Experimental Investigation into the Applicability of Depressurization to Dissociate Methane Hydrate in an Unconsolidated Sedimentary Sample

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ABSTRACT

The gas production behavior of a methane hydrate-bearing sedimentary sample was experimentally investigated during the dissociation process by depressurization. A unique apparatus of 10 meter-scale was developed to expand the in-situ applicability of depressurization. An unconsolidated sedimentary sample was prepared using artificial particles that have a similar grain-size distribution of sandy layers to that in real hydrate fields. In the experiments, pressure, temperature, and gas production volume were measured. The results showed that the gas production behavior was dominated by the fluid flow, which is unlike previous experimental results performed using centimeter-scale samples.

KEY WORDS: methane hydrate; dissociation; gas production; depressurization; dominant factor;

INTRODUCTION

Recently, research on gas hydrates has focused on methane hydrate since an enormous amount of natural gas hydrates, predominantly methane gas, is deposited in permafrost regions and in marine sediments worldwide. Accordingly, it is expected to become an alternative energy resource but currently unconventional (Sloan and Koh, 2008). Until now, the recovery schemes for natural gas caged in the solid state have not been commercialized, however three conceptual methods (i.e. thermal stimulation, depressurization, inhibitor injection, and their combination) have been investigated in experiments and numerical simulations. Depressurization has been identified as a promising method in many previous lab-scale studies due to its economic feasibility. This method can enhance gas production and prevent hydrate reformation when used in conjunction with other methods (Moridis et al., 2007; Li et al., 2008; Ahn et al., 2010). For such reasons, a lot of experimental and numerical works have been conducted to understand characteristics of depressurization-induced gas production. One of the emerging issues has to do with the dominant factors of depressurization-induced gas production behavior among three fundamental phenomena: the kinetics of hydrate dissociation, heat transfer from surroundings, and the fluid flow through the reservoir (Tang et al., 2007; Oyama et al., 2009; Konno et al., 2010). A factor is considered dominant when it limits and controls the gas production.

Tang et al. (2007) derived the hydrate intrinsic dissociation constant by fitting the laboratory hydrate depressurization experiments with the numerical simulation results. From sensitivity analyses based on the numerical simulation, they concluded that the gas hydrate production is kinetic-controlled for a laboratory-scale hydrate core while it is flow-controlled for a field-scale hydrate reservoir. Oyama et al. (2009) built a dissociation model for applying depressurization method that takes into account heat transfer and mass transfer. This model was evaluated using experimental results and demonstrated that the heat transfer from the surroundings is dominant in the core (15 cm long) dissociation process. Konno et al. (2010) conducted laboratory core scale experiments using artificial cores (15 cm long) and analyzed the rate-determining factors of depressurization-induced gas production by using numerical simulations. They revealed that the dominant factor of gas production behavior transits from the fluid flow to heat transfer in a low permeability core. They also suggested that it is necessary to scale up an experimental apparatus to more than 0.5 m long in order to simulate the gas production behaviors in field-scale reservoirs.

The above mentioned previous works exhibited the scale-dependent properties of the dominant factors and the significance of the fluid flow on depressurization-induced gas production behavior. However, they have not demonstrated how the flow dominates the gas production behavior under the constraints of experimental scale.

In this study, a 10 meter-scale apparatus was developed to simulate the depressurization-induced gas hydrate production of a field-scale reservoir. The gas production behavior was investigated from the viewpoint of the dominating factor by observing the pressure, temperature, and gas production over time in the depressurizing process.

EXPERIMENTAL METHODOLOGY

Experimental apparatus