Novel Productivity Enhancement Concept for a Sustainable Utilization of a Geothermal Resource – The SURE Project

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ABSTRACT

Within the EC funded Horizon 2020 project SURE (Novel Productivity Enhancement Concept for a Sustainable Utilization of a Geothermal Resource, www.SURE-H2020.eu) the radial water jet drilling (RJD) technology will be investigated and tested as a method to increase inflow into insufficiently producing geothermal wells. Radial water jet drilling uses the power of a focused jet of fluids, applied to a rock through a coil inserted in an existing well. This technology is likely to provide much better control of the enhanced flow paths around a geothermal well and does not involve the amount of fluid as conventional hydraulic fracturing, reducing the risk of induced seismicity considerably. RJD shall be applied to access and connect high permeable zones within geothermal reservoirs to the main well with a higher degree of control compared to conventional stimulation technologies.

SURE will investigate the RJD technology for deep geothermal reservoir rocks at different geological settings such as deep sedimentary basins and magmatic regions at the micro-, meso- and macro-scale. Laboratory tests will include the determination of parameters such as elastic constants, permeability and cohesion of the rocks as well as jetting experiments into large samples at ambient as well as simulated reservoir conditions. Samples will be investigated in 3D with micro CT scanners and with standard microscopy approaches. In addition, advanced modelling will help understand the actual mechanism leading to the rock destruction at the tip of the water jet. Last but not least, experimental and modelling results will be validated by controlled experiments in a quarry (mesoscale) which allows precise monitoring of the process, and in two different geothermal wells. Here, we outline the concept of the project.

1. INTRODUCTION

Within recent years, many sites have been explored and investigated for their suitability of an economic energy provision from geothermal heat. One major showstopper for the use of geothermal resources is the risk of a low-productive well, especially in low and medium enthalpy reservoirs but also in high enthalpy reservoir rocks where the permeability distribution is often strongly heterogeneous, as for fracture or karst reservoirs. In order to increase the number of economically viable wells at such sites, the technology of enhancing a geothermal reservoir has been considered. Hydraulic or acid stimulation techniques adapted from the oil and gas industry have been applied to improve the performance of such enhanced or engineered geothermal systems - EGS (Blöcher, 2012). It is obvious from developing EGS (Schindler, 2008) and magmatic (Valdez-Perez, 2014) systems that tapping into high permeability zones like fracture systems (van Oversteeg et al., 2014) is generally key for achieving high flow rates. Sufficiently high flow rates have been reached by hydraulic stimulation technologies, which proved to be successful in establishing initial productivity increases (e.g., Zimmermann, 2010); the sustainability of EGS systems, however, remains to be proven. Another critical issue with hydraulic stimulation treatments results from the large amount of fluids injected to tap into high permeable zones. These injections may cause seismicity (e.g., Häring, 2008), which is mostly deemed unacceptable by the public. In addition, fluid

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volumes flowing back from the well after the stimulation have to be properly handled and disposed of.

Another way to increase the productivity of a well is to drill multiple laterals from a single mother bore (e.g., Bosworth, 1998). Multilaterals by conventional drilling are often done in the oil and gas industry and eventually combined with hydraulic stimulation treatments. Multilateral drilling, however, is usually too expensive for geothermal projects. In order to overcome this limitation, coiled tubing conveyed jet drilling assemblies have been investigated for multilateral drilling in geothermal reservoirs (e.g., Finsterle, 2013; Kolle, 2009). Until December 2014, although tested at the surface, such approaches have never been applied downhole within a geothermal project in Europe. Within this project, the radial water jet drilling (RJD) technology (e.g., Cinelli, 2013) will be investigated and tested for a sustainable and efficient productivity enhancement in low productive geothermal wells. Radial water jet drilling uses the power of a focused fluid jet, which is capable of drilling multiple laterals of about 100 m length out of the main well and thereby stimulating the well with full control on the operational parameters like initial direction of the lateral, length, fluid pressure etc. In contrast to hydraulic stimulation treatments, this technology can potentially provide a network of enhanced fluid pathways around a geothermal well to intersect with existing high permeable structures like fracture or karst systems within the reservoir, independent of the ambient stress field. However, whether the initial direction of the lateral is altered by local geological features is an open question that will be appropriately addressed.

Compared to conventional hydraulic stimulation treatments with required fluid volumes of more than 1000 m³, only a fraction of the fluids is needed for RJD (< 10 m³). Thereby the environmental risk as well as the risk of induced seismicity is considerably reduced. If the technology can be shown to increase the efficiency of a geothermal well, it will provide an interesting alternative to conventional hydraulic stimulation treatments and it eventually allows a more efficient hydraulic stimulation with much smaller artificial fractures in a combined operation.

