Simulator for drilling at depths up to 5,000 meters

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Geotechnologies department staff prepare the rig for testing. Credit: Fraunhofer-Gesellschaft

To tap into geothermal reservoirs, boreholes must be drilled deeply into the earth's crust. Due to the extreme pressures and temperatures involved, this is expensive and time consuming. A research team from Fraunhofer IEG has now developed a test rig that simulates downhole conditions at several thousands of meters below the earth's surface. Analyzing these experiments enables operators to optimize drilling during the planning and the operating stage and helps them develop and test new drilling tools, thus minimizing costs and economic risks. This will make geothermal engineering more efficient, helping to accelerate the transition to a new, sustainable energy economy.

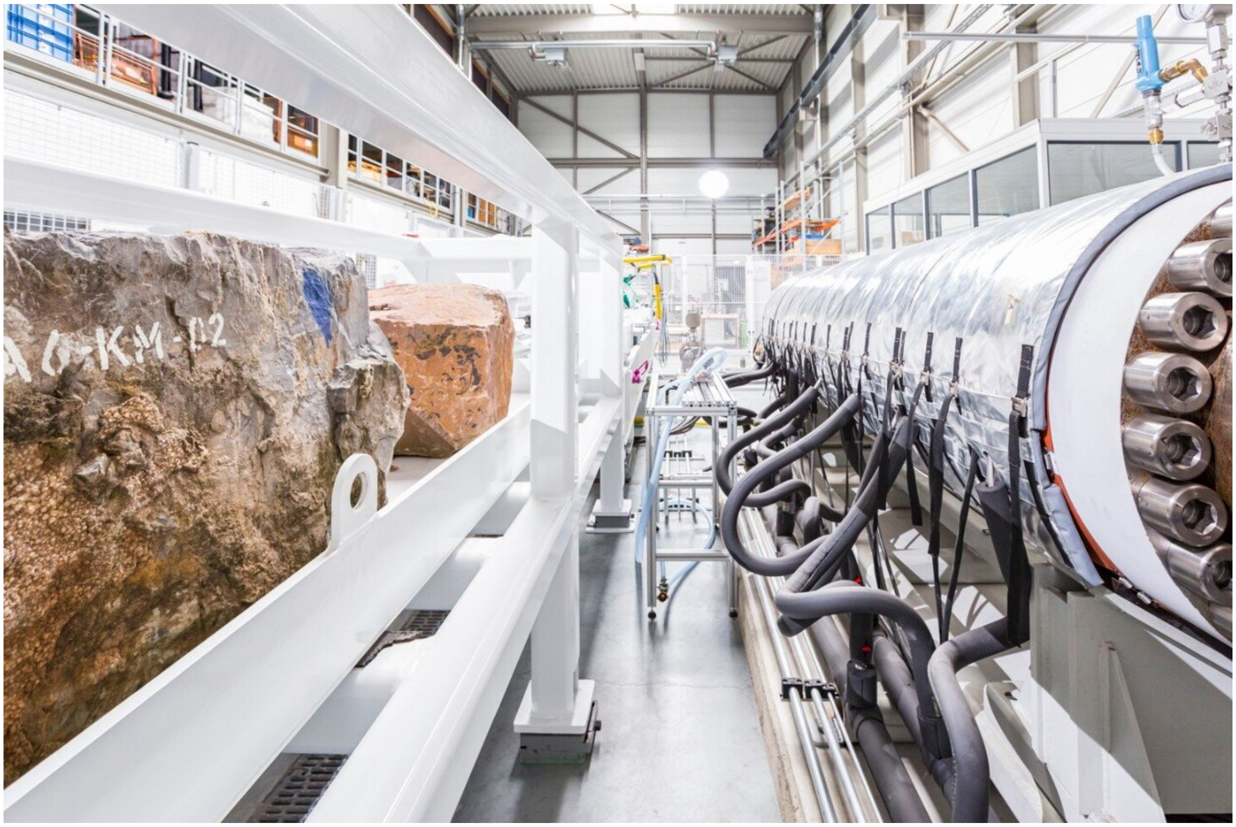
With the coal production era reaching its end, geothermal energy is gaining more attention as the next main resource to provide virtually inexhaustible quantities of energy. It can be exploited in form of heat or be used to generate electricity, irrespective of weather conditions or the time of day. Deep geothermal engineering involves drilling boreholes up to depths of several thousand meters below the earth's surface where temperatures can reach 100 degrees Celsius. The drilling process can encounter multiple types of rock, each one with different properties such as hardness, strength and density. Each type of rock may interact completely differently with the downhole drilling bit and equipment. Given all these factors, the complete drilling process and its surface equipment requirements, such as pumping, are complex procedures that require careful planning.

