Article

Study on CO\(_2\) Huff-n-Puff Development Rule of Horizontal Wells in Heavy Oil Reservoir by Taking Liuguanzhuang Oilfield in Dagang as an Example

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Abstract: Heavy oil reservoirs are often characterized by high viscosity and poor mobility, which is more complex with the presence of bottom water. The conventional vertical well development method has low oil recovery efficiency and limited controlled reserves of a single well. In addition, water cut can increase dramatically when the edge-bottom water breaks through. Horizontal well and CO\(_2\) huff-n-puff is an effective alternative development model for heavy oil reservoirs. This development method makes efficient use of CO\(_2\) and accords with the “Carbon Capture, Utilization, and Storage (CCUS)”. The horizontal well can increase the drainage area. The dissolution of CO\(_2\) improves the mobility of crude oil and increases formation energy. In this paper, we established numerical simulation models based on the Liuguanzhuang oilfield in Dagang. The characteristics and producing rules of the horizontal well and CO\(_2\) huff-n-puff development in the heavy oil reservoir were studied. The results show that the production characteristics of horizontal well and CO\(_2\) huff-n-puff were similar to Steam-Assisted Gravity Drainage (SAGD). CO\(_2\) forms a viscosity reduction area above the horizontal well and the heavy oil flows into the wellbore due to gravity after viscosity reduction. The CO\(_2\) huff-n-puff can effectively enhance the production area of horizontal wells compared with the depletion development. However, the improvement in the production area gradually decreased as CO\(_2\) huff-n-puff cycles continued. There was a boundary of production area against the horizontal well, with the main production of heavy oil occurring at the upper and either end of the horizontal well. The CO\(_2\) huff-n-puff has a restraining effect on the edge-bottom water, which is confirmed via the proposed theoretical model.

Keywords: CO\(_2\) huff-n-puff; horizontal well; heavy oil reservoir; bottom water breakthrough; numerical reservoir simulation

1. Introduction

CO\(_2\) huff-n-puff is one of the main technologies for oilfield development, which is widely used in the development of low-permeability, tight-oil, and heavy-oil reservoirs. Moreover, it is the main applying direction in heavy oil stimulation. Ways to conduct effective carbon capture, utilization and storage (CCUS) have become a widely held concern among scholars in recent years [1–9]. Since CO\(_2\) has higher solubility in heavy oil than other gases, the stimulation mechanism of CO\(_2\) huff-n-puff is more prominent, which can control the production gas–oil ratio in a short period and significantly increase the cumulative oil production in heavy oil reservoirs [10–13]. The viscosity reduction effect of CO\(_2\) is remarkable, the applicable range of heavy oil properties is wide, and the viscosity reduction ratio can reach 99.8%. The crude oil expands and the expansion coefficient can reach 1.28. Both experimental studies and field tests show that CO\(_2\) huff-n-puff technology is one of the most successful EOR methods for heavy oil recovery [14–18].
Previous researchers carried out various studies on enhancing oil recovery using CO$_2$ huff-n-puff technology in oilfields. In 1986, Haskin et al. [19] demonstrated the influence of CO$_2$ injection volume and soaking time on crude oil production with different viscosities based on the CO$_2$ huff-n-puff project in Texas. The higher the viscosity of crude oil, the larger the amount of CO$_2$ injection required. In 1988, Monger et al. [20] studied the CO$_2$ huff-n-puff effect of a light sandstone reservoir in southern Louisiana. The field test showed that the larger the reservoir volume swept using CO$_2$, the lower the viscosity of reservoir crude oil. At the same time, CO$_2$ injection can also inhibit water production in oil wells [21,22]. In 1994, Miller et al. [23] summarized the effect of CO$_2$ huff-n-puff from 1984 to 1989 in the light oil reservoir of Big Sinking Oilfield in Kentucky. In 5 years, $1.22 \times 10^4$ t CO$_2$ gas was injected accumulatively, the number of huff-n-puff wellheads reached 290, the stimulation operation volume reached 390 times, and the final huff-n-puff oil increment was $1.8 \times 10^5$ bbl. The study conducted by Wehner et al. [24] in 1996 showed that the CO$_2$ huff-n-puff development technology has a high oil production rate, short production decline cycle, and high gas–oil ratio at the initial stage. When oil production reaches the peak, the water-oil ratio will not decrease anymore and gradually recover to the initial level. In 2012, Firouz A.Q. et al. [25] carried out a comparative experiment of methane solvent and methane–CO$_2$ mixed solvent huff-n-puff in heavy oil reservoir and found that the recovery ratio of CO$_2$ huff-n-puff was higher under the same conditions. When the pressure is low, the effect of heavy oil huff-n-puff with methane–CO$_2$ mixed solvent is better than that with pure methane solvent. Supercritical CO$_2$ has a good effect on reducing crude oil viscosity [26,27], and the viscosity reduction effect is far better than that of methane; thus, pure CO$_2$ solvent heavy oil huff-n-puff has the best effect. The injected gas can form foam with crude oil under certain conditions, and the foam can improve the displacement efficiency of the reservoir and ultimately increase the oil recovery [28,29]. CO$_2$ combined with foaming agents can enhance oil recovery through producing bubbles and reducing oil viscosity [30]. In addition to viscosity reduction and volume expansion of crude oil, CO$_2$ injection can also reduce near-wellbore reservoir damage, which can enhance crude oil production [31–33]. Compared with conventional vertical well huff-n-puff development, horizontal wells increase the reservoir swept volume of CO$_2$ and are more suitable for continuous heavy oil reservoirs [34–36]. Compared with vertical well development, bottom water breakthrough can change water coning to water line advancement, and the overall pressure distribution of bottom water is relatively stable and easier to control. Horizontal well and CO$_2$ huff-n-puff development are more beneficial in inhibiting bottom water coning [37–40].

