GEOTHERMAL RISING CONFERENCE

Success of world's first Hybrid PDC and Particle Drilling bit for Geothermal Applications

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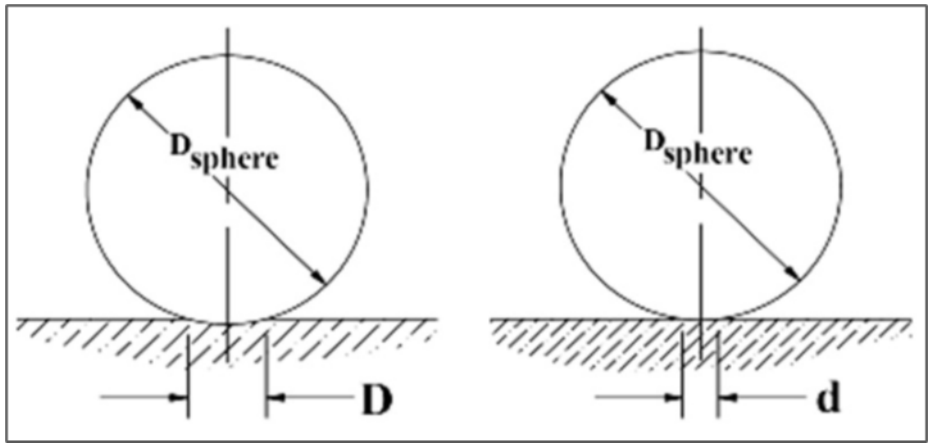
Agenda

- Introduction, What is Particle Impact Drilling?
- Objectives
- Previous work
- Materials and methods
- Results and discussions
- Conclusions and recommendations

Introduction

What is Particle Impact Drilling?

- MV 2 – Mass Times Velocity Squared
- Removes rock by blasting it away with hardened steel particles
- Particles accelerate to 500ft/sec through bit and impact hard/brittle rock 12 Million times per min
- Particle volume 2-3% of total fluid volume
- Theoretical max ROP in Granite greater than 120ft/hr



Introduction

What is Particle Impact Drilling

- Surface Set up

- Automated Control System

Objectives of collaboration project

- Reduce the cost of geothermal wells
- Drill hard igneous rock at greater than 40 ft/hr
- Solve the Particle Drill Bit stability challenges
- On bottom/off bottom indication
- Reduce body erosion

Previous Work

- David Cannon Well 1
- Short runs
- Damage from ricochets
- Damage from touching bottom
- Damage from lateral and Torsional vibration
- Internal Erosion

New Particle Drilling PDT 33

Used Particle Drilling PDT 44

Materials and Methods

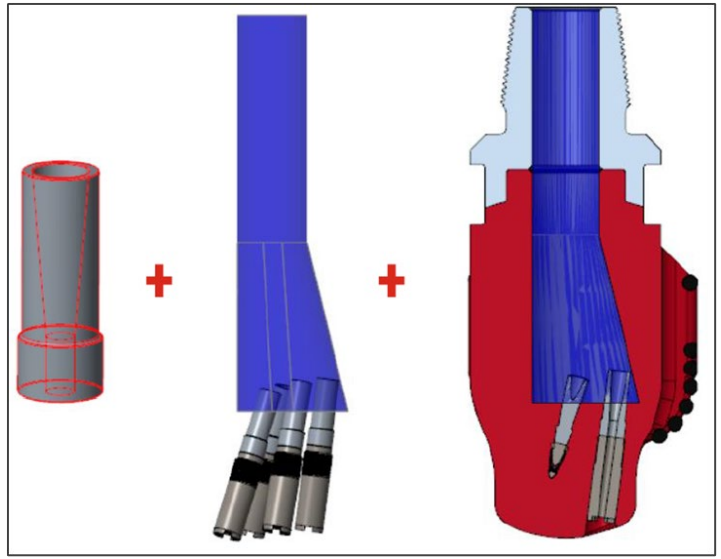
New Hybrid Design

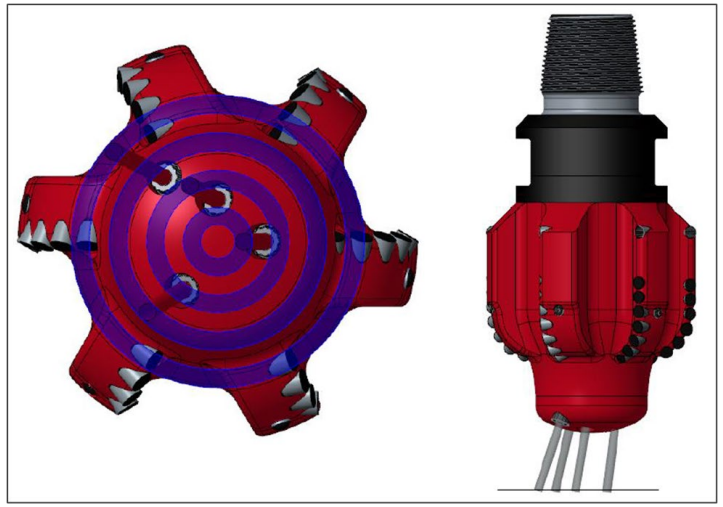
- Joint Workshop/Partnership
- External design
- Particle Pilot, Reamer
- Cut the correct outside diameter
- Reduce lateral and torsional vibration
- Mitigate the pilot touching the bottom of the hol
- Torque, WOB, Diff P signal

Materials and Methods

New Hybrid Design

- Internal design
- 77% of rock removed by particles
- Minimize internal erosion
- Correct bottom hole pattern





Materials and Methods

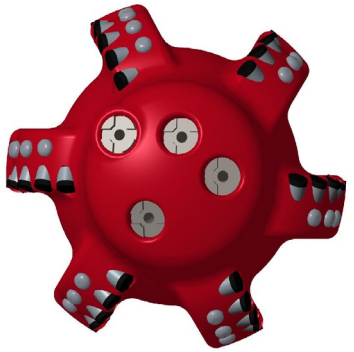
Lab Testing

- First 2 tests, no reamer, establish bottom hole pattern
- Third test, 60 RPM, WOB 2-3000 lbs, ROP 50 ft/hr average, 150 ft/hr instantaneous
- Fourth test, 4-6-8000 lbs, ROP 100 ft/hr
- Fifth test 4-5000 ft/lbs, 75ft/hr steady state

Materials and Methods

Field Testing

- Granite quarry, Marble Falls, Texas
- 45Kpsi “Pink Granite”
- 2 Particle Drilling Hybrids
- 298M in 23 hrs, Average 13 M/hr
- Reamer Damage
- Ricochet damage
- Low WOB, Shallow Depth



Conclusions and Recommendations

Step Change in performance

- PDC Reamer created stability
- Hybrid PD/PDC Reamer created on/off bottom signature
- High ROPs in hard brittle rock
- Cutter layout needed further optimization
- More ballistic nose and body made of cast carbide
- One-piece nozzle to improve manufacturability

Conclusions and Recommendations

Next Steps

- Next Steps
- All design changes have been implemented
- 2 new bits have been built
- Need runs in different igneous rock types

References, Acknowledgements and Disclaimers

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- **REFERENCES**

- Self, J., Stevenson, M., Roberts, T., Rivera, R.,Onderko, L.,. "Fixed Cutter Bit & Cutter Technology Set New Performance Standards for Geothermal Drilling." *Proceedings Geothermal Rising Conference Transactions Vol45, (2021).*

Thank You!