i.BOGS simulates extreme reservoir conditions

In response to this challenge, the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, has developed and is operating a new test rig, named match.BOGS. This is designed to simulate in situ conditions during downhole and drilling operations. The test rig consists of three main modules: i.BOGS, an autoclave system; drill.BOGS, a drilling module; and fluid.BOGS, a module to produce synthetic fluids. match.BOGS can be used to physically simulate and enable investigation of all the processes involved in drilling of a borehole up to a depth of 5000 meters. The monitoring system features a range of sensors including acoustic, thermal and optical measurement systems.

Analysis of the monitoring system data offers insights into the set up and optimization of drilling tools operation. "This makes it easier to plan drilling operations and to determine, in advance, parameters such as the type of drilling tool, drilling process parameters and required pressures," explains Volker Wittig, head of Advanced Drilling Technologies at Fraunhofer IEG.

The i.BOGS autoclave system was developed and constructed exclusively for the Fraunhofer IEG research team according to its precise specifications. It can handle rock samples to a length of 3 meters and to a diameter of up to 25 centimeters. The pressure vessel within the autoclave system subjects these samples to pressures of up to 1250 bars and temperatures of up to 180 degrees Celsius. This simulates downhole conditions equivalent to those at a depth of 5000 meters below the earth's surface. The pressure vessel has a wall thickness of 20 centimeters and is secured by a total of 25 bolts, each weighing 9 kilograms. Thus the test stand is able to withstand extreme conditions safely. Special borehole tools or pumps can also be incorporated for the purpose of testing specific requirements.



Downhole testing: match.BOGS simulates reservoir conditions down to several thousand meters. Credit: Fraunhofer-Gesellschaft

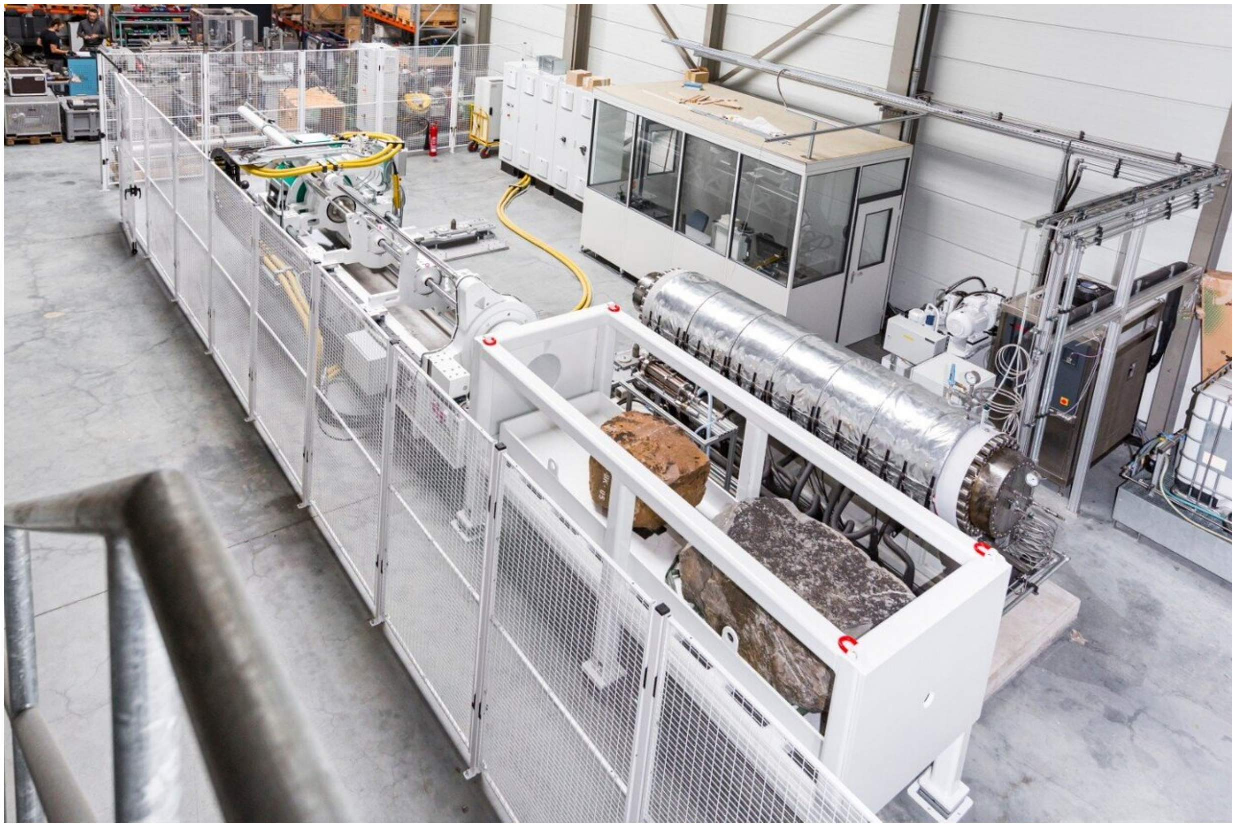
Drilling tools with laser and high-voltage pulses