This paper established a conceptual model of the horizontal well and CO$_2$ huff-n-puff based on the Liuguanzhuang Oilfield in Dagang. The study aims to analyze the production behavior of horizontal wells through reservoir numerical simulation. The paper also examines the impact of crude oil viscosity and reservoir permeability on the efficiency of CO$_2$ huff-n-puff, while the production behavior of different huff-n-puff cycles was analyzed. Moreover, we present a case analysis of a typical heavy oil reservoir in Liuguanzhuang and verify the conclusions of numerical simulation research. The study deepens the accuracy of understanding the production law and provides a theoretical basis and reference for the field development of horizontal well and CO$_2$ huff-n-puff.

2. Overview of the Study Area

There are many oil-bearing formations in the Liuguanzhuang oilfield; the depth of the reservoir is 1300–2200 m. There are high-quality oil and gas reserves located between the Ming and Sha layers. Figure 1 shows the characteristics of the complex reservoirs, which include structure and lithology. The reservoirs are mainly controlled via structures and have uniform oil–water contact. The oil and gas accumulate in the high part of the reservoir and are controlled through the distribution of sand bodies.
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Figure 1. Reservoir profile of Liuguanzhuang oilfield.

Liuguanzhuang oilfield is characterized by late accumulation. The reservoirs are generally oxidized via water washing. According to the statistics regarding the crude oil properties of each layer series, the density of crude oil at 20 °C is between 0.92 and 0.95 g/cm³, and the viscosity of degassed crude oil at 50 °C is between 100 and 10,000 mPa·s. The overall performance is that the crude oil properties of the Guan and Ming layers are characterized by high crude oil density, high crude oil viscosity, high asphaltene content, low freezing point, low wax content, and low sulfur content, with these properties belonging to heavy oil. The study area of this paper is mainly located in the Guan layer.

3. Study on the Producing Law of CO2 Huff-n-Puff
3.1. Numerical Model Parameter Setting

The mechanism model of the horizontal well and CO2 huff-n-puff was based on the Guan layer in the Liuguanzhuang reservoir through applying Eclipse and tNavigator simulators. The compositional model was established with the PVT properties of the crude oil. The components and mole fraction of crude oil are shown in Table 1. Figure 2 shows the relative permeability function curve in the numerical simulation. The conceptual model establishment schematic diagram is shown in Figure 3.

