PLASMABIT – Innovative drilling and casing system

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Keywords: Drilling, Casing, Thermal, Plasma.

ABSTRACT

Currently, the price of the geothermal well is increasing with its depth exponentially due to friction, tripping and other negative features. PLASMABIT technology is being developed to drill with a constant speed, without need to change a drilling bit on regular basis, working in a HPHT environment. Therefore the drilling cost using PLASMABIT is rising only linearly with the drilling depth. As a result, the overall drilling cost, infrastructure cost and drilling time are radically cut. PLASMABIT technology is based on high-energy electric plasma, thermal treatment and thermo-hydraulic explosive process for the fragmentation with the aim of increasing the productivity of the drilling process. The key effort is to develop the technically and economically efficient technology with constant penetration rate for the deep drilling.

1. INTRODUCTION

Worldwide, there have been several attempts to develop breakthrough cost-effective deep drilling concepts. Their common aim is to significantly decrease the overall price of the drilling process, particularly to keep the high constant speed, energy efficiency and shorter drilling time. Advantages of these technologies should rise with a drilling depth.

There are above twenty innovative boring technology candidates of different maturity and degree of proving such as: laser, spallation, plasma, electron beam, pallets, enhanced rotary, electric spark and discharge, electric arc, water jet erosion, ultrasonic, chemical, induction, nuclear, forced flame explosive, turbine, high frequency, microwave, heating/cooling stress, electric current and several other.

None of the above mentioned is currently proved to be effective in real conditions and none is solving the problem in complex including the energy and material transport from 5 to 10 km technically and economically. Referring to state-of-the-art of the technique, only the most promising technologies will be described, as well as those which are now being proved. The technologies can also be evaluated with respect to properties such as specific energy required to extract one cubic centimeter, maximum output applicable at borehole bottom, or maximum achievable boring speed.

2. NON-CONVENTIONAL TECHNOLOGIES

The following examples of extrapolation of non-revolutionary solutions, which still do not have the properties of radical innovation necessary for deep drilling systems, can be quoted:

2.1 Casing drilling rotary systems

Transfer of torque and temporary stability of the borehole is secured by casing rotation:

- Boring by help of rotary casing (Tesco Casing Drilling).
- The technology applying composite coil piping with electric line for drive (Halliburton/Statoil-Anaconda).

2.2 Mechanical water jet disintegration

Most patents refer to water jet rock cutting. Different modification variants are described, e.g. utilization of cavitation, turbulent processes, combination with mechanical processes, etc. Among other US Pat 5,291,957 describes the water jet process combined with turbulent and mechanical processes.

2.3 Mechanical water jet disintegration

Considerable progress towards significant innovation is shown in US Pat 5,771,984 authored by Jefferson Tester et al: "Continuous drilling of vertical boreholes by thermal processes: rock spallation and fusion", where energy for the boring equipment on the bottom is supplied by pressurized water for borehole flushing, and that for turbine drive.

This invention is the basis for Potter Drilling LLC Company, where prototype tests are underway already. The research was held by Robert Potter and Jefferson Tester at Massachusetts Institute of Technology and subsequently at Potter Drilling company.

By the effective impact mode settings, a spallation mechanism is an effective and gainful to achieve a main task. However, in each simulation model, the simplification leads to a validation of every tested and modeled case in order to identify energy and kinetics forces to be used. This technology has one of the lowest energy needed to disintegrate one cubic centimeter. On the other side, the main drawbacks are that spallation effect is not possible in all kinds of rock, the working downhole temperature interval is very narrow and restarting of the process in high pressure environment is very difficult.

2.4 Laser and microwaves

During the recent decade, intense research has been made into utilization of high energy laser beams for rock disintegration. Primarily, conversion of military equipment is concerned. Laser energy is used for the process of thermal spallation, melting, or evaporation of rock.

