The effects of flame-heating on rock strength: Towards a combined drilling technology

Edoardo Rossi\textsuperscript{1,2}, Michael A. Kant\textsuperscript{2}, Philipp Rudolf von Rohr\textsuperscript{2}, Martin O. Saar\textsuperscript{1}

\textsuperscript{1}Geothermal Energy and Geofluids group, Institute of Geophysics, ETH Zürich, Sonneggstrasse 5, 8092 Zürich, Switzerland
\textsuperscript{2}Transport Processes and Reactions Laboratory, Institute of Process Engineering, ETH Zürich, Sonneggstrasse 3, 8092 Zürich, Switzerland

1 Motivation

In a geothermal project, the drilling costs are responsible for \( \approx 40\% \) of the overall costs. Indeed, drilling in hard rocks with conventional drilling methods (roller-cone and PDC bits) implies very high drill bit wearing and low rates of penetrations (ROP).

\[ C_{d,i} = \frac{C_{b,i} + C_{r}\left(T_{d,i} + T_{i,l} + T_{c,i}\right)}{\Delta D_{i}} \]

when: \( \begin{cases} 
\text{ROP} \uparrow & \Rightarrow T_{d,i} \downarrow \\
\text{bit wearing} \downarrow & \Rightarrow T_{i,l} \downarrow 
\end{cases} \quad \Rightarrow \quad \text{Drilling costs} \downarrow \]

\( C_{b,i} \): cost of the bit run \textit{i} \quad \textit{[CHF]} 
\( T_{d,i} \): trip time \textit{[h]} 
\( C_{r} \): rig cost \textit{[CHF]} 
\( T_{c,i} \): connection time \textit{[h]} 
\( \Delta D_{i} \): drilled distance \textit{[m]} 

2 Concept

Combine conventional drilling with thermal drilling methods to drill through hard rocks:

- Flame treats the rock surface
  - Thermal weakening of the material (cracking, mineralogical changes…)
- Cutting tools export the weakened material
  - Lower weight on bit (WOB) and torque \( \rightarrow \) lower bit wearing rate
  - Increase rate of penetration in hard rocks (ROP)

3 Preliminary Experiments

Experiments on rate of penetration (ROP) in thermally treated Granite showed the effectiveness of the presented method. Granite samples are flame-treated at different temperatures.

- Increase of ROP for \( T > 400{\degree}C \)
- At 1000{\degree}C, four times faster drilling

\[ \text{Fig. 2: Relative rate of penetration in Granite at different treatment temperatures.} \]

4 Application

Design of a combined thermo-mechanical drill head

- 6.5-inch drill head
- 50 kW burner. Combustion fluids: methane and oxygen
- Drilling cutters next to flame-jets
- Air shielded-flame nozzles:
  - Prevent thermal wearing of cutters
  - Enhance flame heat transfer in aqueous environment

\[ \text{Fig. 3: Combined thermo-mechanical drill head and air shielding.} \]

References