Table 1. Crude oil component division data sheet.

<table>
<thead>
<tr>
<th>Component</th>
<th>CO2</th>
<th>C1</th>
<th>C2~C5</th>
<th>C6~C10</th>
<th>C11~C20</th>
<th>C21~C30</th>
<th>C30+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mole fraction</td>
<td>0.001</td>
<td>0.085</td>
<td>0.114</td>
<td>0.15</td>
<td>0.22</td>
<td>0.25</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Figure 2. Relative permeability function curve: (A) oil–water relative permeability; (B) gas–liquid relative permeability.
The horizontal section of the horizontal well is located in the middle of the reservoir grids, and the length of the horizontal section is 200 m, according to the horizontal well parameters of the actual block. The horizontal section is fully perforated. The development mode is CO₂ huff-n-puff development, and the huff-n-puff cycles are five times. In each cycle round, CO₂ injection lasts for 20 days, well soaking lasts for 15 days, and well production lasts for 60 days. The daily gas injection volume is 15,000 m³/day. Table 2 shows the basic parameters of the model. Through the reservoir conceptual model, the study on pressure diffusion of well soaking, oil viscosity, saturation change after different cycles of development, and production area of the horizontal well is carried out.

### Table 2. Parameters of conceptual model of horizontal well huff-n-puff technology policy.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid dimensions</td>
<td>L × W × H, m = 60 × 41 × 15</td>
<td>Average porosity, f</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>L × W × H, m = 300 × 205 × 15</td>
<td>Crude oil viscosity, mPa·s</td>
<td>2000</td>
</tr>
<tr>
<td>Initial oil saturation, f</td>
<td>0.65</td>
<td>Crude oil viscosity, mPa·s</td>
<td>2000</td>
</tr>
<tr>
<td>Initial reservoir pressure, MPa</td>
<td>13</td>
<td>Rock compressibility, 1/bar</td>
<td>3.5 × 10⁻⁵</td>
</tr>
<tr>
<td>Depth of top surface, m</td>
<td>1300</td>
<td>Density of formation water, kg/m³</td>
<td>1000</td>
</tr>
<tr>
<td>Mean penetration, mD</td>
<td>1000</td>
<td>Density of formation crude oil, kg/m³</td>
<td>981.76</td>
</tr>
</tbody>
</table>

### 3.2. Pressure Diffusion Law of Soaking the Well

Figure 4 shows the average reservoir pressure change curve during five cycles of CO₂ huff-n-puff production. With the development of the simulation, the reservoir pressure decreases from 13 to about 7 MPa. The gas injection stage can make the pressure of the whole area rise again, but the overall trend is downward. The gas injection stage can increase the average pressure of the whole area by 3–4 MPa. The pressure increases by about 3 MPa in each huff-n-puff cycle. In the subsequent cycles, the minimum pressure of the whole area retains about 7 MPa and does not decrease significantly, which shows CO₂ huff-n-puff can supplement and maintain certain reservoir energy.

![Average pressure change curve of reservoir.](image-url)
Figure 5 compares the pressure distribution histogram of the numerical model grid at the end of gas injection and well soaking. During the 15-day well soaking process, there is an obvious process of outward pressure diffusion. The pressure is gradually swept outward from the near horizontal well area. The pressure of the whole area changes from 13~21 to 16~18 MPa. At the end of the well soaking stage, the overall pressure distribution of the whole area is more uniform, though there is a certain pressure-swept boundary.

**Figure 5.** Model grid pressure distribution histogram: (A) completion of 1st cycle of gas injection; (B) completion of 1st cycle of soaking.

