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Relative Permeability Experiments for Estimating CO2 Movement

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Carbon dioxide Capture and Storage is thought now as an option of green house gas reduction. Saline aquifers are most possible target for the geological sequestration in Japan. There are still many unknown factors for geological sequestration into saline aquifers such as how CO2 will spread and move in saline aquifer or how is the possibility that CO2 will penetrate through low permeable formations and reach to surface. Many numerical simulations have been done for geological sequestration into saline aquifers, but there are still few data about two phase flow properties such like relative permeability using CO2 in super-critical condition.

Many relative permeability measurements have been done in petroleum reservoir engineering for a long time and two laboratory experiment methods, steady state method and unsteady state (displacement) method, represent them. In the steady state method two fluids are injected into the specimen at pre-determined rate, and the permeability can be calculated from flow rate of either fluid and pressure difference between both ends of specimen. But the steady state method doesn't meet the general process in fluid storage or production, where one fluid is displacing the other. In the unsteady state (displacement) method, one fluid of wetting phase which saturates a specimen is displaced by other fluid of none-wetting phase.

To evaluate the relative permeability from the unsteady state experiments, however, analytical or numerical method is needed because the saturation in the specimen is not homogeneous during displacing process. The JBN method is generally used in petroleum reservoir engineering, which is one of the analytical methods for one dimensional displacement (or oil-recovery) problem. Because this method needs the derivation of the measurements such like flow rates and pressure difference, the results using the measurements directly might be erroneous, so some adequate approximations of the measurements or other manipulations should be done. In addition, the flow condition that is assumed in the JBN method, neglect the effects of capillary pressure, compressibility of fluids and gravitational force, so the JBN method is inadequate if these effects are serious. In many researches the history matching techniques are adopted to derive the optimal relative permeabilities by using two phase flow numerical simulations and minimal residual routines.

On these backgrounds, we have made new experimental equipment on permeability test for rocks using super-critical CO2. Our experiment is based by the displacement method and the saturation of the specimen is calculated by fluid volume balance. For the volume measurements, a separator corresponding to high pressure was set through the outlet line so that the flow-out fluids from the specimen separate here. To evaluate saturation of specimen, we must consider the storage volume (or dead volume) in the line that affects total fluid volume which flows into and flows out from the specimen. There are two portions of line that constitute the dead volume, one is the in-flow part from the injection syringe pump to the specimen and the other is out-flow part from the specimen to the separator. The former has been detected by the flow rate and pressure change when displacing fluid reaches to the top of specimen. The latter was measured initially and reduced from the total outflow volume.

Some sandstones and mudstones were tested to evaluate relative permeabilities. The test results has revealed following facts.

1)Relative permeabilities of displacing CO2 calculated by average flow rate are almost equal to those by JBN method, but those of the displaced water are somewhat different.

2)The simulations using Tough2 with the relative permeability by JBN method, can reproduce the test behaviors.

3)Theoretical models such as Corey(1954) doesn't match with our test results, so more flexibility is needed to model the test results.

Keywords: CCS(Carbon dioxide Capture and Storage), Two Phase Flow, Relative Permeability, Laboratory Experiment