Properties of Steam/Water Flow in Geothermal Rock

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Sponsor: US Dept of Energy, through the Stanford Geothermal Program.

Description: Steam/water relative permeability and capillary pressure are important properties for geothermal reservoir engineering, in that they have a major influence on the performance of geothermal reservoirs under development. All numerical simulations of geothermal reservoir performance require the input of relative permeability and capillary pressure values, yet actual data on these parameters has not been available. The Stanford Geothermal Program (SGP) has succeeded in making fundamental measurements of steam/water flow in porous media and thereby made significant contribution to the industry by providing both understanding of the phenomena as well as actual parameter value measurements. Two important problems left to undertake are the measurement of steam/water relative permeability and capillary pressure in geothermal rock (most of the previous study was conducted in high permeability sandstone as well-controlled test material), as well as the understanding of how steam-water boiling mixtures flow in fractures.

The Stanford Geothermal Program uses both theoretical and experimental approaches to conduct the research. We use numerical simulation for modeling work and we use an X-ray CT scanner as one of our main experimental tools to measure in-situ water saturation and its distribution. We also design and construct purpose-built apparatus to conduct the experiments needed.

The mechanism of two-phase flow through fractures exerts an important influence on the behavior of geothermal reservoirs. Currently, two-phase flow through fractures is still poorly understood. In this project, nitrogen-water experiments were conducted in both smooth- and rough-walled fractures to determine the governing flow mechanisms. The experiments were done using a glass plate to allow visualization of flow. Digital video recording allowed instantaneous measurement of pressure, flow rate and saturation. Saturation was computed using image analysis techniques. The experiments showed that the gas and liquid phases flow through fractures in nonuniform separate channels (see Fig. 1).

Figure 3: Examples of gas-water flow channels.

The data from the experiments were analyzed using Darcy's law and using the concept of friction factor and equivalent Reynold's number for two-phase flow. For both smooth- and rough-walled fractures a clear relationship between relative permeability and saturation was seen. The calculated relative permeability curves follow Corey-type behavior, as shown in Fig. 2. The sum of the relative permeabilities of the two phases is not equal to one, indicating phase interference. The equivalent homogenous single-phase approach did not give satisfactory representation of flow through fractures. The graphs of experimentally derived friction factor with the modified Reynold's number do not reveal a distinctive linear relationship (as has sometimes been associated with multiphase flow in fractures).

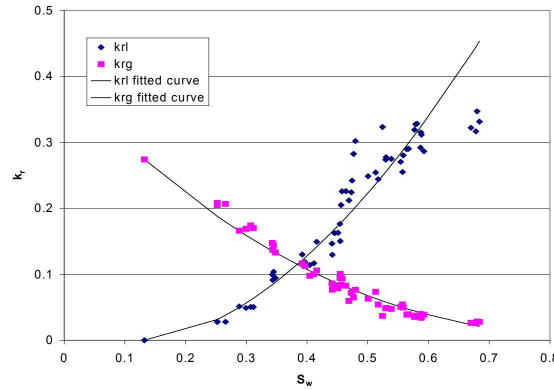

Figure 2: Drainage relative permeability curves in a rough-walled fracture.

Status: The project is ongoing. At present the fracture flow experiments are considering steam-water flow, which in preliminary experiments has been seen to differ significantly from nitrogen-water flow.

Publications:

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