Geophysical Research Abstracts
Vol. 13, EGU2011-11537, 2011
EGU General Assembly 2011

Model of two-phase flow in the brine cicrcuit of a geothermal power plant

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With two boreholes successfully drilled and their sufficient productivity proven, geothermal energy can be exploited basically by extracting hot brine from a deep reservoir using an electrical submersible pump (ESP) in one borehole and reinjecting it into the other one after extracting heat in a heat exchanger.
The brine extracted usually contains considerable amounts of dissolved salts (e.g. NaCl, CaCl) and gases (e.g. N_2, CH_4, CO_2). Due to the large pressure difference between aquifer and the above ground facility (hydrostatic + friction), degassing and/or evaporation can occur during production with all its consequences: The degassing of small amounts of gas increases the volume gas fraction considerably. The gas fraction influences density, viscosity, heat conductivity of the resulting two-phase medium. Density reduction at constant mass flow increases the fluid's mean velocity, causing an increased wall friction. Thus, it can significantly affect the performance of the connected devices (pump, heat exchanger etc.).
Furthermore in the case of degassing of CO_2, the pH rises, which can lead to precipitation of solids. In order to avoid this, the pressure should be kept above a certain value in the whole brine circuit.
For designing and dimensioning of the brine circuit a hydraulic model is needed. It must be capable of reproducing the physical properties of the brine in a two phase flow including the degassing process. Such a model would allow for a prediction of the ESP's pressure head required to maintain a given pressure level at the well head. That way the ESP's power consumption can be estimated, which is usually crucial for the economic performance of the whole geothermic power plant.
As there are no specific property functions for brines, being a mixture of varying composition, the fluid's properties have to be calculated using correlations for two-phase media and property functions from the literature for density, specific enthalpy and solubility for aqueous solutions of chlorides and nitrogen as well as carbon dioxide.
We present a numerical model of the production well. It has been implemented in Modelica (modeling language) using the developing environment DYMOLA. The well model accounts for degassing, evaporation, heat conduction through the pipe wall and pressure losses through two-phase friction. It also features a fluid property model for the two-phase brine, which can be adapted to specific compositions. The well is discretized and balances of mass, momentum and energy are calculated for each segment. In order to decrease numerical effort while still having a resolution fine enough where needed, an automatic step size adaptation has been developed.