In terms of physics processes of material evaporation solutions, there are laser beam units with high energy (MW to TW), but lasting only microseconds to nanoseconds, some units exceptionally in femtoseconds range. These principles are not practically applicable for drilling processes, but there are good theoretical reference source for theoretical work on the processes of evaporation, agglomeration, condensates, clustering, as well as the energy flow processes shielding the arc from the evaporated rock. Article by Bulgakov, N.M.: Pulsed laser ablation of solids: Transition from normal vaporization to phase explosion describes a quick and explosive vaporization of the material under the effect of intense heat flux from laser beam.

Using laser vaporization has, however, significant shortcoming. Laser beam is essentially a point source of heat. To cover the whole area beam should be defocused, which declines at a significantly its power density (W/m2) or the beam must be scanned over the surface and thereby delivered energy falls per unit area of 2 or 3 orders of magnitude. The method is being developed by company Foro Energy. This technology requires combination of classical mechanical drilling and weakening of the rock by laser. Similarly, major reference source is the use of electromagnetic waves in millimeter range for melting, for evaporation of rocks for the purpose of drilling, described in the article MITEI Seed Fund Program: Millimeter Wave Deep Drilling for Geothermal Energy, Natural Gas and Oil[5] difficult.

2.5 Electric spark discharge through rock material (Plasma Channel Drilling)

Most The methods utilizing electric discharge are based on long-term experience gained in other application areas.

Originally, the research was conducted in Tomsk, Russia and afterwards in Scotland and subsequently in Norway. This method is further being developed by the Norwegian University of Science and Technology. A high voltage (200kV - 300kV) with sharp rise edges (under 200 ns) is used to create electrical breakdown in rock and short high energy spark is used to create a compressive stress pulse in the rock substrate. This process creates cuttings, where the size of cuttings in not under the control and size can spread between 1 mm to some centimeters. This is the reason that this technology could not act alone, but must be combined with classical mechanical drilling for comminution and flushing with standard mud technologies.

2.6 Electrical Plasma Torch

This technology is over 40 years old and is based on heating of gases by electrical arc inside the generator. The plasma torch generator passes gas such as air, argon, nitrogen, water steam, through the electrical arc to create a plasma “torch”. US Patent 4,055,741 Plasma arc torch by Bykhovsky, D.G. et al describes vortex plasma generators. Their common disadvantage is temperature limitation by 5,000 - 7,000 K.

The torch technologies have some drawbacks, which caused that efforts to use plasma torches for drilling purposes were, until now, unsuccessful. The main drawback is that the plasma torch generator is using intermediate gas heating with cascade of non-efficient heat transfers. First, the relatively short electrical arc heats the vortex moving gas, where the radiative energy is lost to the walls of generator and the expanding hot gas through the nozzle creates the torch. Then the torch impacts the rock material and the heat transfer with lower efficiency delivers energy used for disintegration process.

2.7 Direct electric arc plasma (PLASMABIT technology)

The electric arc generated between electrodes is formed and pushed out of the generator by the action of a magnetic field and hydro-mechanic forces toward contact proximity to the rock. This concept enables, that significant part of the arc directly heats the target rock material. Moreover, the substantial portion of the heat flow from the arc is headed to the destruction of the material. Additional benefit is, that the arc is formed and guided so that a significant part of the electric arc is outside of the plasma generator which significantly reduces the need for cooling and minimizes the energy losses.

Direct influence of the arc on the rock makes possible to completely eliminate the intermediate gas heating, which is the main drawback of conventional plasma torch generators. Thermal energy of direct electrical plasma and kinetic energy flow in pulse mode exceeds several times minimum requirements for rock disintegration.

3. RADICAL INNOVATIONS OF DIRECT ELECTRIC ARC PLASMA TECHNOLOGY

The radical innovations of the PLASMABIT technology are as follows:

- Arc with temperatures of tens of thousands of degrees Kelvin heats directly the rock, especially the radiation component, without heating of intermediate gas (as in conventional plasma torches, which reduces the efficiency of heat transfer into the rock).
- Area-wide, relatively homogeneous heat flow from spiral form long arc on the whole surface for high-intensity disintegration process.