### 3.3. Production area of Horizontal Well

Figure 6 shows the variation in the remaining oil saturation and crude oil viscosity in different huff-n-puff cycles. With the increase in huff-n-puff cycles, the production area of the horizontal well expands continuously, and the area with low crude oil saturation and viscosity increases. However, compared to the third and fifth cycles, it can be seen that the increasing range of production area becomes smaller. The increasing rate of production area is gradually decreased as CO2 huff-n-puff cycles continue, and there is a boundary in the production area of a single-well huff-n-puff. From Figure 5, the overall production area at both ends (heel and toe) of horizontal wells is larger, the producing distance outward is farther, and the grid range of low crude oil saturation and low viscosity is expanded outwardly.

**Figure 6.** Remaining oil saturation and crude oil viscosity field: (A) remaining oil saturation change; (B) viscosity change in crude oil.

Figure 7 shows the distribution of remaining oil saturation of the reservoir after five cycles of CO2 huff-n-puff development, including the top view A and the cross sections in three different directions of B, C, and D. From section A, after five cycles of huff-n-puff, both ends of the horizontal well are the main production areas, while the middle part is
seldom exploited. Section B shows there is more oil produced from the upper area than the lower area, and most crude oil is produced in the area right above the horizontal well with many blue grids. The production areas of the heel and toe of the horizontal well are larger than those of the middle section of the horizontal well; however, the overall saturation color above the middle section of the horizontal well is bluer, and the crude oil recovery degree within the range of huff-n-puff is larger. Section C is the section at both ends (heel and toe) of the horizontal well, and section D is the section at the middle section of the horizontal well. Compared with sections C and D, both ends of the horizontal well have a larger production area. With the increase in huff-n-puff development cycles, the crude oil saturation decreases ever-more obviously. The main oil recovery comes from the area above the horizontal well.

**Figure 7.** Schematic diagram of oil saturation in production area of horizontal well at end of five cycles of CO₂ huff-n-puff: (A) top view; (B) parallel horizontal well section; (C) vertical sections at heel of horizontal well; (D) vertical section in middle of horizontal well.

This producing character of the heavy oil reservoir is related to oil viscosity and the development mode of CO₂ huff-n-puff. Due to the high viscosity of heavy oil, similar to SAGD (steam-assisted gravity drainage) development, the production of heavy oil mainly depends on the physical (temperature rise) and chemical (viscosity reduction) effects of injected agents to reduce viscosity of crude oil and enhance mobility, allowing oil to flow into the wellbore due to gravity. The injected CO₂ mainly moves to the reservoir above the horizontal well, mixes with the crude oil, and dissolves, forming a gas cavity viscosity reduction area with an elliptical section above the horizontal well. In the production stage, the crude oil after viscosity reduction flows into the horizontal wellbore due to gravity; thus, the crude oil-producing degree in this area is the highest.

Figure 8 shows the streamline model of the horizontal well in the production stage. The streamlines at both ends of the horizontal well are denser than those in the middle area (under the same perforation density). From Figure 8A, the perforation point in the middle of the horizontal well has two parallel boundaries, while, at both ends, the perforation points can be regarded as hemispherical boundaries, and the streamline swept volume is larger. From Figure 8B, the upper streamline of the horizontal well is dense and the lower part is sparse, indicating that after multiple cycles of huff-n-puff, the upper-located crude oil easily flows into the wellbore due to gravity, and the lower-located crude oil is less effectively produced.

**Figure 8.** Streamline of horizontal well for CO₂ huff-n-puff: (A) top view; (B) parallel horizontal well section.
4. Analysis of Influence Factors of CO2 Huff-n-Puff Development

4.1. Effects of Different Crude Oil Viscosity

Figure 9 shows the remaining oil saturation distribution of the reservoir after five cycles of CO2 huff-n-puff under different crude oil viscosities. Under the same permeability condition (set to 1000 mD), the horizontal well mechanism models with different crude oil viscosities (50 mPa·s, 800 mPa·s, 2000 mPa·s, 3200 mPa·s) were built.

