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Numerical Study of Formation Mechanisms of CO_2 Hydrate

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Recently, methane gas extraction from gas hydrate deposits has been widely discussed and studied. There is an advance production strategy by using CO_2 injection. There are several attractive features of this novel technique. Injecting CO_2 into a gas hydrate deposit causes the replacement between CO_2 molecules and CH4 molecules inside the hydrate crystal structure. The reaction leads to the CO_2 hydrate formation and CH4 gas release. The free CH4 gas can be produced by depressurization process. Because of the formation of CO_2 hydrate, we also benefit from the CO_2 sequestration. However, the mechanisms of CO_2 hydrate formation play essential roles in this operation. Numerical simulation can be a convenient tool to study gas hydrate production. Therefore, it is crucial to establish a reliable module of CO_2 hydrate reaction. The propose of this study is to determine the thermal dynamic parameters of CO_2 hydrate reaction, for a simulation use, depending on a laboratory experiment data.

In this study, a numerical model used for CMG-STARS reservoir simulator is set up according to a laboratory experiment of CO_2 hydrate formation. The experiment was done by a research team from National Taiwan University of Science and Technology (NTUST). The numerical grids are designed to imitate the real equipment that had been used in the experiment. To observe the influence of different parameters which are affective to the reaction, there are series of sensitive analyses of flow properties, hydrate reaction parameters, and thermal properties. Afterward, a CO_2 hydrate reaction module is built according to the history matching of the temperature and pressure data from an experimental CO_2 hydrate formation research. Then, the hydrate saturation result is verified by an analytical solution.

The major findings in this study are: (1) A CO_2 hydrate reaction module is established according to the experimental CO_2 hydrate formation data. (2) The reaction parameters in the module such as activation energy and reaction equilibrium constant are the key elements of the CO_2 hydrate phase behaviors. The phase changes process inside the porous media controls the molecular exchange with CH4 hydrate. (3) The thermal properties of the porous media can influence the amount of formation and dissociation of CO_2 hydrate. (4) Both results of experiment and simulation work show similar reaction that CO_2 hydrate formation begins at the interface between water and gas. This indicates that this study successfully establishes a CO_2 hydrate module which is capable of simulating the actual CO_2 hydrate reactions of laboratory experiment.