Novel Productivity Enhancement Concept for a Sustainable Utilization of a Geothermal Resource – The H2020 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) the radial water jet drilling (RJD) technology is investigated and tested as a method to increase performance of insufficiently performing 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, thereby 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. We investigated the technology over various spatial and temporal scales ranging from short term laboratory experiments to field scale applications. Here we give an overview about our work during the last 40 months.

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 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 the SURE 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 up to 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.

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 (Figure 1). 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 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).

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 (Blöcher et al., 2016)

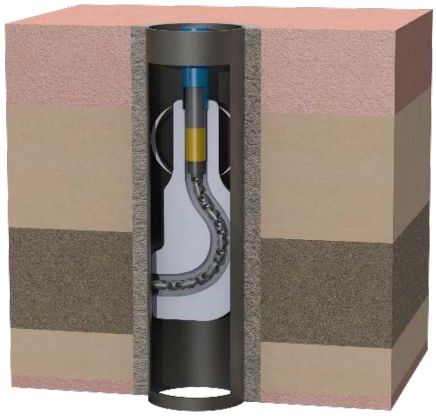

Figure 1: Deflector shoe with milling assembly to mill a hole into the casing from Reinsch & Blöcher 2016.

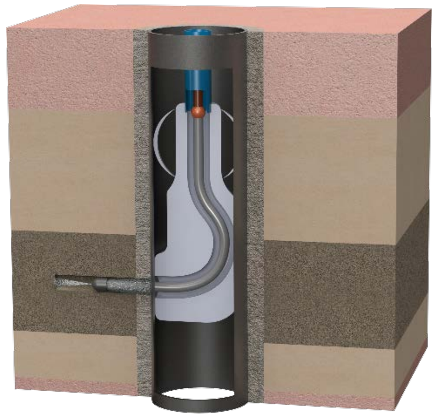

Figure 2: Deflector shoe with jetting assembly to jetting into the casing from Reinsch & Blöcher 2016.

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 is investigated, eventually adapted, and tested at the micro- (µm-dm), meso- (dm-m) and macro-scale (m-km).

2. MICRO-SCALE

Rock physics measurements in the laboratory were 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 (Bakker et al., 2019). The hydraulic properties of fractures (Kluge et al., 2017) and the stability of laterals in the simulated in-situ stress field were measured in the laboratory

(Bakker et al., 2017, Medetbekova et al., 2018). The results of these measurements are compared to the basic physical properties of the rocks to investigate predictive correlations.

3. MESO-SCALE

Rock blocks large enough to be jetted with real scale jetting technology were collected for testing in the laboratory. Material from the same blocks was also used for the microscale experiments. That way the active jetting experiments performed under ambient (Hahn and Wittig, 2017) as well as in-situ reservoir conditions (Hahn et al., 2019) can be related to the microscale investigations and to the basic rock properties determined at the smaller scale. Another integral part of meso-scale investigations 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 was investigated (Reinsch et al., 2018). Based on the learnings from this work, an optimised jetting nozzle will be designed.

4. MACRO-SCALE

Finally, RJD will be investigated at the field scale, in two geothermal wells. In addition, a third field experiment was evaluated (Petrauskas et al., 2017). 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. In the original project plan, the field operations were planned for the second project year. Due to several delays these are scheduled for spring/summer 2019.

5. 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 (Xiang et al 2019). Specific models will investigate the rock destruction process at the grain scale, taking into account the physical parameters and properties determined in the laboratories (Chen et al 2019). Flow models will be developed to predict the overall improvement of well performance due to the RJD treatments (Salimzadeh et al, 2018a, 2018b; Peters et al, 2018, 2019a, 2019b) as well as the stability of the laterals (Latham et al., 2019), well testing of wells with multiple laterals (Egberts and Peters, 2019) and sustainability of the enhanced system as a whole. Furthermore, the simulation results will be used to optimize not only the jetting process itself but also the placement of the laterals (Peters et al, 2019c).

6. CONCLUSION

Still a long way to go but on a good track…. To be updated

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