Effect of Permeability in the Wellbore Decomposition Zone on Decomposition Characteristics of Reservoir Methane Hydrates Postprint

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Abstract

Submarine natural gas hydrate reservoirs feature complex geological structures, and the permeability of the wellbore decomposition layer varies significantly with different production well locations. However, the permeability of the wellbore decomposition layer directly determines the gas and water migration characteristics and production efficiency during hydrate production; improper well placement may lead to gas accumulation in the reservoir and secondary hydrate formation, directly affecting hydrate production efficiency. Therefore, to investigate the influence of wellbore decomposition layer permeability on the dissociation characteristics of methane hydrate in the reservoir, this study establishes permeability gradients corresponding to wellbore decomposition layer dry densities of 1.40 g/cm^3, 1.75 g/cm^3, 1.80 g/cm^3, 1.85 g/cm^3, and 1.90 g/cm^3 under a reservoir hydrate dry density condition of 1.40 g/cm^3, and employs both depressurization and thermal injection methods to explore the effects of wellbore decomposition layer permeability on the temperature-pressure response and gas production characteristics of the methane hydrate reservoir during production. Experimental results demonstrate: (1) The presence of the wellbore decomposition layer exerts an inhibiting effect on gas production from hydrate dissociation in the reservoir. As the permeability of the wellbore decomposition layer decreases, gas accumulation within the sediment pores becomes increasingly pronounced. During depressurization, secondary hydrate formation occurs near phase transition temperature conditions, and pore pressure exhibits a "decrease-then-increase" fluctuation. When the wellbore decomposition layer dry density d$ 1.80g/cm^{3}$, the "accumulation-breakthrough" phenomenon of reservoir gas production becomes evident, with a particularly significant escalation in the peak gas production rate of the hydrate reservoir; (2) During thermal injection production, as the permeability of the wellbore decomposition layer decreases, the pore pressure, interlayer pressure, and production pressure of the hydrate reservoir all increase to varying degrees; although the elevation

of reservoir temperature exerts a certain promoting effect on gas accumulation in pore pressure, the wellbore decomposition layer remains the primary factor causing gas accumulation, with the severity of accumulation descending from production pressure, to interlayer pressure, and then to pore pressure; (3) The permeability of the wellbore decomposition layer has a negligible influence on reservoir temperature during methane hydrate dissociation, and its effect on reservoir temperature can be disregarded during production.

Full Text

The Influence of Permeability of the Decomposition Layer Around the Well on the Decomposition Characteristics of Reservoir Methane Hydrates

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Abstract

Submarine natural gas hydrate reservoirs exhibit complex and heterogeneous geological structures, resulting in substantial variations in the permeability of the decomposition layer surrounding extraction wells depending on their placement. This permeability directly governs gas and water migration characteristics during hydrate exploitation, thereby determining overall production efficiency. Improper well placement can lead to gas accumulation within the reservoir and secondary hydrate formation, which severely compromises extraction efficiency. To investigate the influence of wellbore decomposition layer permeability on methane hydrate dissociation characteristics, this study established a permeability gradient by configuring the dry density of the decomposition layer around the well at 1.40 g/cm^3, 1.75 g/cm^3, 1.80 g/cm^3, 1.85 g/cm^3, and 1.90 g/cm^3 under a constant reservoir dry density of 1.40 g/cm^3. Both depressurization and thermal injection methods were employed to examine the effects of decomposition layer permeability on the temperature-pressure response and gas production behavior during exploitation. The experimental results reveal three key findings: (1) The presence of a wellbore decomposition layer impedes gas production from hydrate dissociation. As the permeability of this layer decreases, gas accumulation within sediment pores becomes increasingly severe. During depressurization, secondary hydrate formation occurs near phase transition temperature conditions, causing pore pressure fluctuations characterized by an initial decrease followed by an increase. When the dry density of the wellbore decomposition layer d $\geq$ 1.80 g/cm^3, a distinct "accumulation-breakthrough" phenomenon in gas production is observed, accompanied by a particularly sharp increase in the peak gas production rate. (2) During thermal injection, decreasing permeability of the wellbore decomposition layer leads to varying degrees of increase in pore pressure, interlayer pressure, and production pressure within the hydrate reservoir.

Although the rise in reservoir temperature somewhat exacerbates pore pressure accumulation, the decomposition layer remains the primary factor causing gas accumulation. The severity of accumulation, from highest to lowest, follows the order: production pressure, interlayer pressure, and pore pressure. (3) The permeability of the wellbore decomposition layer has a negligible effect on reservoir temperature during methane hydrate dissociation, and its influence can be disregarded during exploitation.

Keywords: Wellbore decomposition layer; Temperature-pressure response; Gas production characteristics; Permeability; Depressurization; Thermal injection

Note: Figure translations are in progress. See original paper for figures.