# Development of Methane Hydrate Reservoir Simulator and Its Application

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Methane hydrate (MH) is being highlighted as next-generation hydrocarbon resources due mainly to its huge in place and cleanness. The Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium), which was organized to attain the exploration and exploitation of MH resources, has been implementing a variety of research projects. As part of such research projects, we have been developing a state-of-the-art numerical simulator (called 'MH21-HYDRES') for rigorously predicting MH dissociation and production performances. The main functions of this simulator and the examples for the simulation studies conducted using this simulator are introduced in this presentation.

The gas production from MH reservoirs is significantly different from that from conventional oil and gas reservoirs in terms of the mechanism and the phenomena, since (1) MH is a solid, (2) reservoir behaviors are associated with the chemical reactions such as MH dissociation/formation, and (3) reservoir properties, especially permeability, change drastically by MH dissociation. Therefore, it is impossible to predict MH reservoir performances by conventional oil and gas reservoir simulators, which lead to the commencement of the development of the numerical simulator specialized for MH reservoirs.

Currently MH21-HYDRES has the following functions:

∗Three-dimensional Cartesian and two-dimensional radial coordinate systems can be applied with dynamic local grid refinement.
∗Four-components (methane, water, methanol and salt) are available.
∗Five-phases (gas, water, ice, MH, (precipitated) salt) are available.
∗Gas and water flows are calculated based on Darcy's law.
∗Dissociation of MH/ice and formation of MH/ice are expressed by kinetics defined by Kim-Bishnoi equation or similar equations.
∗Endothermic dissociation of MH/ice as well as the exothermic formation of MH/ice are taken into consideration.
∗The equilibrium pressure for the three phases of MH-methane-water (or -ice) is estimated as a function of temperature and salt/methanol concentration.
∗Multiple wells including vertical and horizontal wells can be incorporated.
∗Various boundary conditions can be applied.
∗Graphical input/output system is available

This simulator divides the target reservoir into multiple grid blocks, for which the pressure, temperature, water saturation and methanol and salt mass fractions are calculated solving the system of discretized non-linear equations for the component mass conservation and the overall energy conservation. To shorten the computational time, it is preferable to reduce the total number of grid blocks and hence to increase the size of grid blocks. On the other hand, larger grid blocks result in more significant numerical errors, which is more serious in a MH simulator than in a conventional oil and gas simulator. To resolve these problems inconsistent with each other, the Dynamic Local Grid Refinement function is incorporated into the simulator, which allows the allocation of fine grid blocks only to the important regions of MH dissociation/formation at every time step, in order to shorten the computational time without reducing the accuracy of prediction.

Using this simulator, we have been conducting various simulation studies. As one of such simulation studies, the relationship between reservoir characteristics and the efficiency of MH dissociation and production methods were examined, through which numerous insights into the mechanisms of MH dissociation and the applicability of MH production methods were obtained. We have been also conducting the field scale simulation focusing on the existing MH reservoirs with diverse characteristics including those located in Mallik and in the Eastern Nankai Trough. These studies suggest that the gas production from MH reservoirs is promising if reservoir characteristics are favorable with high permeability and initial temperature.