By performing a conventional hydraulic stimulation treatment in a homogeneous, isotropic reservoir or by jet drilling a series of laterals into different directions around the main well within such a reservoir, the productivity of the well can be doubled at best. In heterogeneous reservoirs, a significantly higher increase can be expected. Having sufficient information on the heterogeneity, it is important to control the geometry of the generated fluid pathways during a stimulation treatment. Hydraulically enhanced fracture networks depend strongly on the nature of the ambient stress field. Generating fluid pathways independent from the ambient stress field is only possible by applying conventional drilling or jet drilling technologies like RJD. However, the influence of the ambient stress field on the orientation of the jetted lateral will also be investigated.

Within the SURE project, the RJD technology is systematically investigated and thoroughly tested for the application in different geothermal reservoir rocks, including hard rocks and high enthalpy environments. For the different geothermal reservoir rock types, a specification of the parameters characterizing and controlling the jet-ability (i.e. the potential to drill a hole by the jetting approach) will be performed for the applied technical equipment. To qualify the technology for geothermal reservoir rocks in different geological settings such as deep sedimentary basins or regions with igneous host rocks, the jetting technology will be investigated, eventually adapted, and tested at the micro- (µm-dm), meso- (dm-m) and macro-scale (m-km).

The experiments are designed to detect and understand the limitations of the existing technology, to improve the design, where possible, to investigate if additional information about the geological structure is obtainable while drilling, and finally to iteratively develop an enhanced jetting technology for rock properties that have so far prevented the successful application of water jetting in the respective rock types.

2. APPROACH

For RJD, a workover rig will install a 2 7/8” tubing with a 100 m 2 3/8” tailpipe to which a deflector tool (Figure 1) with decentralising springs is attached to the desired depth. Including a gyro service, the deflector tool can be oriented in the desired direction within the mother well. Through this tubing, a mini coil (1/2" Coiled Tubing) will be run to the depth of interest. Using the installed deflector tool, a 1" milling bit on a flexible chain attached to a positive displacement motor will create a first exit by milling a hole into the existing casing. Afterwards, the mini coil will be retrieved from the wellbore. In a second step, a 100 m long flexible high pressure hose will be run into the wellbore on the mini coil. This hose will exit the well through the previously created hole. By pumping water into this hose at a high pressure, the water exiting the hose through specially designed nozzles (Figure 1) of very small diameter will deconsolidate the formation and create an open-hole lateral with a diameter of about 1-2" perpendicular to the wellbore (Figure 2).

In contrast to a conventional stimulation treatment (hydraulic, acid or thermal), the radial jet drilling technology enables the operator to control the initial orientation of the lateral used to connect high permeable zones - independently from the direction of the ambient stress field - at comparable and most of the times even much lower costs. However, it will be tested if the lateral can be considered to be straight or if its geometry is influenced by the local geology. During the jetting operation, it is planned to properly measure all jetting parameters (pressure, flow rate, rate of penetration,…) in order to infer details about jetted rock formation. To locate the lateral within the formation, different monitoring strategies like acoustic monitoring during jetting will be tested. It is furthermore planned to adapt the deflector shoe to allow for a retrieval of the drilled material, which is lost in the well otherwise.

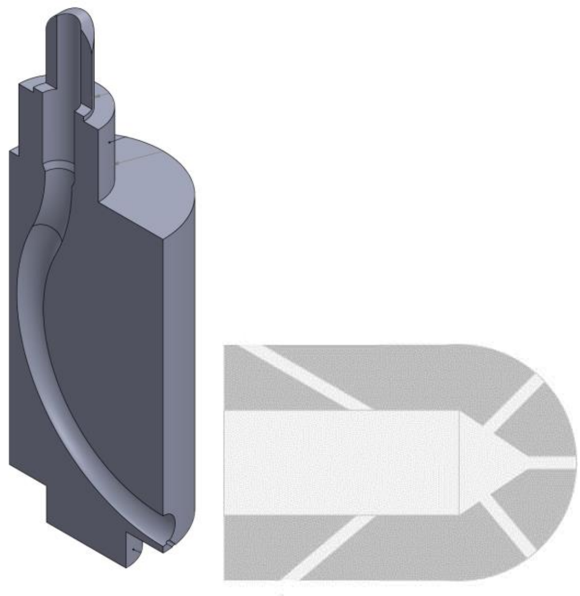

Figure 1: Left: Deflector shoe used to deflect the jetting nozzle. Right: Static nozzle used for RJD operations.