![Streamline of horizontal well for CO2 huff-n-puff](image)

**Figure 9.** Schematic diagram of oil saturation change in different crude oil viscosities affecting production area of horizontal wells: (A) top view; (B) parallel horizontal well section; (C) vertical sections at heel of horizontal well; (D) vertical section in middle of horizontal well.

Under the condition of low crude oil viscosity, the injected CO2 flows upward to the top of the reservoir (Figure 9B), and the crude oil at the upper part of the horizontal well will be continuously produced as the huff-n-puff cycles continue. Since most of the gas flows upward, the crude oil at the lower part is less effectively produced. As the crude oil viscosity increases, the mobility ratio of gas and crude oil increases; less CO2 flows to the top of the reservoir, being dissolved into the high-viscosity crude oil; and the injected gas flows horizontally to increase areal conformance (Figure 9C,D). Thus, the production area of the horizontal well decreases in the vertical direction and increases in the lateral direction. With the increase in crude oil viscosity, the overall production area of horizontal wells shows a decreasing trend.

4.2. Effects of Different Crude Oil Viscosity

Figure 10 shows the remaining oil saturation distribution after five cycles of CO2 huff-n-puff under different reservoir permeabilities. With the same crude oil viscosity (2000 mPa·s), horizontal well mechanism models with different permeabilities (50 mD, 300 mD, 1000 mD, 2000 mD) were built.

![Remaining oil saturation distribution](image)

In the case of low permeability, the mobility of heavy oil is rather small, as gravity cannot displace the heavy oil sufficiently. Moreover, due to the limited upward diffusion of gas, the downward flow of heavy oil is not obvious due to gravity, indicating that low permeability limits gravity and the shape of the vertical and horizontal production area of the horizontal well is relatively regular (Figure 10C,D). With the increase in permeability, the injected CO2 obtains a longer flowing distance in both vertical and horizontal directions (Figure 10B,C); the production area of the horizontal well becomes wider in all directions; and the upward expansion is more obvious, which results from upward diffusion of CO2. Meanwhile, the gravity drainage effect becomes more obvious, which makes the oil recovery in the upper part of the horizontal well higher and the production effect remarkable.
4.2. Effects of Different Crude Oil Viscosity

Figure 10 shows the oil saturation change diagram of influence of different reservoir permeability on production area of horizontal wells: (A) top view; (B) parallel horizontal well section; (C) vertical sections at heel of horizontal well; (D) vertical section in the middle of horizontal well.

4.3. Effects of Bottom Water

No matter if a vertical or horizontal well is being studied, bottom water coning occurs, which causes the water cut to rise. It is difficult to control EOR of heavy oil reservoirs with bottom water. Water coning can form dominant channels in developing progress.

Under the condition of bottom water, several conceptual models with different crude oil viscosities were built (Figure 11). When the oil viscosity is low, the bottom water breakthrough occurs more easily, and the oil saturation in the middle of the horizontal well decreases more rapidly. When oil viscosity is high, the dominant flowing channel of bottom water gathers to the toe and heel of the horizontal well, and the flow density at both ends of the horizontal well is larger. With the increase in crude oil viscosity, this phenomenon is more obvious.

Figure 11. Remaining oil saturation field of conceptual models of heavy oil reservoir with different crude oil viscosities and bottom water (profile).

Figure 12 shows the water saturation distribution at the end of the last cycle of production and after the next cycle of gas injection via CO₂ huff-n-puff. As shown in Figure 12, the water saturation at the bottom of the horizontal well decreases obviously after gas injection, indicating that CO₂ injection has a certain effect of inhibiting bottom water. However, within the production cycle, it be cannot maintained for a long time, which is mainly due to two reasons: (1) with the development of horizontal wells, there is a dominant flowing channel for the formation water below the horizontal wells; and (2) the main production position of the horizontal well in heavy oil reservoirs is located near the
heel and toe of the horizontal well. The injected CO$_2$ is partially dissolved in the crude oil of lower formation, which increases the mobility of crude oil and makes the bottom water flow into the wellbore more easily.

