A combined thermo-mechanical drilling method: Laboratory experiments towards its implementation in the field

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A combined thermo-mechanical drilling method: Field implementation and demonstration

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ABSTRACT

Introduction

Global electricity production from geothermal heat relies on finding cost-effective solutions to enhance drilling of deep geothermal wells. Conventional drilling methods, based on mechanical removal of the rock material, feature high drill bit wear rates and low rates of penetration, especially in hard rocks (Angelone & Labini, 2014). This, in turn, results in increased specific well costs (€/MWh) and therewith a decreased economic appeal of deep geothermal projects. Hence, in order to favor/promote the use of deep geothermal heat for electricity production, advances in drilling performance for deep wells must be attained/achieved. In this respect, alternative drilling concepts are investigated worldwide with the aim of boosting the drilling performance and reducing the overall project costs. An interesting approach to effectively remove hard rock materials is thermal spallation drilling. This method uses a hot jet, impinging on the rock surface, to induce high thermal stresses which are responsible for crack initiation and propagation and therewith they are able to trigger the thermal spallation phenomenon at the rock surface. This excavation mechanism showed substantially higher penetration rates in hard rock materials, compared to conventional rotary drilling methods. Nevertheless, the thermal spallation onset cannot be established when soft materials or stress-relieving fractured rock formations are encountered.

Therefore, with the aim of improving the drilling performance in both soft and hard rock materials, we investigate a combined drilling method where conventional, rotary drilling is assisted by a heat source (Rossi et al., 2018). In this manner, during drilling in hard rock materials, thermal spallation can be used to achieve improved penetration rates, compared to conventional mechanical drilling methods. On the other hand, when softer rocks are encountered, the material is thermally treated with the flame before being removed by the drilling cutters. A prior thermal weakening of the material therefore facilitates the mechanical removal of the rock and enhanced drilling performance can be achieved. Laboratory experiments demonstrated that the thermal assistance induces considerable improvements for the subsequent removal of the rock material. In order to prove the applicability of thermal spallation drilling in conventional drilling systems and the related performance improvements compared to state-of-the-art methods, a field demonstration of the technology is carried out in a full-scale drill rig.

Experiments on drilling performance

Experiments in the laboratory are conducted to show the drilling performance improvements of assisting conventional drilling via a pre-treatment of the rock material. In order to show this, we investigate the interaction of a drilling cutter with a soft sandstone and a hard granite after thermally treating the material and compare the results to untreated material conditions. The combined thermo-mechanical drilling method is experimentally modelled by a thermal treatment of the rock samples (a sandstone and a granite) which includes a heating process until a maximum temperature of 800°C, followed by a fast water cooling until ambient temperature. After this, scratching experiments are performed on the rocks and the two main cutting performance parameters, removed rock volume and wearing rate, are measured. A comparison between the

proposed thermo-mechanical drilling method and conventional mechanical drilling is carried out by analysing the cutting performance parameters for the material after the thermal treatment and under baseline conditions.

In Fig. 1, the cumulative removed rock volume and the worn tool volume are shown along the distance of the performed scratch. As shown in Figs 1.a and 1.b, the drilling performances in granite are considerably enhanced by thermally treating the material prior to the mechanical removal performed by the drilling cutter. Furthermore, the wear rate of the drilling cutter is significantly reduced for the whole scratching distance range. The same experiments are performed in the sandstone material, as shown in Figs 1.c and 1.d. This softer rock, shows overall improved removed rock volumes when the material is thermally treated in the oven, especially for large scratching distance values.

Thus, the presented results show that the combined thermo-mechanical drilling method features substantially increased penetration performance, compared to conventional drilling method. This is particularly evident in the hard granite material, where the rock removal is greatly facilitated with additionally lower induced wear rates of the drill cutters. Overall, laboratory experiments on the combined thermo-mechanical drilling concept showed evidences for greatly improved drilling performances, especially for the hard granite material. Hence, the field implementation of the drilling technology aims to show the applicability of a thermal assistance to conventional drilling systems with a focus on the occurring geothermal well cost reduction.

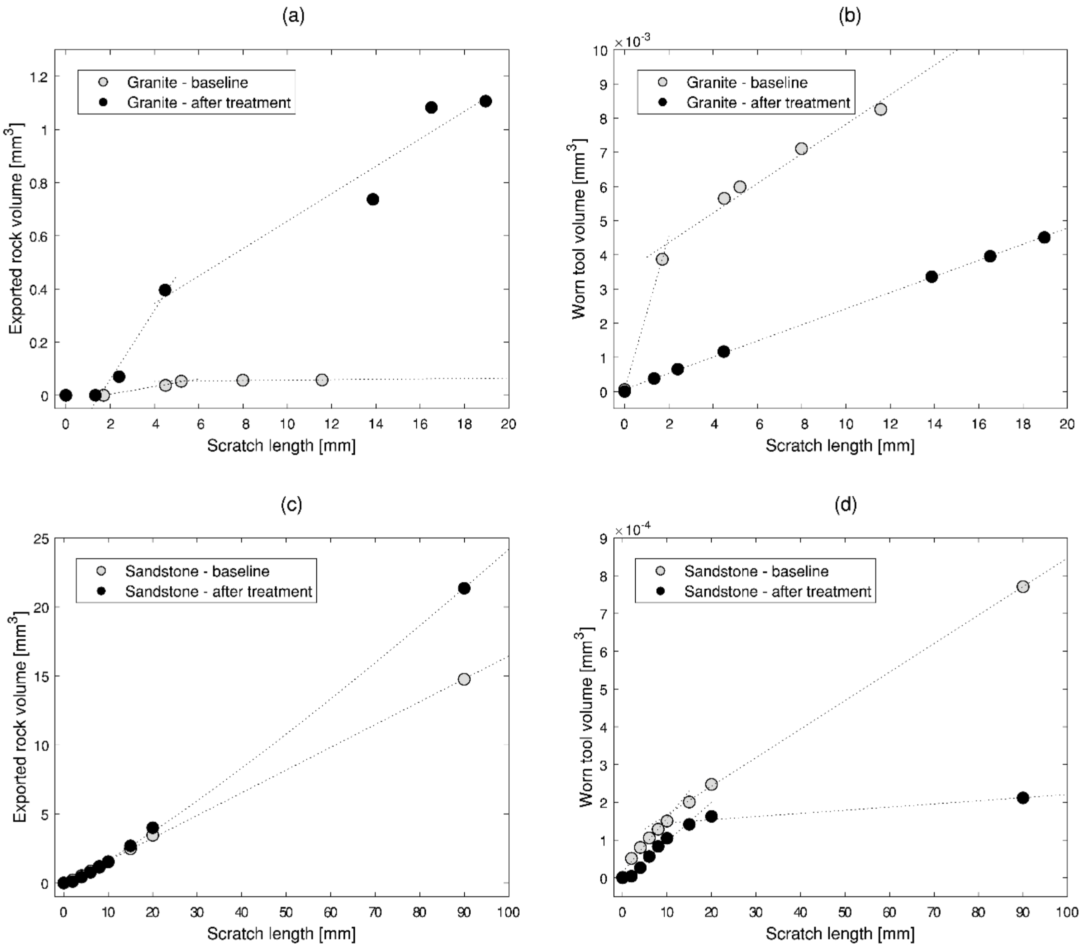

Fig. 1: Removed rock volume and worn tool volume after scratching experiments on a granite (a) and (b); and a sandstone (c) and (d) for the untreated material case (gray circles) and after the thermal treatment (black circles).

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