Thermally induced Laser rock drilling: fundamental laser-rock interaction lab tests and its integration into a full-scale drilling Process

Shahin Jamali[a], Volker Wittig[a], Rolf Bracke[a]

a. International Geothermal Centre

Shahin.jamali@hs-bochum.de

Keywords: Laser Drilling, Thermal Drilling, Thermal spallation, Thermal rock softening, Laser-rock interaction

ABSTRACT

The interest in geothermal energy has been growing substantially over the past years, but a more widespread exploitation of deep geothermal energy is still dependent on 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 rate of penetration (ROP), limited delivery of energy to bottom hole assembly (BHA), high bit wear and thus, low tool life. Thermal drilling processes, e.g. based on laser technologies, has been under development at GZB in Bochum, to overcome the latter problems in hard rock drilling by applying more energy in form of thermal energy into the rock.

Laser-water-jet is used to deliver thermal energy to the rock surface. laser-water-jet operates via a laser beam coupled into a water-jet using the physical principle of total internal reflection. The LaserJet is protected through an air shrouding method from the drill head exit nozzle till it reaches the rock surface. The laser beam induces thermal stresses by rapid increase in temperature, which consequently results in rock's mechanical strength reduction and also its spallation. The spalls will be washed away and flushed out by traditional means of cuttings transport via the drilling mud system. the possibly remaining, now softened hard rock elements, will be crushed and removed with the optimized mechanical drill bit, assisting in the overall thermal drilling process.

Various factors mainly including mineral composition, porosity, fracturing and thermal expansion have an effect on determining the rock strength. In case of high-temperatures, thermal expansion of rock minerals has a great influence on values of rock strength which leads to structural changes, deformations and spalling, fracturing, softening and physical properties changes (velocity of propagation of elastic waves) in rock.

Four main rock types have been investigated during the experiments to study laser-rock interaction, rock spallation and weakening process. In each set of experiments, one of the possible processes and parameters effecting the LaserJet-rock interaction has been studied from primary to complex parameters including: Energy requirements, melting and vaporization zones, rock sedimentation orientation, laser discharge type like continuous or pulsed, peak power intensity, repetition rate and radiation time in beam radiation forms of single pulse, lines and circles.

Parallel, GZB developed a new, multi sensoric MWD system (MOUSE) as the main control mechanism to quantify, monitor and evaluate the process during rock breaking and drilling. Acoustic emission signals generated from the bit-rock interface have been monitored during the experiments. Every recorded signal has been characterized based on combination of signal features which are specifically developed numerically for the process to identify various drilling

and rock cracking situations (spallation and rock softening in this case study).

This paper discusses the LaserJet Drilling (LJD) lab tests results including fundamental investigations on laser-rock interaction / destruction process and Laser drilling AE analysis and evaluation process. Furthermore, the complete Laser drilling system setup including BHA, and LJD field tests will be discussed and presented.

REFERENCES

Shahin Jamali, 2018. Principle investigation of LaserJet Drilling process and its rock interaction. Ph.D. thesis, Ruhr University Bochum – International Geothermal Centre, Bochum, Germany.