Increase of the efficiency of a borehole heat exchanger by gas sparging technology

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One of the main limiting factors of geothermal energy systems is the heat transfer in the ground. This transfer strongly depends on the different types of soil and the soil layering along the borehole heat exchanger as well as the grouting material and the groundwater flow in sandy and gravelly ground. Assuming a closed geothermal system for exploitation of shallow geothermal energy at a location with no groundwater flow or unsaturated soil, the critical region is the heat transfer between the grouting and the ground. The relevant heat transfer process is conduction which is a very slow process and sets a limit to the efficiency of the geothermal system. However, forced convection is the dominating heat transfer process at locations with ground water flow. This allows a significantly faster heat transfer and thereby increases the heat extraction rate. An open geothermal system uses this advantage of pumping groundwater out of a well through a heat exchanger back into an infiltration well. This method also increases the efficiency of the system but can cause some major disadvantages for the environment and can be judged critically by the authorities because of the direct use of groundwater.
To counteract the drawback of no groundwater flow a patented method (EU patent: 09401001.4-2301) will be presented and is shown in figure 1. This method calls gas injecting borehole heat exchanger (GIBHE) combines a closed system with a groundwater circulation technology. In this system a groundwater circulation is artificially created in a saturated sandy soil to increase the convective heat transfer in the soil and therefore the heat capacity of the whole geothermal system. Gas is injected at the bottom of the borehole heat exchanger to create a gradient of density which causes the groundwater circulation around the geothermal system. The gas-water-mixture has a lower density compared to the surrounding groundwater. This causes an influx of groundwater at the base of the system. Due to its lower density the water table inside the pipe elevates above the surrounding groundwater level and causes an outflow which leads to a groundwater circulation.

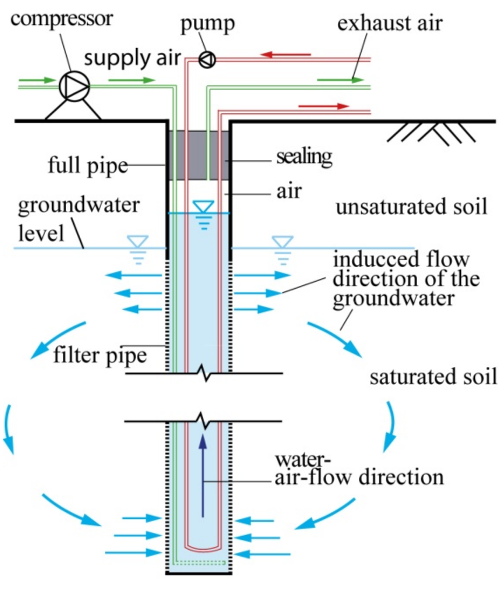

Figure 1- air sparging borehole heat exchanger [Grabe et al. 2013]

Further scientific works shows that this effect can be modeled by numerical simulations [Grabe et al. 2013]. Hereby was shown that the groundwater circulation leads depending on the permeability of the soil to a significant increasing of the efficiency of the borehole heat exchanger. This improvement can raise the efficiency up to a multiple. The required energy to blow the gas into the system is much smaller than the profit of this method. This proves that a circulation of groundwater is started ad therefore the efficiency raises instead of that the efficiency increase is due the energy just provides by the compressed gas. With the help of this technology it is not necessary to pump all of the required water mass up to the ground surface like it is done for open geothermal

systems. The water movement takes place in the ground with less contact to the surface and to possible pollution.
To investigate the effect under in situ conditions a field test was conducted. Therefore, a borehole heat exchanger was constructed with respect to the requirements from the patented system. The whole borehole heat exchanger was build similar to a well. Around the filter pipe filter sand was placed to ensure a good hydraulic conductivity to the groundwater and a reliable operation. Inside this filter pipe a borehole heat exchanger was installed together with a tube that reaches the bottom of the well to inject gas. Next to the GIBHE an array of 12 pore water pressure and temperature probes were set up in the ground to be able to measure any kind of change of the groundwater in the surroundings. The inlet and outlet temperature of the system can be measured as well as the mass flow of the borehole heat exchanger and the volume flow of the gas injection.
First of all, a reference value for the efficiency was determine by setting the inlet temperature for the heat exchanger to a fix value and waiting for nearly steady state condition. During this stage no gas sparging was in progress and the borehole heat exchanger was run like an ordinary one with the difference of having water as surrounding material instead of backfilling material. After a nearly equilibrium is reached the next stage was started. To create an artificial groundwater flow the gas sparging was started. Again this stage was also executed until a nearly steady state condition was determined. The influence of the temperature distribution in the ground was as expected higher than without gas sparging. Therefore, another steady state stage was conducted without gas sparging to analyse the fully developed temperature distribution in the ground.
The mechanism of the gas sparging technology and the field test itself will be presented. First results from the individual stages show an increase of the efficiency especially for short periods.

Reference:

Grabe J., Menzel F. and Ma X. (2013): Combination of borehole heat exchangers and air sparging to increase geothermal efficiency. Proc. of 18th International Conference on Soil Mechanics and Geotechnical Engineering 2013 in Paris/France, pp. 3355-3358