![Figure 12. Water saturation field (profile): (A) end of production stage; (B) end of gas injection stage.](image)

**5. Oilfield Case Study and Discussion**

Figure 13 displays the actual model of Guan 3–4 layers in the Liuguanzhuang oilfield. The initial oil saturation of Guan 3-4 layers is 0.65, and the crude oil viscosity is 2300 mPa·s. This reservoir with edge-bottom water is mainly controlled via faults and sand bodies, while the oil-bearing layer is relatively thick. The reservoir is primarily made of movable water; the geological reserves are relatively large, accounting for more than half of the overall geological reserves of the third fault block, and are the main development layer series of the third fault block.

![Figure 13. Actual model of Guan 3-4 layer in Liuguanzhuang oilfield.](image)

There are 14 production wells, 3 water injection wells, and 2 CO$_2$ huff-n-puff horizontal wells in the actual model. From March 2015 to June 2021, we simulated the development of Guan 3-4 layers in the Liuguanzhuang oilfield. Figure 14 displays the historical matching result curve of the whole area, which shows that the overall matching is satisfactory.

Figure 15 shows the production performance curve of the Liu 5–14H wells. After a period of depletion development, the well is converted into a CO$_2$ huff-n-puff well. There is a sudden increase in water production, which indicates that bottom water breakthrough occurs, resulting in an increase in water cut. After the first cycle of gas injection, the oil production increases to 12 m$^3$/day at the maximum, and the water production decreases at the initial stage of well production, indicating that CO$_2$ injection has an obvious effect on inhibiting bottom water at the initial stage; however, the water cut increases rapidly at the later stage, indicating that the decrease in crude oil viscosity enhances the mobility of reservoir fluids and makes it easier for bottom water to flow into the wellbore.
There are 14 production wells, 3 water injection wells, and 2 CO2 injection wells. (1) The CO2 flooding recovery is high; (2) All horizontal wells have different degrees of bottom water coning, producing lower crude oil; (3) The horizontal well mainly produces crude oil in the heel and toe areas, and the producing area around the middle of the horizontal well is smaller. The producing radius of the horizontal well in depletion development is about 30 m, and the radius of the production area can be expanded to about 60 m in huff-n-puff development.

To improve the crude oil recovery, it is suitable to arrange horizontal wells in this area to adopt CO2 huff-n-puff development; however, the horizontal wells should be arranged as far away from bottom water as possible and close to the middle and upper parts of the reservoir, and the well production cycles of CO2 huff-n-puff development should be reasonable, which can effectively prevent bottom water breakthrough. From the simulation results of the actual model, the overall production law of horizontal well huff-n-puff development in the heavy oil reservoir with bottom water conforms to the mechanism model.

**Figure 14.** Historical matching result curve: (A) daily fluid production and daily water production fitting curve; (B) cumulative oil production and cumulative water production fitting curve.

**Figure 15.** Liu 5-14H production performance curve.

Figure 16 is the reservoir profile of Guan 3-4 layers in the Liuguanzhuang oilfield. Liu 5-14H, Liu 5-10H, and Liu 5-8H in the profile are all horizontal wells, among which Liu 5-14H is a huff-n-puff well. The CO2 huff-n-puff production characteristics and rules of heavy oil reservoirs with bottom water are as follows:

1. The huff-n-puff CO2 is enriched in the upper part of the horizontal well, unlocking the upper crude oil, and the oil recovery is high;
2. All horizontal wells have different degrees of bottom water coning, producing lower crude oil;
3. The horizontal well mainly produces crude oil in the heel and toe areas, and the production area around the middle of the horizontal well is smaller. The producing radius of the horizontal well in depletion development is about 30 m, and the radius of the production area can be expanded to about 60 m in huff-n-puff development.

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34. Yoosook, H.; Maneepin, K.; Boonpramote, T. CO₂ utilization for enhance oil recovery with huff-n-puff process in depleting heterogeneous reservoir. *Energ. Proced.* 2017, 141, 184–188. [CrossRef]


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