International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 19, No. 2, June 2009, pp. 124–134

Numerical Study on Dissociation of Methane Hydrate and Gas Production Behavior in Laboratory-Scale Experiments for Depressurization: Part 3—Numerical Study on Estimation of Permeability in Methane Hydrate Reservoir

Yasuhide Sakamoto, Masayo Kakumoto, Kuniyuki Miyazaki, Norio Tenma, Takeshi Komai and Tsutomu Yamaguchi
Methane Hydrate Research Laboratory, National Institute of Advanced Industrial Science and Technology (AIST) Tsukuba, Ibaraki, Japan

Mai Shimokawara and Kotaro Ohga
Graduate School of Engineering, Hokkaido University, Sapporo, Hokkaido, Japan

We conducted an experimental study on the dissociation of methane hydrate (MH) and gas production behavior by depressurization in sediments. To reproduce the actual flow condition of gas and water, disc-shaped samples of MH in sediments were used. Horizontal radial flow in porous media during MH dissociation was studied under a variety of vertical loads in order to reproduce field conditions in real MH sediments. From experimental observations, it was found that the MH dissociation consisted of 2 stages due to the latent heat of sediments and thermal conduction. Based on experimental results, we carried out numerical simulations of laboratory-scale experiments for depressurization. Thermal conductivity that dominated dissociation behavior was optimized. Further, we formulated realistic relative permeability curves that allowed us to reproduce the gas-water production behavior under the existence of MH.

INTRODUCTION

Methane hydrate (MH) existing in marine sediments close to Japan is expected to be developed as an alternative energy resource to oil and coal (Okuda, 1993; Sato et al., 2001a, b). To develop this domestic resource in the future, the Agency for Natural Resources and Energy (ANRE) under the Ministry of Economy, Trade and Industry (METI) formulated Japan's Methane Hydrate Exploitation Program in 2001 and established the Research Consortium for Methane Hydrate Resources in Japan (MH21) consisting of the following 3 divisions: Resources Assessment, Production Method and Modeling, and Environment Impact (METI, 2001). This project is based on the mid- and long-term program aimed at the commercial production of methane gas from an MH reservoir in 2016. In 2003, the preliminary drilling Tokaioki–Kumanonada was carried out, and the existence of a zone containing a large amount of MH was confirmed in the east Nankai trough area. From the current estimation results, the resources available in this sea area are estimated to be 1.1×10^{12} m^3, which is 14 times the current natural gas consumption in Japan per year (METI, 2007). We have conducted research and development to establish gas recovery methods with high productivity and economic efficiency from the MH reservoir existing in such marine sediments.

Several MH extraction methods from reservoirs in marine sediments have been proposed, such as depressurization, thermal stimulation and inhibitor injection. These are all based on the in-situ dissociation of MH that is transformed into methane gas and water. However, in the thermal stimulation process, the problem of thermal efficiency for an injected fluid is assumed. On the other hand, in the inhibitor injection process, the chemical materials used as an inhibitor are expensive. In addition, the environmental impact due to the utilization of such materials is a concern. Depressurization is thus regarded as the most effective process for gas recovery from the viewpoints of gas productivity and economic efficiency, compared with the other in-situ dissociation processes (Kurihara et al., 2005). During depressurization, the pressure decrease around the bottom hole of the production well is initiated by discharging water from the well and reducing the water head. As the pressure decrease propagates into the sediments from around the well to surrounding layers, MH dissociation proceeds. The dissociated gas flows depending on the pressure gradient and is then recovered from the production well (JOGMEC, 2004).

It is necessary to develop a numerical simulator to predict gas productivity from an MH reservoir and carry out a parametric study to optimize the production system. As a part of the development of the numerical simulator, we have constructed a numerical model for the MH dissociation process in porous media, where the occupation condition of MH in the pore space was considered. In addition, on the basis of the measured results on permeability with MH formation, the absolute and relative permeabilities were formulated as functions of the MH saturation, sand grain diameter, and porosity (Sakamoto et al., 2007a, b).

To develop a numerical simulator, it is necessary to clarify the typical physical phenomena during MH dissociation and evaluate quantitatively the effects of the respective parameters on the MH dissociation and production behavior. Some experimental studies on depressurization have been reported. Yousif et al. (1988) conducted experimental work on depressurization using a Berea sandstone core. Kawasaki et al. (2005) visualized the migration

Received September 9, 2008; revised manuscript received by the editors January 5, 2009. The original version was submitted directly to the Journal.
KEY WORDS: Methane hydrate, dissociation, depressurization, permeability, simulation.