Modeling of Usage of Air Injection Well in a Geothermal System

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1 Introduction

2 Numerical modeling of an air injection well

3 Results of simulations

4 Conclusion and outlook
Introduction

- Borehole heat exchanger
Heat transfer mechanisms of soil heat exchanger

\[
\left( \rho \cdot c \right)_{\text{soil}} \frac{\partial \theta}{\partial t} = \text{div}(k \cdot \text{grad} \theta) - \nu \cdot \text{grad} \theta + \text{Heat source}
\]

- Heat conduction in tubewall
- Heat conduction in pile
- Conductive heat transport in soil
- Convective heat conduction in groundwater
- Heat transfer pile-soil/groundwater
- Heat transfer tubewall-pile
- Heat transport heat transfer medium-tubewall
- Convective heat transport
 Combined air injection well with a borehole heat exchanger and air conditioning system
Distribution of water pressure and difference between air injection well and aquifer
**Groundwater circulation**
Modeling of Usage of Air Injection Well in a geothermal System

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Basis system

- One Aquifer between 2 aquitards
- Above and under the aquifer, the BHE is filled
- BHE in aquifer is piped
- Heat transfer and 2 phase fluid flow in the well is not considered
- Axial symmetric

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity ($k$)</td>
<td>2.53 W/(m•K)</td>
</tr>
<tr>
<td>Specific heat capacity ($c$)</td>
<td>1750 kJ/(kg•K)</td>
</tr>
<tr>
<td>Drainable porosity ($n$)</td>
<td>0.35</td>
</tr>
<tr>
<td>Density ($\rho$)</td>
<td>2100 kg/m³</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>$10^{-5}$ m/s</td>
</tr>
</tbody>
</table>
**Boundary and initial conditions**

\( \theta = 20^\circ \text{C} \) at the wall of air injection well and
\( \text{grad} \theta = 0 \) for all other boundaries.

\( \theta(t = 0) = 10^\circ \text{C} \)
2 physics: groundwater flow and heat transfer

Sequential simulation:

- in the first step: groundwater flow, steady state
- In the second step: heat transfer, 90 days
3 Results of simulations

Groundwater flow velocity field around the air injection well

Time=7.776e6  Contour: Velocity field [m/s]
Arrow: Velocity field

Max: 1.218e-5
Min: 3.671e-12
Temperature field after an heat injection period of 3 months

Results of simulations

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Specific Heat Injection Capacity

The total injected surface heat quantity $e_h(t)$ in kWh/m after a certain time $t$ can be calculated using the equation:

$$e_h(t) = \int_{\Omega} \rho c \left[ T(t) - T_0 \right] dA$$

The specific heat injection capacity $P_s(t)$ is a time dependent value:

$$P_s(t_n) = \frac{E_h(t_n) - E_h(t_{n-1})}{l \cdot (t_n - t_{n-1})}$$
Results of simulations

Calculated time dependent specific heat injection capacity

Efficiency increasing factor: 50% over a period of 90 days
Calculated relative efficiency increasing factor in dependent of hydraulic conductivity and water/air mixture density
Conclusion and outlook

- 2D-Simulation of air injection wells was successful
- the combination of air injection well in borehole can improve the heat injection capacity vastly
- 3D-Simulation will also be performed
- Laboratory and field test are planned, in order to verify the numerical results
Thanks for Your attention