Newsletter
February 2023

Novel Drilling Technology Combining Hydro-jet and Percussion for ROP Improvement in Deep Geothermal Drilling

Editorial

We are currently living in an interesting era during which climate urgency and energy transition are a common topic among the global public. The ORCHYD project plays a critical role in facilitating energy transition to a sustainable resource and we are happy to welcome you to our first newsletter. This newsletter will brief you about the technological advancements made in this project. Thanks to the contributions from our partners, we were able to meet all the objectives of the first reporting period. It is our pleasure to inform you that we have passed the first review from the European Commission.

It is evident that deep geothermal energy is a leading candidate in providing clean, sustainable, and non-intermittent energy. However, drilling for geothermal energy constitutes to nearly 50% of the total expenses creating a bottleneck in scaling the utilisation of this resource. One of the main reasons is the drastic reduction in the drilling rate through hard crystalline rocks in particular those found deeper than 4 km. The ORCHYD project is like turbocharging geothermal drilling, taking it from a crawl to a sprint, with the goal of increasing the drilling rate by four. We combine high pressure water jetting with percussion drilling and exploit the stress release effect to achieve this. A downhole intensifier and a mud-driven hammer will be used to drill through hard rocks, granites in particular. The fully fluid-driven prototype combining the intensifier and the hammer will be tested at our laboratory in Pau, France, using a full-scale pilot drilling bench.

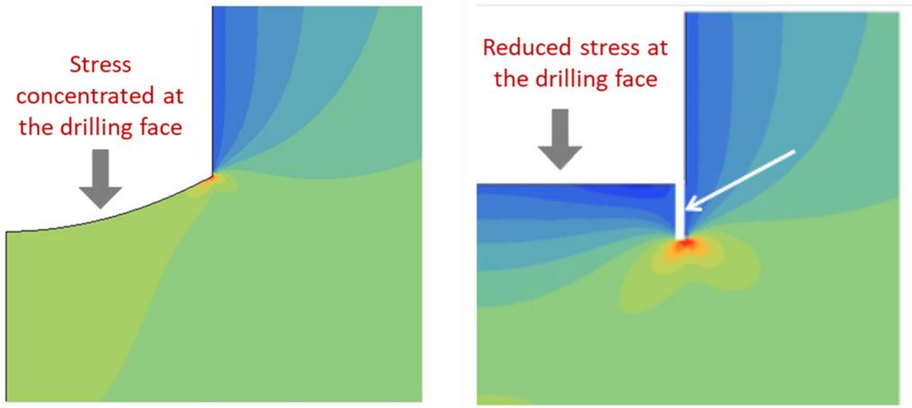
The strength of our consortium is to combine high-level experimental, theoretical and numerical approaches. We have already been able to show a 170% improvement in penetration rate under representative test of medium deep drilling conditions. We are pushing the limits in geothermal drilling technology, and we are excited to continue sharing our progress with the broader community. The ORCHYD project is making significant progress in developing a game-changing technology for geothermal drilling. Join us in our mission to create a sustainable path for energy transition by contacting us at contact@orchyd.eu to learn more. Together, we can make a real difference in the fight against climate change.

Enjoy the read,

ARMINES/Mines Paris-PSL
ORCHYD Project Management Team

Innovative drilling method

The ORCHYD project is tackling one of the biggest challenges in geothermal drilling - the slow progress in hard, deep granite rocks. These rocks, found at depths greater than 4 km, are notoriously difficult to drill through using conventional rotary methods, which typically achieve a rate of only 1-2 m/hr.



Principle of the stress release process

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We believe that percussive drilling has the potential to significantly improve the drilling rate in these hard granite zones. To take this to the next level, we are taking a revolutionary approach by combining percussive drilling with high-pressure water jet (HPWJ). By doing so, we aim to harness the power of both methods and overcome the challenges posed by the increasing confining stresses at depth.

