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Numerical Studies of Methane Gas Production from Hydrate Decomposition by Depressurization in porous media

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Abstract

As a kind of potential new sources of energy, the dissociation processes of gas hydrates using the depressurization method has been investigated by experimental observations and numerical simulations. In this study, on the basis of summarizing the existing model, a one-dimensional mathematical model containing four phase (water phase, gas phase, hydrate phase, ice phase) and three constituents (water, gas, hydrate) using the finite difference method (FDM) was established for methane hydrates decomposition by depressurization in porous media. This paper focuses on the ice generation and distribution characteristics through changing the parameters of the relevant settings, and analyzes the effect of ice generation on the pressure, temperature, permeability, cumulative gas production and other parameters. The results show that, generation of ice increases gradually in the hydrates decomposition process, and occurred early near the side area because of the large pressure gradient. The absolute permeability and instantaneous gas generation rate at the early stage decline with ice generation, and the local pressure rise.

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Key Words: Methane hydrate; decomposition; ice generating; Mathematic model; Numerical simulation

Nomenclature

ρ_w 、 ρ_g	the density of water and methane gas
$\overrightarrow{v_w}$、 $\overrightarrow{v_g}$	the velocity of water and methane gas
m_w、 m_g、 m_h	the mass of water and gas per unit volume per and time, consumption mass of hydrate
S_j （$j = w, g, h, i$）	saturation for each phase

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ϕ	porosity
$k_j(j = r, w, g, h, i)$	thermal conductivity
$c_j(j = r, w, g, h, i)$	specific heat at constant pressure
ΔH_h	the heat absorption capacity per unit mass hydrate decomposition
ΔH_i	the latent heat of unit mass of water freeze

1. Introduction

Gas hydrate is a kind of compounds, in which gas molecules is wrapped by hydrogen bonds in water molecules into the cage structure. Developing methods for production of natural gas from hydrate is attracting considerable attention. Nature gas hydrate in 20 Pa ~ 2000 MPa pressure and temperature range 70 K to 350 K can be stable. And the formation and decomposition of it depends on the pressure, temperature, gas composition, the salinity of the water, the characteristics of porous media and other factors. By increasing the system temperature above the temperature of hydrate formation and decreasing the system pressure, the decomposition of hydrate occurred[2].

Compared with the experimental research the advantage of numerical simulation is the lower cost and easy to adjust the space-time scale. Holder et al considered the variation of temperature and simulated the hydrate decomposition[3]. By using the heat transfer equation, the temperature distribution in the hydrate layer was obtained. And the gas flow and the movement velocity of the surface of decomposition were determined. It assumed that the hydrate decomposition only occurs at the interface between two adjacent reservoirs. But it did not consider hydrate decomposition of the flow of water; gas was only considered single phase flow. Based on this model, three-dimensional model was established on the top of the hydrate considering the hydrate decomposition in the process of the formation of liquid water and the impact on the gas production[4]. However, this work were simple because of the limited understanding on gas hydrate behaviour at that time.To combined with dynamic model and improve the mathematical model, one-dimensional three-phase, finite difference simulator to simulate Berea core decompression decomposition process of hydrate. In particle, the hydrate formation and decomposition coupled the interface movement and physical properties change, i.e., porosity and permeability change[5,6]. The simple models are limited to describe the processes for gas hydrate formation and decomposition. By using adopted elastic and viscoelastic model to simulate the gas hydrates decomposition, the effect on the deformation of solid skeleton was investigated.

Although after efforts came from many researchers, the research in numerical simulation of natural gas hydrate decomposition characteristics had significant progress. One of which is that the ice phase was overlooked by most of the model. But ice phase is generated in the process of natural gas hydrate exploitation is real. And its effect is also need to analyze and attention. Therefore, this study consider ice phase into the mathematical model, and analyzed the influence in the hydrate decomposition by depressurization. This paper focuses on the ice generation and distribution characteristics through changing the parameters of the relevant settings, and analyzes the ice with the pressure, temperature, permeability, cumulative gas production.

2. Mathematical model

2.1. Physical model

The schematic of the gas hydrate decomposition by depressurization is shown in Fig.1. Initial parameters of the reservoir respectively are pressure P_0, temperature T_0, absolute permeability K_0, each