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NUMERICAL ANALYSIS OF HYDRATE DISSOCIATION BEHAVIOR IN SAND-PACKED CORES DURING DEPRESSURIZATION AND HEATING

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Introduction

In-place gas value within natural gas hydrates in Nankai Trough of offshore Japan is estimated to be about 7.5 trillion cubic meters that equal 100 years of domestic annual consumption of natural gas. How to recover gas safely and economically from the ocean hydrates is of most interest from the point of engineering, and we have been developing a numerical simulator for evaluating development methods of these hydrates, designing and analysis of production tests, designing of laboratory tests, etc. The objective of this research is to analyze the dissociation behavior of methane hydrate observed from the laboratory experiments of depressurization and heating with the help of a numerical simulator (MH21 Reservoir Simulator). The efficacy of the simulator is discussed through the comparison between experimental data and simulation results.

Experiments

The experimental data of depressurization and heating were obtained at the laboratory of the National Institute of Advanced Industrial Science and Technology (AIST). The details of the experimental conditions and results are presented at a separate paper[1)]. The sand-packed cores with hydrate saturations of 50 to 80 % were prepared and the dissociation experiments were carried out using a Hassler-type core holder. In the depressurization experiments the pressure at one end of the core was decreased to induce hydrate dissociation, and later gas and water were produced at a constant pressure. In the heating experiments hydrate dissociation was induced by heating one end of the core, and gas and water were produced at a constant pressure. We measured the volumes of gas and water produced and the temperatures at the both ends during the experiment.

Simulation Runs

The simulator used for this analysis is the MH21 reservoir simulator that has been developed under the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium). The simulator theory is presented at another paper[2)]. The primary input data for simulation are core properties (length, diameter, porosity, thermal conductivity of sand grains, absolute permeability, relative permeability curves and capillary pressure curves), hydrate number, initial conditions of pressure and temperature, initial saturations of gas, water and hydrate, production surface pressure, temperature of surroundings, heat transfer coefficients on the periphery of the core. One important input data is the permeability reduction index N that expresses the tendency of decreasing permeability with increasing hydrate saturation. We simulated the laboratory experiments of heating and depressurization by using this simulator. In the simulations input data were carefully given to reproduce the experimental procedure. Almost all the data were determined from the experimental conditions, but the relative permeability and the capillary pressure curves under the presence of hydrate are unknowns. We assumed zero capillary pressure and a typical relative permeability curves to sand-packed cores. The permeability reduction index N is also a matching parameter in the simulation.

Results & Discussions

Figure 1 shows comparison of the experimental gas production data with simulated results for one depressurization experiment (Initial pressure: 10 MPa, Production surface pressure: 4 MPa). Figure 2 shows comparison of temperature changes with time during the same experiment. The permeability reduction index N was set to be 2.0 for this simulation. Although the simulated results were not completely matched with experimental data, the tendencies of gas production and decreasing temperature with hydrate dissociation are reproduced by the simulation. The simulation results indicate the supply of heat from the periphery of the core had an important role to continuous hydrate dissociation.

The disagreements between experimental and simulated results are also recognized for the other experiments to a greater or lesser degree. Since the value of N is about 2.0 for unconsolidated sand packs and the duration of hydrate dissociation was simulated appropriately, the most suspicious factors are considered to be relative permeability curves and capillary pressure effect at the end of the core. We are now trying to find the better simulation results by changing these parameters. The studies of parameter matching will suggest us better modeling of relative permeabilities and capillary pressures under the presence of hydrate. More results including the simulation of heating will be presented at the conference.

Hydrate dissociation in natural sediments is a complex phenomenon combined with mass and heat transfer. Many mathematical models (such as permeability, thermal conductivity models, etc.) and empirical equations are used in the MH21 reservoir simulator. The validity of these models and equations can be checked through the comparison between experimental data and simulation runs. The precision of the simulator will be considerably improved by our current validation studies.

Acknowledgments

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References

(1) Ebinuma, T. et al., An experimental study of dissociation of mock methane hydrate sediments. (presented at the same conference).
(2) Masuda, Y. et al., A field-scale simulation study on gas productivity of formations containing gas hydrates, Proc. 4th International Conference on Gas Hydrates, p. 40 - 46, Yokohama, Japan, May 2002.

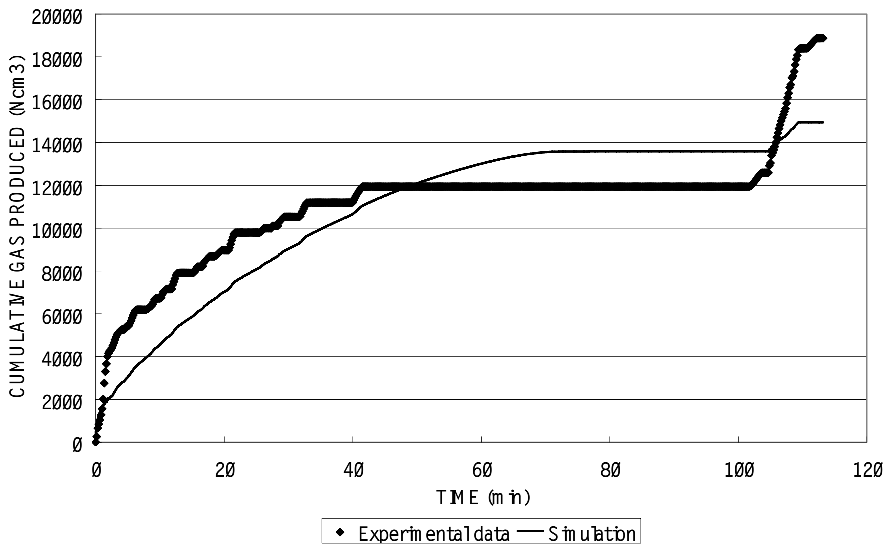

Figure 1 Experimental and simulated gas volume produced vs. time.
Depressurization experiment:
Initial pressure = 10 MPa, Production surface pressure = 4 MPa.

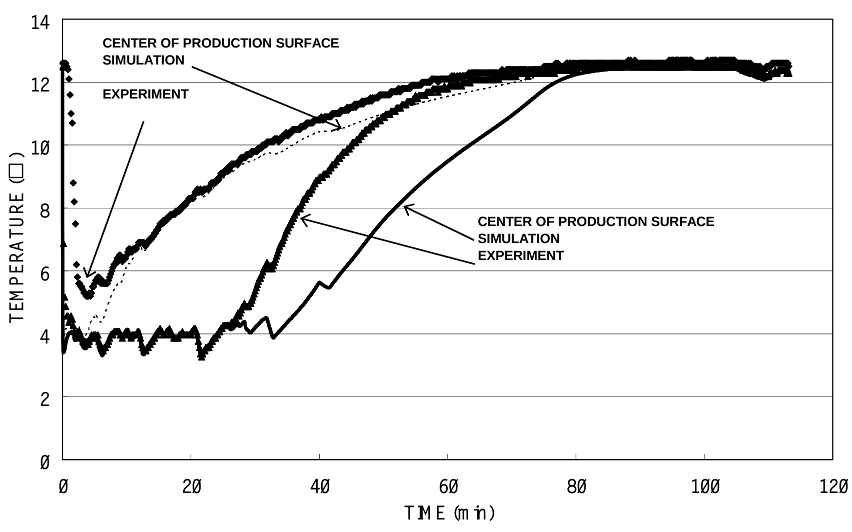

Figure 2 Experimental and simulated temperature vs. time.
The same depressurization experiment as shown in Figure 1