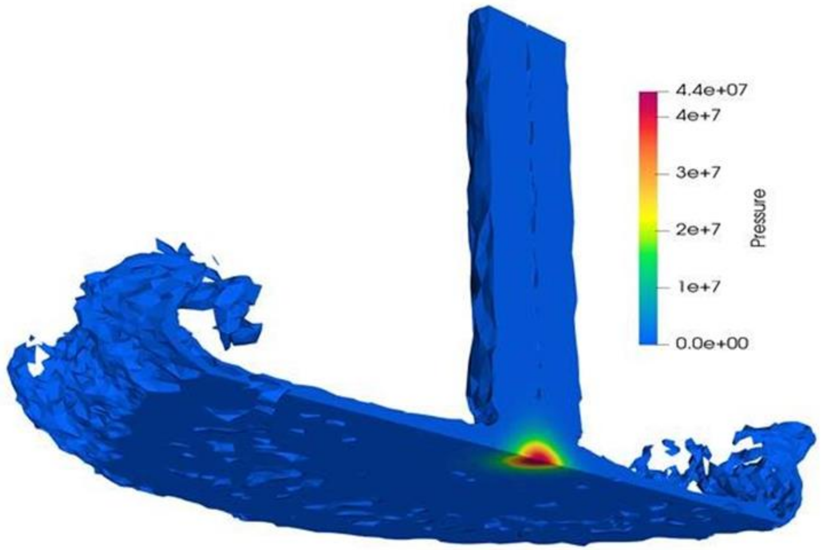
The HPWJ is an innovative technique that creates a peripheral groove on the rock surface, up to 2 cm deep. This groove helps to isolate the rock section from the surrounding stress, reducing the energy required to break it and increasing the drilling rate. Additionally, the groove creates a free surface that reflects the shock waves during percussion, which further aids in rock breakage. The ORCHYD project is studying the phenomena through both numerical simulations and experimental works, in order to validate and optimize the performance of the HPWJ technique.

Self-relief drilling

It was shown through numerical simulations that the confining stress regimes on the rock surface in downhole conditions can be reduced by creating a peripheral groove. This concept known as self-relief drilling emulates the drilling conditions closer to the surface by reduction in the rock stresses and the energy required to break them.

Simulation and optimisation of the jetting process

One of the key areas of research in the ORCHYD project is the downhole submerged High Pressure Water Jet Grooving process. This research is focused on determining the optimal nozzle and orifice diameter, as well as fluid pressure inside the nozzle, that will deliver enough impinging pressure to the bottom-hole rock surface to create a peripheral groove while the bit rotates and breaks through hard rock, such as granitic rock, at in-situ stresses representative of depths of 5 km. This information is crucial for the success of the hybrid technology. Results from Imperial College London (ICL) team indicate the jet core destructive power is maintained within a distance from the nozzle of about 7 to 10 nozzle diameters and that the core jet velocities needed are in excess of a typical bullet. Such high velocities are best created with a narrow nozzle orifice and the nozzle chamber pressure and power available to the fluid jet needs to be greatly amplified above the ambient bottom hole mud pressures of around 50 MPa at targeted depth. The jet formation process, characteristic of water jet distribution, pressurization performance, and impinging pressure under different parameters were also studied based on a computational fluid dynamics (CFD) method.