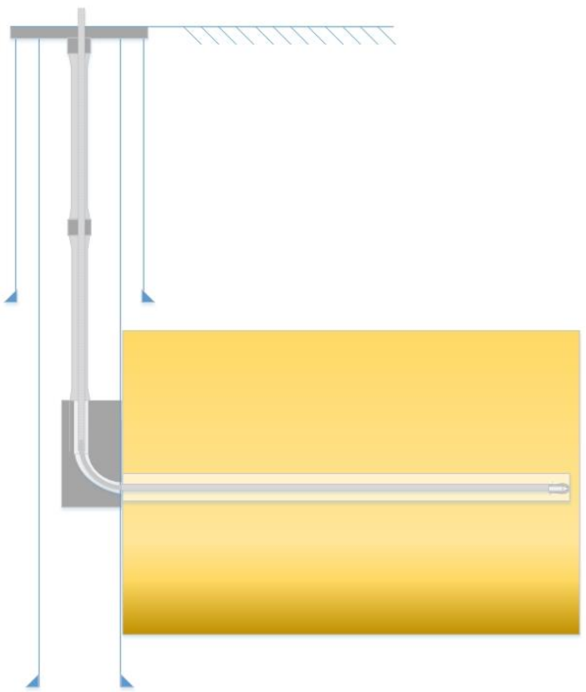

Figure 2: Concept of the Radial Water Jet Drilling (RJD) technology.

3. PROJECT STRUCTURE

The project is subdivided into seven workpackages, where the main experimental work will be performed in WPs 4-6 and the transfer and integration of the experimental data into conceptual models and numerical simulations is done in WP 7 (Figure 3).

3.1 Micro Scale Investigations

Rock physics measurements in the laboratory will be performed to systematically investigate the dependency of the jet-ability of the rocks on their physical properties. The properties determined include elastic moduli, porosity and permeability and their dependence on (fluid) pressure and temperature. The hydraulic properties of fractures and the stability of laterals in the simulated in-situ stress field will be measured in the laboratory. The results of these measurements will be compared to the basic physical properties of the rocks to investigate a potentially predictive correlation between the two.

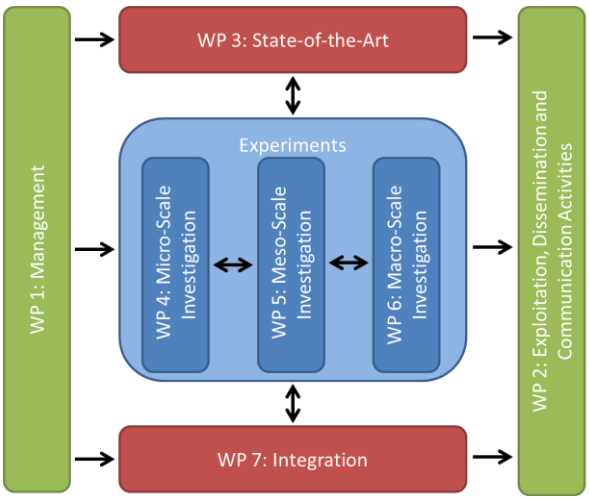

Figure 3: Workpackage structure for the SURE project.

3.2 Meso Scale Investigations

Rock blocks large enough to be jetted with real scale jetting technology will be collected for testing in the laboratory. Material from the same blocks will also be used for the microscale experiments. That way the active jetting experiments performed under ambient as well as in-situ reservoir conditions can be related to the microscale investigations and to the basic rock properties determined at the smaller scale. Another integral part of this workpackage is a drilling experiment in a quarry, where the geometry of the laterals as well as seismic acquisition as a monitoring tool during the jetting activity will be investigated.

3.3 Macro Scale Investigations

Finally, RJD will be investigated at the field scale, in two geothermal wells. These field tests will serve to validate and improve the model predictions made on the basis of laboratory testing. A strong focus lies in the long-term performance of the stimulated wells. Therefore, an extended monitoring programme is planned. As both tests are planned in wells owned by commercial operators, a direct transfer of project results to the relevant stakeholders is guaranteed.

3.4 Integration

Conceptual models to simulate the experimental results at all scales investigated play a key role in the interpretation and understanding of the experimental results and of the RJD technology in general. Furthermore, the results will be used to optimize not only the jetting process itself but also the placement of the laterals. Specific models will investigate the rock destruction process at the grain scale, taking into account the physical parameters and properties determined in the laboratories. Flow models will be developed to predict the overall improvement of well performance due to the RJD treatments as well as the long-term stability of the laterals and sustainability of the enhanced system as a whole.

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