Experimental studies of dissociation behaviors of hydrate-bearing sand by core tests and rapid-scanning X-ray CT imaging

Takao Ebinuma[1]; Hiroyuki Oyama[1]; Takashi Uchiumi[1]; Kiyofumi Suzuki[1]; Jiro Nagao[1]; Hideo Narita[2]

[1] MHRL, AIST; [2] MHRL,AIST

Methane hydrate has considerable potential as a new source of energy. Methane hydrate occurs in a variety forms. The form considered the most suitable for exploitation is that found in the pore spaces of sandy sediments, which has a larger gas permeability than other forms. Methane-hydrate-bearing laminated layers were discovered in the Eastern Nankai Trough, where reserves of methane hydrates were found in sand layers laminated between mud layers. This laminated structure, which includes the sand layers, was formed by turbidity currents. Although marine methane hydrate layers are found in deepwater, they are located only several hundred meters below the sea floor. These methane hydrate layers are thus unconsolidated, in contrast to oil and natural gas reserves that are found in consolidated sand layers. We are developing methods for recovering methane gas by dissociating methane hydrates in the sand layer, which has a large intrinsic permeability that is adequate for gas flow. We have studied depressurization, thermal recovery and inhibitor injection methods with a view to dissociating methane hydrates. These methods are based on the phase equilibrium condition of methane hydrate.

Major considerations in developing production methods for methane hydrates are its dissociation behavior and also the gas and water flows to the production well generated by its dissociation in sediments. Therefore, we have developed a method for preparing artificial methane hydrate-bearing sandy sediments. Using core specimens of these artificial sediments, we experimentally investigated the dissociation of methane hydrate by depressurization and heating. A core holder was developed for high-pressure experiments. A confining pressure was applied to the core specimen using a rubber sleeve to simulate the overburden pressure to the methane hydrate layers. The pore pressure, which affects the stability of methane hydrate, was controlled independently from the confining pressure. Temperature and pressure were measured at many points on the core specimen during dissociation of methane hydrate, and the dissociation process was visualized directly using rapid-scanning X-ray CT imaging with a resolution of 0.25 mm and a scanning speed of 40-s at intervals of 2-min.

Dissociation by depressurization was performed by adjusting a backpressure regulator. The results showed that the temperature reduction induced by depressurization depended on the phase equilibrium state of methane hydrate and that dissociation occurred preferentially at the periphery of core. This behavior was due to the heat flux from outside of the core; the heat flux controlled the dissociation rate. A heat exchanger was installed at one end of the core to simulate thermal stimulation. In this experiment, a clear dissociation front was observed to propagate unidirectionally. The dissociation rate depended on the heating temperature and was less than that observed for depressurization. Thermal flooding was also simulated by injecting hot water at a constant rate from the bottom of core. The CT images showed movement of distinct accumulations of dissociated gas being pushed by the hot water. The injection pressure increased greatly when a large flow rate or a high water temperature was used. This behavior is considered to be due to regeneration of methane hydrate at the front of the gas accumulation due to a reduction in the permeability. The gas production rate increased immediately after the gas accumulation reached the opposite end of the core. We discuss characteristic dissociation behaviors and their relation to various production methods.

This work was financially supported by the Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) on the National Methane Hydrate Exploitation Program planned by Ministry of Economy Trade and Industry (METI).