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ScienceDirect

Energy Procedia 125 (2017) 486–493

Energy Procedia

www.elsevier.com/locate/procedia

European Geosciences Union General Assembly 2017, EGU Division Energy, Resources & Environment, ERE

Effects of Geomechanical Mechanisms on Gas Production Behavior: A Simulation Study of a Class-3 Hydrate Deposit of Four-Way-Closure Ridge Offshore Southwestern Taiwan

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Abstract

The purpose of this study is to investigate the effects of the geomechanical mechanisms on the gas production of a depressurized Class-3 hydrate deposit, Four-Way-Closure Ridge. From this case study, we found that there is a lower gas production rate and a longer production plateau when geomechanics are considered in the fluid flow modeling. The Young's modulus and Poisson's ratio are sensitive parameters to the reservoir deformation and the seafloor subsidence. We suggest that the geomechanical issue should be well considered in a hydrate deposit development project.

Peer-review under responsibility of the scientific committee of the European Geosciences Union (EGU) General Assembly 2017 – Division Energy, Resources and the Environment (ERE).

Keywords: depressurization; gas hydrate; geomechanics; reservoir simulation; seafloor subsidence

1. Introduction

The future energy policy of Taiwan will heavily rely on clean energy, including renewable energy and low-carbon energy, to meet the target of mitigating CO_2 emissions. Taiwan's long-term national greenhouse gas (GHG) emission reduction goal is to reduce GHG emissions to no more than 50% of the 2005 emission level by 2050 [1]. Natural gas is a clean energy source with relatively low carbon emissions. The share of natural gas in total electricity generation

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1876-6102
Peer-review under responsibility of the scientific committee of the European Geosciences Union (EGU) General Assembly 2017 – Division Energy, Resources and the Environment (ERE).
10.1016/j.egypro.2017.08.163

will increase from 30% to 50% by 2025 in Taiwan [1].

Natural gas can be obtained from gas hydrates. Gas hydrates, an unconventional gas resource, exist at low temperature and high pressure environments. Gas hydrates are crystalline and composed of natural gas and water mixtures with three chemical structure types: S1, S2, and SH [2]. Gas hydrates can be deposited in the permafrost and deep-sea sediments, and most of the hydrate deposits are the S1 type hydrate [2]. S1 type hydrate is also the main type discovered in offshore southwestern Taiwan [2-3].

In the past decade, Taiwan's geologists discovered vast resources of gas hydrates in southwestern offshore Taiwan [4]. Recent studies showed that Taiwan's gas hydrate resources are approximately 500 to 2700 billion standard cubic meters (Gm^3), which are capable of meeting Taiwan's energy usage for about 25 to 135 years. Gas hydrates provide a great opportunity for Taiwan to have its own energy resources in the future.

There are four types of gas hydrate deposits: Class-1 to Class-4 [4]. In this study, we focus on the Class-3 hydrate deposits, which is a stable hydrate layer between impermeable overburden and underburden. To produce natural gas from a gas hydrate deposit, depressurization and thermal stimulation can be used. The principal of depressurization and thermal stimulation is to change the formation environment to trigger hydrate dissociation, then the natural gas is released and produced. Depressurization is the most efficient method to produce natural gas from a hydrate deposit [2].

When depressurization is used, the degree of the pressure drawdown is the most important factor. Gas production and the degree of the pressure drawdown have a positive correlation. A larger pressure drawdown will lead to a higher gas production. However, during this process, the decreased pore pressure will generate an increased effective stress in the rock matrix; this means that formation deformation might occur [6]. Consequently, the risk of surface production facility damage is increased.

For the geomechanics issue, Chin [7] developed a one-way coupled hydrate production model to predict the possible subsidence area. He used the Tough+Hydrate [8] simulator with a geomechanical module. Kim [9] developed a two-way coupled model for the simulation and found a more accurate calculation. The Nankai Trough case study on a gas hydrate production test also focused on the evaluation of subsidence at the seafloor [10].

The purpose of this study is to investigate the effects of the geomechanical mechanisms on the gas production from a Class-3 hydrate deposit using the depressurization method. The case of a Class-3 type hydrate deposit of Four-Way-Closure Ridge was studied for that purpose.

2. Geological setting

The studied hydrate deposit, in the Four-Way-Closure (FWC) Ridge, was discovered by the bottom simulating reflectors (BSRs) (Fig. 1). The geological investigation showed that the hydrate deposit is located in the northeastern part of the FWC Ridge [11-12]. The deposit type of the FWC Ridge is Class-3 based on the geophysical interpretation.

The area of the studied hydrate deposit is about 0.69 km^2 with a thickness of 5 to 205 meters. The porosity of the deposit is 0.37 to 0.425 [13], and the initial hydrate saturation was assumed to 50% from the literature [12, 14-18].

The no-flow boundary condition was considered in this study area because there is a pinch-out at the northern and eastern boundaries and a mudstone block at the western boundary. The no-flow boundary condition assumed at the southern boundary is based on the available geological data.