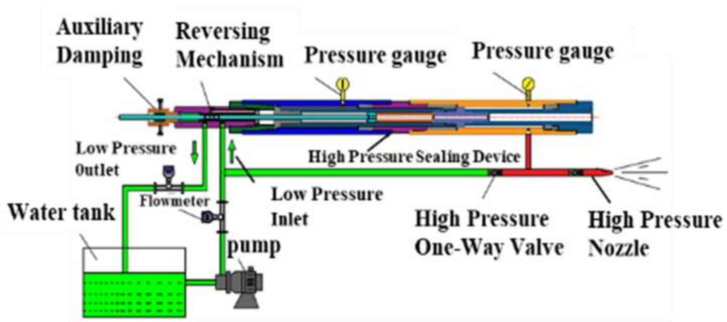


Divergence zone creates high impinging pressure on rock surface

To understand jet-rock destruction by such a small ~1 mm jet acting on what is often a coarse grained >5 mm crystalline rock, a rock destruction numerical model that represents the effects of rock microstructure weaknesses is required. ICL have created a granite model using material parameters calibrated with novel methods that include micro-indentation tests and miniature Brazilian Disc tensile tests, that are applicable to jet or hammer destruction. The model shows fragments being removed to a depth of ~5 mm under the impinging pressure of the traversing jet. These computationally expensive models which are typically run for very short time intervals and short traversing distances provide early indications of the constraints on slotting significant grooves.

Design of an intensifier for high-pressure generation

In order to generate the high-pressure water jet for the rock grooving process, two types of intensifier technologies were developed by ORCHYD partners from the University of Petroleum China (UPC). The first technology utilizes the axial vibration energy of the drill string to pressurize the fluid. The investigation on this one is now completed and they have turned their attention to hydraulic- and screw-type intensifier designs which are more compatible with the low weight-on-bit hammer systems that are to be used in ORCHYD. This intensifier type is directly driven by drilling fluid hydraulic power, the output characteristics of the intensifier are analysed by means of computational fluid dynamics. We have successfully manufactured a prototype and we are planning to conduct lab tests as soon as possible to evaluate its performance. The aim of these tests is to optimize the design of the intensifier and fine-tune the parameters that affect its performance.



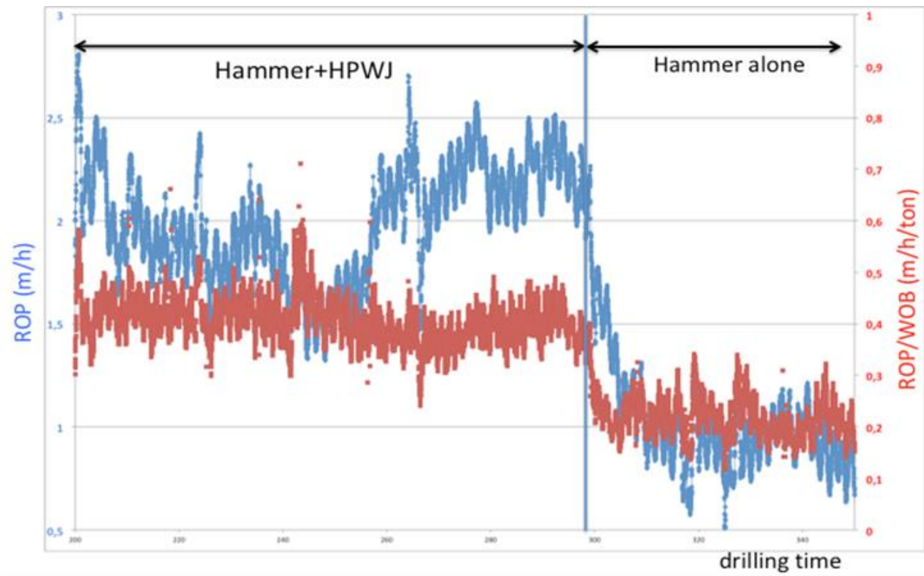
Working principle of the new intensifier

Experimental demonstration of the stress release process

To test and demonstrate the stress release process, the ORCHYD project has taken two steps. Firstly, a rock grooving study was conducted using a high-pressure cell adapted at ARMINES laboratories. By rotating the rock specimen, the jet sweeps out a circular traverse to crack and fragment rock in its path, creating an irregular groove. Under

