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Innovative Thermal Drilling Technology based on Laser Drilling: fundamental investigation of laser-rock interaction and field applications

Shahin Jamali, Volker Wittig, and Rolf Bracke
International Geothermal Centre, Advanced Drilling Technologies, Germany (shahin.jamali@hs-bochum.de)

The interest in geothermal energy has been growing substantially over the past years but more widespread exploitation of deep geothermal energy is still dependent on a novel, adequate drilling technologies that may overcome the challenges in drilling into geothermal reservoirs. Main technical challenges of today hard rock drilling, resulting in poor economics, mainly include low rates of penetration (ROP), limited delivery of energy to the bottom hole assembly (BHA), high bit wear and thus low tool life.

Thermal drilling technologies based on laser supported drilling has been under development in GZB Bochum, as a novel drilling technology, to overcome the latter problems and improve the current drilling process used in hard rock drilling.

laser-water-jet (LWJ) is used to deliver the thermal energy to the rock surface. laser-water-jet is defined as a laser beam coupled into a laminar water-jet using the physical principle of total internal reflection. The LaserJet is protected and shrouded by air from the drill head exit nozzle until it reaches the rock surface. The beam induces the intended thermal stress by a sudden increase in temperature, which consequently will result in rock's mechanical strength reduction and spallation. Thermal spallation is defined generally as applying excessive rapid thermal energy, rather than mechanical stress and penetration, onto a rock surface resulting in thermal stresses that do initiate weakening and fragmentation of the solid into spalls, which are disk-like flakes by expanding the existing flaws in the rock structure. The spalls, which have an average size of 0.1 to 2 mm, will be dislodged from the rock surface and washed away by means of cutting transport. As the process goes on, the now softened (thermally weakened) hard rock enables the optimized mechanical drill bit to assist in the process and crush the rock efficiently. The GZB developed, multi sensoric acoustic system (MOUSE) has been used as the main measurement system to control, quantify, and evaluate the process during and after the experiments.

Certain rock types have been investigated to study the laser-rock interaction, the rock thermal spallation, and thermal softening(weakening) processes. Main parameters such as energy requirements, melting and vaporization zones, discharge type like continuous or pulsed, peak power, intensity, repetition rate, radiation time and rock sedimentation orientation in terms of single pulse, lines, and circles have been targeted during such experiments.

The over one thousand LaserJet Drilling (LJD) lab experiments result including fundamental investigations on laser-rock interaction, thermal rock softening(weakening) and thermal spallation processes will be discussed in detail. Furthermore, an evaluation of LaserJet drilling acoustic emission (AE) results will be discussed and presented.