- Rotating arc spiral in addition to the thermal influence having the centrifugal pump function removing disintegrated rock.
- Compared to conventional plasma torch technology, direct electric arc plasma technology allows the use of electrohydraulic phenomenon, generating shock waves and pressure and uses generated mechanical power for the destruction and transport of disintegrated rocks away from the area between the arc and the rock.
- The system allows the generation of pressure wave mode and pulsed magnetic field increasing the power of generated current pulses with a time transformation of charging/discharging from 4 to 7 orders of magnitude (s/μs), thus allowing an increase in instantaneous pulse disintegration effect with power pulses in scale of MW or GW.
- System allows obtaining electrical and/or optical characteristics of the arc in the interaction with the rock to derive indirect sensory information (e.g. online spectroscopy, etc.).

4. PLASMABIT SUBSYSTEMS

This comprehensive system consists of several complementary subsystems each solving a specific task during drilling process:

PLASMABIT Rock disintegration system - Non-contact drilling process based on innovative approach modified for extreme thermal, physical and pressure conditions.

ContiCase™ - PLASMABIT continuous Casing-While-Drilling add-on - Efficient casing production from is immediately reinforcing inner wall and preventing its collapse.

PLASMABIT Interface with surface subsystem - Advanced cabling solution for energy and material supply for PLASMABIT rock disintegration system enabling real-time Measuring-While-Drilling with online connection to down hole drilling activities.

PLASMABIT Movement and anchoring subsystem - Autonomous movement and anchoring subsystem works in underground extreme conditions of high temperatures and high pressure securing synchronization of the drilling process with surface material supply channels.

Figure 1: PLASMABIT system

4.1 PLASMABIT Rock disintegration subsystem

Different independent energy generators in the PLASMABIT system ensure energy for efficient rock disintegration process. The subsystem works continuously and reliably for months. Rock disintegration subsystem ensures:

- Destructive spatial plasma impact
- Full drilling diameter impact
- Computer control over impact and speed of disintegration
- Enhanced electrode guarding principle
- Working reliability
- Extremely resistant cooled electronics
- Emphasis on failure prevention

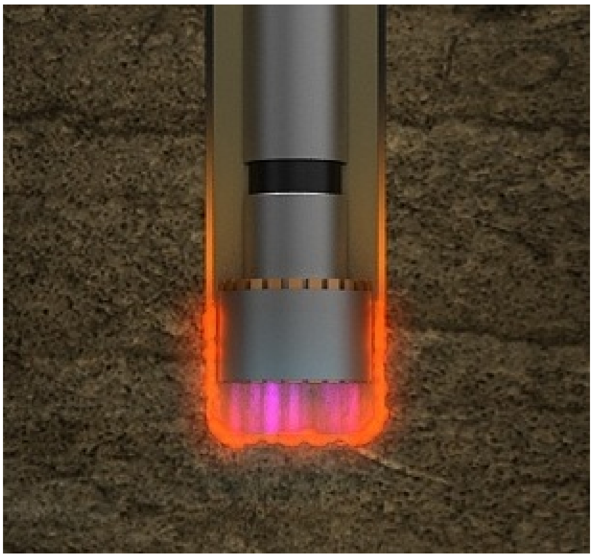

Figure 2: Rock disintegration subsystem in action

4.2 ContiCase™ - PLASMABIT continuous Casing-While-Drilling add-on

ContiCase offers several significant advantages:

- **Improved stability** of the boreholes for the horizontal, directional and vertical wells
- **One-step process** - Construction of the borehole parallel to drilling without tripping
- **Management of casing** - Advanced control electronics secures ability to vary the thickness of the casing. Therefore there is a direct relationship to the casing strength and maximum production speed
- **Temporary casing and increased wellbore stability** - Ability to create a melted rock crust on well border – vitrification, smooth circular cross-section

