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

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1 Motivation

In a geothermal project, the drilling costs are responsible for ≈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).

$$C_{d,i} = \frac{C_{b,i} + C_r\left(T_{d,i} + T_{t,i} + T_{c,i}\right)}{\Delta D_i}$$

when: $\begin{cases} ROP \uparrow & \Rightarrow \quad T_{d,i} \downarrow \\ \text{bit wearing} \downarrow & \Rightarrow \quad T_{t,i} \downarrow \end{cases}$ $\Longrightarrow$ **Drilling costs ↓**

$C_{b,i}$: cost of the bit run i $[CHF]$
C_r: rig cost $\left[\frac{CHF}{h}\right]$
$T_{d,i}$: drilling time $[h]$
$T_{t,i}$: trip time $[h]$
$T_{c,i}$: connection time $[h]$
ΔD_i: drilled distance $[m]$

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 → lower bit wearing rate
  → Increase rate of penetration in hard rocks (ROP)

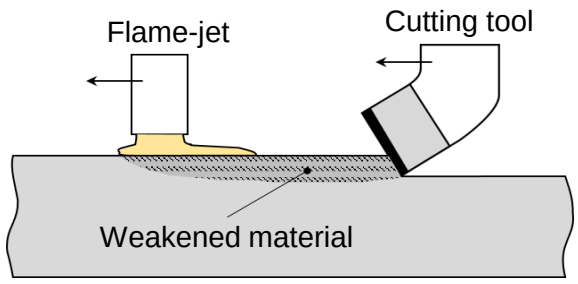

Fig. 1: Material weakening due to flame thermal treatment and cutting tool used to export material.

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°C
- At 1000°C, four times faster drilling

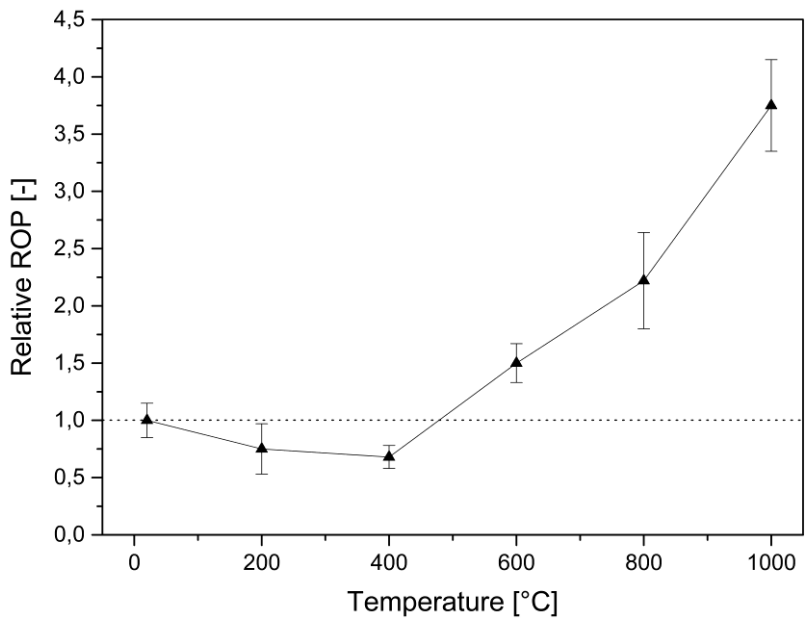

Fig. 2: Relative rate of penetration in Granite at different treatment temperatures.

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

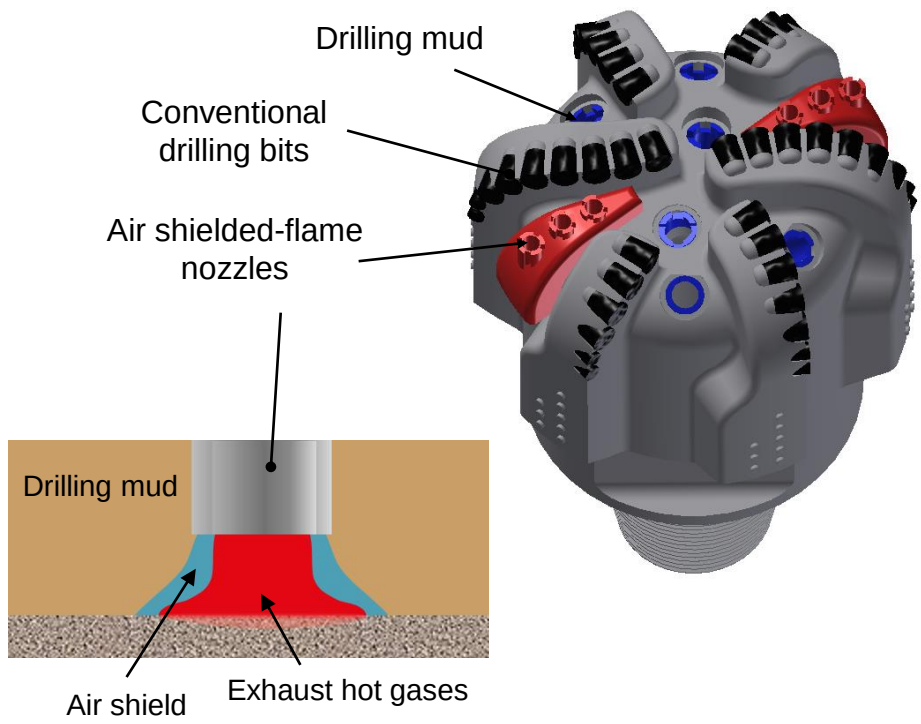

Fig. 3: Combined thermo-mechanical drill head and air shielding.

References

[1] Gill J.A., Hard Rock Drilling Problems Explained by Hard Rock Pressure Plots, 1983. In IADC/SPE Drilling Conference, New Orleans, Louisiana, SPE-11377-MS.

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