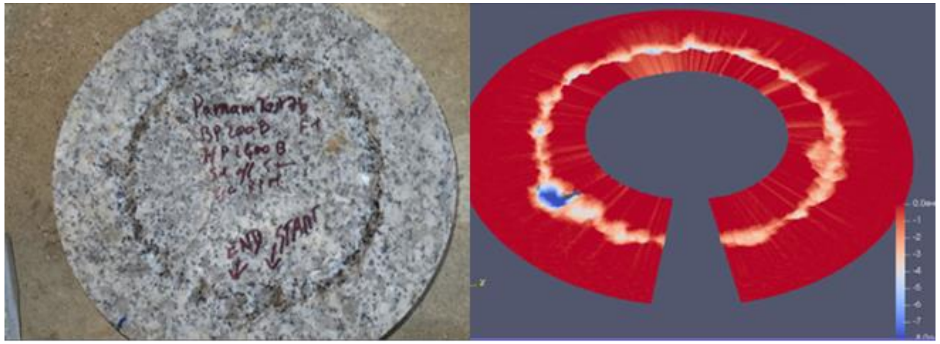
jetting conditions for maximum impinging pressure, as established by the fluid dynamics numerical models, grooving depths and profiles are highly variable, but an average of 5 mm depth has been observed in the most resistant granites tested, assistance from any concurrent weakening that may occur with local hammer action from bit inserts when the fully hybrid system is operational.

For this, the ORCHYD project has adapted a new experimental design at the test facility in Pau, France. The facility is equipped with experimental rigs that are capable of simulating downhole drilling conditions, including realistic rock stresses and mud pressures. The rig was modified to allow a high-pressure fluid line to pass through it, connecting the Mudhammer to the drill bit. The hammer bit was specifically designed by Drillstar to direct the high-pressure fluid from the centre of the axis to the



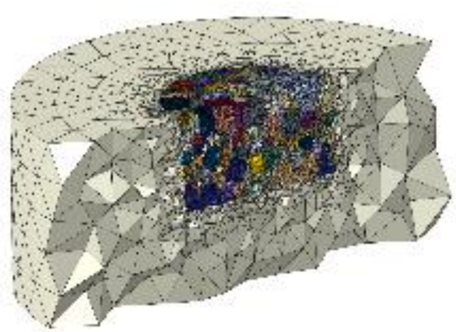
Drillability with and without the high pressure water jet slotting periphery of the drill bit. A powerful pump generates the high-pressure water jet at 2500 bars, that is required to create the peripheral grooves in the rock surface.

At this stage of the project, we were able to demonstrate an increase of 170% in the drilling rate through Sidobre granite while the percussion drilling was aided by the HPWJ.



Grooved rock sample and 3D scan reconstruction

Multiscale modelling investigation to optimize and adapt the percussive drilling action to the new bottomhole configurations



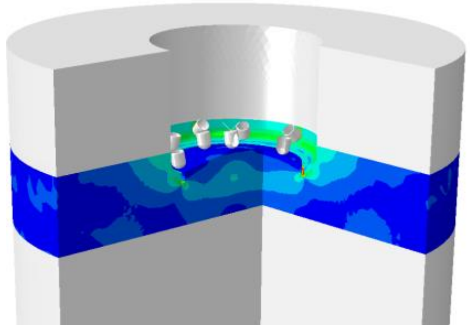
Modelling development was carried out by SINTEF and ICL to investigate the rock breaking processes under representative deep percussive drilling conditions at a mesoscale and a microscale level (i.e. the full drill bit scale and the insert scale).

- Preliminary parametric finite element (FEM) and discrete-finite element (FDEM) studies were conducted with various bit profiles and groove depths. These studies confirmed that the presence of grooves promotes rock breaking efficiency and revealed a dependency of rock fracturing mode on the bit profile.

- At this stage, the influence of microstructure was considered only at the microscale level. ICL developed a novel multiscale characterization/calibration method based on an integrated experimental-FE-machine learning technique to investigate the microstructure's influence on the rock breaking process.

