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Numerical simulation of supercritical CO_2 injection into subsurface rock masses

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Abstract

Carbon dioxide (CO_2) is considered to be one of the greenhouse gases that may contribute most to global warming on the earth. Disposal of CO_2 from stationary sources into subsurface structures has been suggested as a possible means for reducing CO_2 emissions into the atmosphere. However, much remains to be done in the issues regarding the safety and reliability of CO_2 geological sequestration. In this study, we have developed a simulation code by using the mathematical model of two phase flow in porous media to analyze the flow dynamics in the subsurface. The equation of state for CO_2 covering the fluid region from the triple point to the supercritical region is employed to model the states of CO_2 gas, liquid and supercritical state. The correct understanding of the CO_2 state under the geological formation condition is an important factor to predict the injection pressure and CO_2 fluid permeation because the fluid density has a great effect on the injection behavior. The numerical simulation was implemented under several geological conditions including gas, liquid and supercritical states to examine the optimal injection condition. Comparing the numerical results obtained using the equation of state for CO_2 with those obtained using the ideal gas equation, it has been shown that the difference in the injection pressure appears to be significant near the condition of the critical point of CO_2 and the phase equilibrium curves between the gas and liquid states. The numerical simulation has been implemented to examine the effect of the reservoir condition on the injection behavior. The injection pressure is decreased at the lower reservoir temperature and higher hydrostatic pressure condition. The CO_2 permeation is also strongly affected by the reservoir condition, and the spatial CO_2 saturation becomes higher with increasing reservoir temperature. It has been demonstrated that the simulation code developed in this study may be useful to provide knowledge required to select the reservoir condition for CO_2 geological sequestration.

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Keywords: CO_2 geological sequestration; Numerical simulation; Supercritical CO_2; Two phase flow

1. Introduction

Human activity since the industrial revolution has had the effect of increasing the concentration of atmospheric greenhouse gases such as carbon dioxide (CO_2) [1]. Increasing concentrations of greenhouse gases lead to enhancing the greenhouse effect. A reduction in the release rate of CO_2 to the atmosphere is considered as essential for control of global warming. One way of achieving CO_2 reduction is to dispose of CO_2 in deep aquifers [2]. Deep aquifers have a large potential for CO_2 sequestration in geological media in terms of volume and duration. The conceptual model of CO_2 geological sequestration is shown in Fig. 1. CO_2 can be stored in aquifers in three ways. First, CO_2 can be hydrodynamically trapped as a gas or supercritical fluid in deep aquifers. Because of a very long flow

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