhole tools
  • Directional/steering tools, vibration tools, drilling optimisation
  • Oil and gas, geothermal, defence, motorsport, renewable energy
  • Design, analysis and testing in-house
  • Rotary seals, vibration mitigation, fatigue, HTHP
  • 50+ years of industry experience

• Daniel Minett-Smith
  • Chartered Mechanical Engineer
  • Undergraduate and post graduate degree in Mechanical Engineering
  • Core interest, theoretical analysis, materials application, validation through testing
Introduction 2

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One of Rockatek’s rotary seal test fixtures - pressure, rotation, various fluids, elevated temperature
Deep directional drilling

• Technique used to access remote reserves
  • Including geothermal energy
• Multiple wells from single surface location
• Access beneath lakes, towns, mountains
• Typical US land ‘J – type’ well
  • Vertical section (5kft-7kft (1.5-2km) vertical depth)
  • Kick-off
  • Curve (6° - 12°/100ft (30m))
  • Lateral (5kft – 20kft (1.5km – 6km))
Directional drilling tools

• ‘Slide’ drilling tools
  • Directional mud-motors
  • Fixed bend
  • Point bend in desired direction/toolface
  • >90% of drill string is NOT rotating
  • High torque and drag
  • Low rate of penetration (ROP)
  • Limited lateral lengths (typically <6kft (1.8km))
  • Lower cost drilling assembly, incumbent technology
  • Simple deployment
Directional drilling tools

- Rotating drilling tools
  - Rotary steerable tools (RSS)
  - Proportional steering mechanism
  - Often with integrated on-board control logic
  - >90% of drill string is rotating
  - Reduced torque and drag
  - Higher ROP
  - Extended reach laterals (20kft/6.1km and more)
  - Higher investment system
  - Maintenance and capital cost
  - Better directional performance
  - Improved hole quality (easier to run casing strings)

Types –
- Push the bit
- Point the bit
- Hybrid
- Mechanical force
- Hydraulic force
- Erosion
The environment

- **Operating conditions**

  **Challenging**
  - High ambient temperature - up to 200°C
  - High ambient/hydrostatic pressure - up to 30,000psi/200MPa
  - Wide range of drilling fluid chemistry - high pH, diesel, paraffin, saline, etc
  - Abrasive particles entrained in drilling fluid
  - Internal oil chemistry - PAO, esters, etc
  - High material strain – mechanical requirements

- **More favourable**
  - Lack of oxygen
  - Service life is relatively short - minimum ‘bit run’ ~ 200hrs

**COST OF FAILURE IS HIGH**
Elastomer components

• Sealing solutions
  • Mud/oil seals
    • Slow moving volumetric compensation seals
    • High speed reciprocation for actuation
    • Rotary shaft seals (with unsteady rotation rate)
    • Need to prevent contamination of clean hydraulic system
    • 6 degrees of vibration
  • Oil/Oil seals
    • High speed reciprocation for hydraulic power (sometimes passing over ports)
    • Rotary shaft seals
    • More insensitive to limited leakage
    • Wide range of oil viscosity
Elastomer components

• Other applications
  • Vibration Isolation/damping (particularly electrical/electronics)
  • High pressure isolation for parts that need to operate in surface atmospheric conditions
  • Compensation bladders/gaiters/diaphragms
  • Power section rotors
Types of elastomers

- Typically NBR and HNBR perform well
  - Good performance in oil, water, alkaline, $H_2S$
  - Reliable when exposed to mechanical flexure (even after pre-ageing)
  - Can be formed and moulded
  - Able to exceed typical temperature limit in downhole conditions (likely due to limited oxidation/cross linking)
  - Cost effective and available
- FKM1/2/3/5: poor mechanical performance
- FFKM: good resistance to environment (>200°C)
  - Expensive
  - Difficult to mould
What is failure?

• System failure likely before catastrophic component failure
  • Hydraulic leak – loss of pressure, reduced lubrication, cavitation
  • Environment invasion – accelerated erosion, wear, filter blockage
  • Increased clearances – vibration, bit bounce, dynamic events

• Modes and mechanisms
  • Chemical reactions and exposure time
  • Abrasion, loss of material
  • Fracture
  • Tearing
  • Creasing
  • Buckling
  • Expansion
  • Puncture

Pressure will offset temperature effects
Knowledge transfer

Oil and gas professionals, technology transfer

• Geothermal energy
  • 99% of planet earth has a temperature in excess of 1000°C
  • Temperature increases 20°C - 40°C per km depth
  • Oil and gas wells in US land are 170°C (~5km deep)
  • Estimated to cost 5million USD per installed megawatt
  • 50% of cost is in the drilling phase

• Pushing the boundaries, targets
  • Typically much larger diameter
  • Fractured formations lead to major loss of circulating fluid
  • Exposure to high temperature fluids (supercritical in some cases)
  • Exposure to steam
  • Slotted/perforated liner (longer exposure to productive formations)
Future elastomers

• Potential solutions, understanding limitations
  • Need to be tailored to each situation
  • Limitations need to be understood and acknowledged

• Topic for discussion amongst this forum
Design, analysis and testing

Underlying principles
• Chemical reactions and rates
• Solutions and diffusion
• Fracture mechanics
• Effects of hydrostatic and environment pressures

• Mathematical modelling (inc. FEA)
• Laboratory experiments
• Physical testing and validation