The drill.BOGS module features two hydraulic cylinders delivering a feed force of up to 400 kilonewtons (kN). An electric motor drives the drill rod into the rock sample with torque values of up to 12 kilonewton meters (kNm). Integrated measurement and process control technologies render this process fully automatic.

This module can be equipped with a variety of drilling tools to enable the researchers at Fraunhofer IEG to test not only conventional tools, which operate by means of mechanical rock disintegration, but also novel drilling technologies. New technologies may use, as an example, bursts of high voltage, a laser beam or a flame-jet to penetrate into the rock surface more easily. "These contact-free drilling technologies result in significant reduction of high-wear rates on expensive drilling tools, thereby extending their service life," Wittig explains. As such, the testing conducted at Fraunhofer IEG is also helping to advance the development of conventional and novel drilling tools.

Synthetic fluids aid the drilling process

To exploit geothermal energy, hot water from underground reservoirs is pumped via a closed circuit to the surface, where it is used either to produce heat or to drive steam turbines to generate electricity. The cooled liquid is then fed back to the underground reservoir in order to reheat the reservoir rocks. "That's why we also need tests to simulate the behavior of fluids in reservoir conditions as they are being pumped to the surface," says Tilman Cremer, research fellow at Fraunhofer IEG. Alongside such geothermal applications, it may also be possible to extract valuable raw materials such as metals, heavy metals, and rare minerals from these geo fluids.



Fraunhofer IEG test rig enables the fast and economic examination of rock behavior under very extreme conditions. Credit: Fraunhofer-Gesellschaft

The fluid.BOGS module produces these synthetic fluids. Researchers then use the i.BOGS module to investigate their flow properties as they interact with the rock samples. Experts at Fraunhofer IEG can therefore study either real fluid samples taken from specific reservoirs or geofluids, which have been created synthetically. These might comprise a precisely calculated mixture of water with, for example, chlorine, calcium, magnesium and various other minerals inside the autoclave of the i.BOGS module. Consequently, these fluids can then be investigated for their flow properties.

When it comes to actual drilling operations, special fluids known as drill muds play an indispensable role. "These fluids lubricate, rinse and cool the drilling tools, and they also carry away the rock removed during drilling," Wittig explains.

The combination of the three modules i.BOGS, drill.BOGS and fluid .BOGS, and all their various configurations, make the match.BOGS test rig a unique facility. As Jascha Börner, team member and research fellow at Fraunhofer IEG, explains: "We can individually set each one of the various parameters—pressure, temperature, flow speed, the composition of the rock sample, and the mixing ratio of the fluids." It is therefore possible to simulate the most diverse conditions and produce precise planning data for real drilling projects.

A boost for geothermal engineering

Preparing for testing at the new facility is a complicated process. First of all, the autoclave systems must be equipped with rock samples. Pressure and temperature are then successively increased. In the meantime, the drilling tools are set up and the requisite fluids prepared. As a rule of thumb, it takes almost a whole day to prepare for the start of simulation. The effort is worthwhile since it brings a whole range of benefits for the advancement of the drilling industry. By using simulation techniques to test the real conditions at a specific site, drilling operators can plan for the actual drilling operations with more confidence. This increases the efficiency of the operation since all the drilling tools can be set up properly in advance, resulting in savings of millions of euros. These measures to optimize geothermal engineering will help make the transition to a sustainable energy system more economic and more efficient.

Provided by Fraunhofer-Gesellschaft