4.3 PLASMABIT Interface with surface subsystem

Interface to coiled tubing solution enables simplification of whole drilling process and logistics.The subsystem is based on multi-channel cabling system for:

- Electrical power supply for PLASMABIT rock disintegration subsystem
- Electrical power supply for PLASMABIT Movement and anchoring subsystem
- Demineralized water supply for PLASMABIT rock disintegration system as a plasma media for thermal disintegration
- Water supply for down hole cooling processes
- Optical fibres and Power-Line-Communication (PLC) for real-time controlling, measuring, sensing, logging and system information gathering of the drilling process
- Carrier rope for cable strength, weight and elasticity support

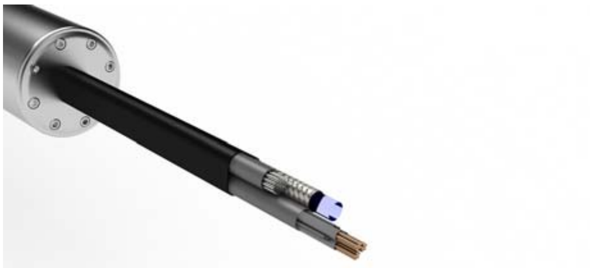

Figure 3: Detail of Interface subsystem

4.4 PLASMABIT Movement and anchoring subsystem

Fully computer-controlled tractor system secures continuous movement of the PLASMABIT rock disintegration system with the drilling process with the following requirements:

- Anchoring system holding whole weight of the PLASMABIT rock disintegration system with no load on the cabling system
- Movement system securing movement of the PLASMABIT rock disintegration system with the drilling process
- Movement system securing synchronization with surface and cabling supply system
- Computer controlled and synchronized with all drilling activities
- Movement and anchoring system securing no load and twist on inner cabling of the PLASMABIT rock disintegration system

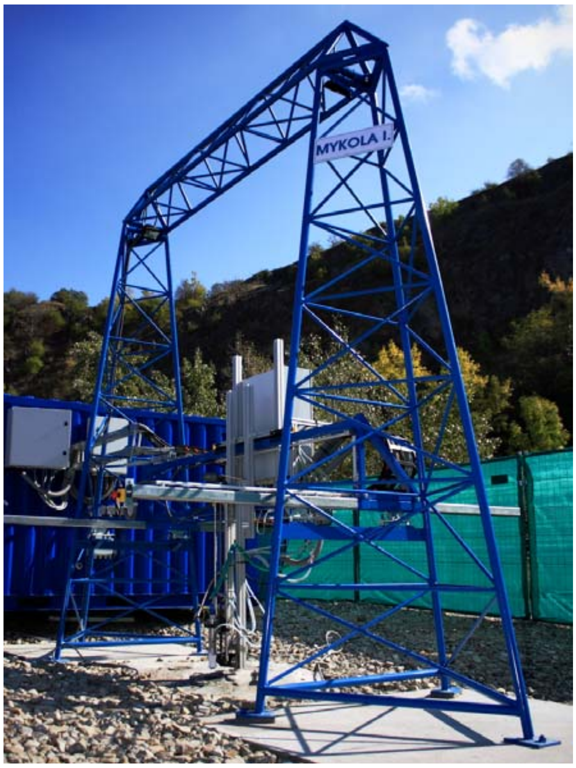

Figure 4: PLASMABIT demonstration site

5. CONCLUSIONS

PLASMABIT is in the stage of demonstration prototype in Deep Drilling Center in Bratislava, Slovakia. This groundbreaking technology for geothermal drilling leads to new implementation possibilities. It is a radical abandonment of the conventional drilling technologies with connected tubes in long strings. The patented technology concept is the result of long year’s effort to solve the problem of the exponentially growing price in relation to the depth drilling and thus enabling real exploitation of geothermal energy for electrical power generation.

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