Experimental investigation of dynamic behaviour of borehole heat exchanger by gas sparging technology

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Introduction

Conventional closed geothermal heat exchangers possess the drawback of a weak dynamic behavior. Considering a geothermal assisted air conditioning, the load on the geothermal system is continuously varying. Designing a system that suits high demands will probably result either in the oversizing for conventional operation or the requirement of backup systems. Both will decrease the efficiency of the overall system. To counteract this drawback a patented method called "gas injecting borehole heat exchanger" will be presented that creates an artificial ground water flow around the borehole heat exchanger. By injecting gas, most commonly air, into the bottom end of the borehole the density of the groundwater changes along the heat exchanger thus causing a circulating flow.

Gas injecting borehole heat exchanger

Based on conventional double-U geothermal borehole heat exchangers the gas injecting borehole heat exchanger (GIBHE) integrates the heat exchanger inside of a well like for water extraction. For a high hydraulic connection between the inside of the well and the surrounding soil, the well is slitted over the total height of a sandy water saturated layer. In contrast to ordinary borehole heat exchangers, the system is not enclosed by grouting material. It is positioned freely in the groundwater inside the well. An additional gas tube is installed in the well which leads down to the bottom of it. Injecting gas, an air-water-mixture is created inside the well having a lower density then the surrounding groundwater. To equalize the difference in density groundwater flows for the lower part towards the well and for the upper part out of the well. The driving force of this mechanism is the resulting pressure difference creating an artificial groundwater flow. Figure 1 shows a drawing of the GIBHE.

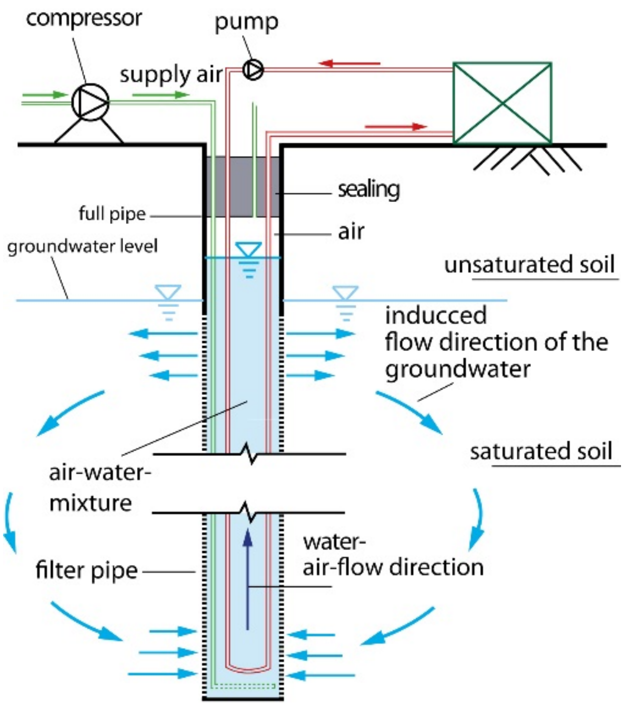

Fig. 1: Schematic sketch of a gas injection borehole heat exchanger

Field Test and Results

For scientific investigation of the GIBHE, a location has been chosen which has a low distance between groundwater table and ground surface. A further requirement was a homogeneous soil with a big layer of sandy soil with a high permeability for improving the artificial groundwater flow. A 19 m long GIBHE and three drill holes to install combined temperature and pore water pressure sensors have been built.

The measurements and evaluation to determine in a first field test the efficiency of a GIBHE has been performed over several months. During this time, three major tests have been implemented to investigate the behavior of such a geothermal system. The first test has been implemented without air sparging. Its purpose was to determine the efficiency of the pure geothermal heat exchanger and is supposed to be the major comparison. The second test has been a long time test with gas injection switched on. The third test has been done with an increased injection rate to determine the behavior of a change of the gas flow rate of the system. Due to a very robust temperature control over a very long time, it has been chosen to set the inlet temperature to 20 °C con-stant. This is a feasible temperature for summer operation of a geothermal assisted air conditioning system. The system was capable to maintain this temperature within a very small fluctuation range. The flow rate of the heat transfer fluid has been set to 17 l/min for all tests. The groundwater temperature was initially 10 °C.

The first test without gas sparging has been measured over a period of 24 days. The result is that for the first two days a heat transfer of approx. 800 W can be achieved. Within 6 days, a stationary operation point is reached with a transfer rate of 600 W. The heat transfer mechanism is just conduction and natural convection. Figure 2 shows the results of the two tests with gas sparging. For test no. 2, the gas injection was turn on to 20 l/min and test no. 3 has been conducted with 30 l/min. The results from test no. 2 shows that the transferred power is increased for the first days significantly to 3,500 W. Within 15 days, the efficiency is decreasing to a stationary point of 1,500 W. The influence of a further increase of the gas injection rate is shown in test no. 3. A sudden and immediately increase of the efficiency is observed. The value rises from 1,500 W to 2,500 W.

The results of the three tests show that the gas injection technology increases the efficiency of a borehole heat exchanger significantly. Comparing the results of steady state of no gas injection with 20 l/min of gas in-jection yield a growth rate of 2.5. Considering the transient operation point, an increase of efficiency of 5 is possible for this configuration. Further increase of the gas injection rate increase the heat transfer rate.

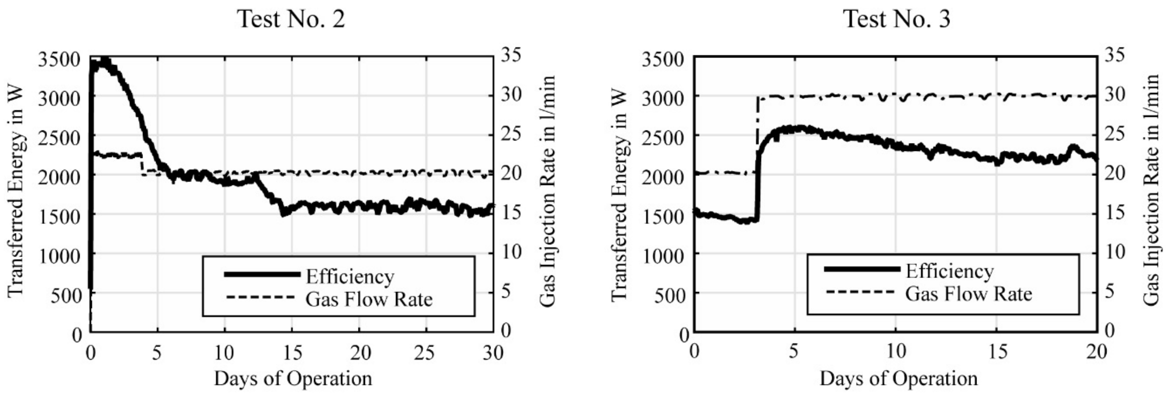

Fig. 2: Results of GIBHE with gas injection, Test no. 2 with 20 l/min, Test no. 3 with 30 l/min

Conclusion and Outlook

This study has shown that the injection technology is capable of a significant increase of efficiency of geothermal systems. Comparing an operation without gas sparging the rate of transferred energy could be raised many times over. This is valid for both a steady state as well as transient operation. The injection rate is de-pends directly on the efficiency. The significant improved dynamic behaviour of a geothermal system offers further application and more possible scopes of operation.

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