- The ORCHYD project has developed algorithms to generate representative rock microstructures, in order to create concurrent insert-rock models. These models embed the rock microstructure into a macroscopic domain, and allow for the use of both FDEM (at ICL) and FEM models (at SINTEF) during the second phase of the project. This will enable a more comprehensive examination of the inter- and trans-granular rock cracking process.

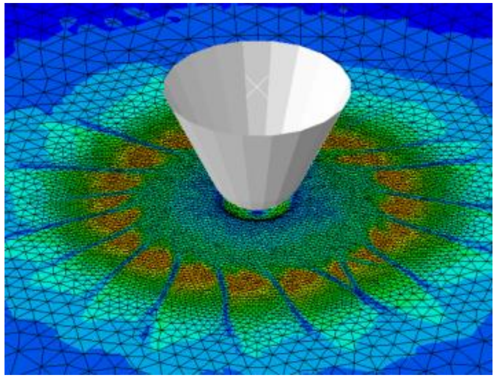
- The ORCHYD project has also begun to study the dynamic response of the drilling system at the macroscale level. The focus is on identifying the main source of nonlinearity and vibrations in the drilling structure, and it has been found that the Bit Rock Interface (BRI) response is a significant contributor. Initial parametric simulations have been conducted to establish a correlation between the intensifier displacement and typical parameters of the hammer-intensifier system, such as hammer pipe length/diameter, intensifier mass/stiffness/damping, external force amplitude/frequency, etc.



The study is now being extended to include further damping, the downhole water hammer, and the BRI response. This will provide a more comprehensive understanding of the dynamic response of the drilling system and will help in the optimization of the drilling process.

- A laboratory characterization study was executed by SINTEF to evaluate various environmentally friendly additives in order to improve the drilling fluid(s) performance. Results highlighted the potential of using Hybrid NanoSilica additives to maximize the friction reduction.

- The ORCHYD project used experimental rock data from previous research projects provided by SINTEF and ARMINES to study the mechanical behavior properties of Red Bohus, Kuru granite, and Sidobre granite rocks. Additional tests were also performed in accordance with the model calibration procedures for these three rocks. These tests



included uniaxial static tests and triaxial confining tests (with confining pressure varying from 0 to 100 MPa) performed at ARMINES and SINTEF, respectively. To manage and organize the testing data, a database framework has been tailored for the project, which is accessible to partners via a web-interface, and supports the multiscale study (e.g. models calibration/validation).

Environmental and social sustainability study

One study of the University of Piraeus (UPRC) analysed the environmental performance of the project. The effects of rate of penetration (ROP) improvement on carbon footprint, ozone depletion, acidification potential, smog, eutrophication, and energy consumption were investigated in eight scenarios using Life Cycle Analysis (LCA). The LCA underscored the favourable environmental impacts of higher ROP values and highlighted the significance of ORCHYD in the path toward sustainable geothermal drilling: ROP and the emission categories studied had an inversely proportional relationship.

Furthermore, Ecological Footprint Assessment (EFA) revealed that ROP enhancement had a positive impact on reducing the ecological impact of deep geothermal drilling: the Ecological Footprint (in global hectares) was reduced by 65.2%. Combining the results of the quantitative assessment methods, the analysis of the environmental impacts of geothermal energy and drilling concluded that deploying ORCHYD technology can lead to a drastic reduction of environmental impacts caused by conventional drilling technology.

The report on social impacts (available at orchyd.eu) addressed public understanding, acceptance, and attitudes toward geothermal drilling. The work aimed to determine how a novel drilling technology interacts with the social acceptance of geothermal energy. The responses were analysed using Principal Component Analysis and Cluster Analysis in an effort to group variables and identify clusters of similar societal attitudes. The analysis identified three different clusters with distinct attitudes toward geothermal drilling operations and geothermal energy. Each group must be approached and informed differently, depending on their level of familiarity with geothermal, their concerns or scepticism.