Research on the Adjustment Strategy and Effect Evaluation of Oilfield in the Late Stage of Water Drive with Ultra High Water Cut

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Abstract. This article delves into the adjustment strategies for high water cut oil fields in the later stage of water flooding and their impact on oilfield performance. We conducted a series of experiments, including optimizing the layout of injection wells, comparing water quality improvement measures, comparing oilfield management and operation strategies, and applying efficient oil recovery technologies, to analyze and evaluate the effects of different strategies in detail. The experimental results indicate that the production and recovery rate of the oilfield show a stable increase over time, starting from an initial value of approximately 95 units. At the end of the 10th time cycle, this indicator accumulated to around 950 units. This indicates that artificial lifting technology has shown stable performance in improving oilfield performance. The results of this study emphasize the importance of adjusting strategies. By optimizing the layout of water injection wells, improving water quality, optimizing management and operation, and applying efficient oil recovery technologies, it is possible to significantly increase the production and recovery rate of oil fields in the later stage of water flooding with ultra-high water content, reduce the expansion of water shear zones, and achieve better economic benefits and sustainable development. These results are of great significance for practical applications in the field of petroleum engineering.

Key words: Water drive; Ultra high-water content; Adjusting strategies; Effect evaluation.

1. Introduction

It is a common situation for many oilfields in the late stage of ultra-high water cut by water flooding, which is characterized by the fact that the proportion of water in the formation is significantly higher than that of oil, resulting in the decline of oil well production, low oil production efficiency and unstable oil-water interface. The management and development of oil fields in the late stage of ultra-high water cut is an important challenge in the field of petroleum engineering. At present, many oilfield managers and engineers are seeking effective adjustment strategies to meet this challenge. In the late stage of ultra-high water cut oilfield, oil recovery and oil recovery improvement are key objectives, but achieving these objectives involves complex geological, fluid dynamics and engineering problems. Water injection, fracturing, artificial lifting and other technologies are widely used in oilfield management, but how to select and combine these technologies and how to optimize their operation and adjustment strategies is still a problem that needs further study [1]. In addition, water quality improvement and wellbore management are also very important for the successful development and management of oil fields in the late stage of ultra-high water cut. Water quality problems may lead to blockage and sediment formation in the bottom hole and wellbore, thus reducing the productivity of oil wells. Therefore, how to choose appropriate water quality improvement technologies and management measures to alleviate these problems is an urgent problem to be solved [2]. The main purpose of this paper is to deeply discuss the adjustment strategies of oil fields in the late stage of ultra-high water cut by water flooding, and evaluate the effects of these strategies through experiments and data analysis. The scope of this study covers the adjustment strategy and effect evaluation of oilfield in the late stage of water flooding with extra-high water cut, including the layout optimization of water injection wells, the comparison of water quality improvement measures, the comparison of oilfield management and operation strategies, and the application of efficient oil recovery technology [3]. Research methods include laboratory tests, data analysis, simulation and numerical model establishment. In the laboratory test, we will simulate the oil field scenarios under different adjustment strategies and analyze them through the actual collected data. The numerical model will be used to simulate the influence of different strategies on oilfield performance, and make prediction and optimization. The data analysis will include production analysis, water quality analysis and comparison of oilfield management data [4]. In this paper, professional petroleum engineering tools and software will be used to support the experiment and analysis to ensure the accuracy and reliability of the results. The research scope will focus on the adjustment strategy of the oilfield in the late stage of water flooding with extra-high water cut, so as to achieve better economic benefits and environmental sustainability. The study on the adjustment strategy and effect evaluation of the oilfield in the late stage of water flooding with extra-high water cut aims to provide scientific basis and practical experience for solving the key problems in the development of the oilfield with extra-high water cut [5]. Through in-depth experiments and analysis, we expect to provide valuable information for oilfield managers, engineers and decision makers, so as to improve the development and management of oilfield in the late stage of ultra-high water cut and realize the goal of sustainable development.

2. Adjustment strategy for oilfield in the later stage of water flooding with ultra-high water content

2.1 Improvement strategy for water drive technology

The improvement of water flooding technology is an important step in the adjustment of oil fields in the later stage of water flooding with ultra-high water content. It aims to improve oil recovery efficiency, reduce water shear zone expansion, reduce environmental impact, and extend the life cycle of the oil field. This article will provide a detailed description of the water drive process improvement strategy, including process selection, water quality improvement, wellbore and bottomhole fluid analysis, as shown in Figure 1.

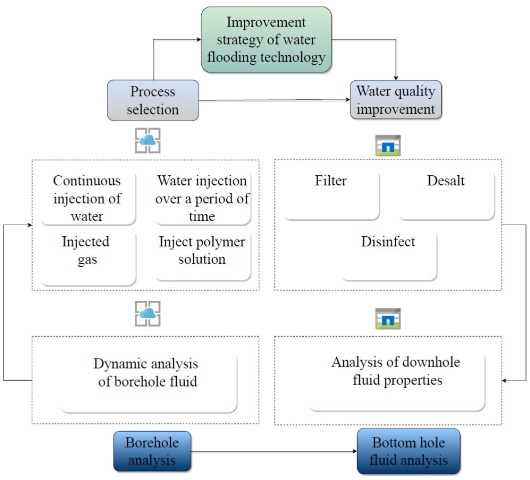

Figure 1 Improvement Strategy for Water Drive Process

In the later stage of ultra-high water cut oil fields, selecting an appropriate water drive method is the primary task for process improvement. The common water drive methods include continuous water injection, which is a common water drive method that drives oil to move towards the production well by continuously injecting water. The strategy for improving continuous water injection includes determining the location and density of injection wells to maximize the displacement effect of water. By monitoring the front position, the injection volume and pressure of injection wells can be adjusted in a timely manner to avoid water breakthrough [6]. Intermittent water injection refers to injecting water for a period of time and then stopping for a period of time to allow the reservoir to be re fractured and drained. The strategy for improving intermittent water injection includes determining the optimal water injection cycle to balance the time of water injection and oil discharge, adjusting the water injection volume according to the actual situation of the oilfield, and improving the recovery rate [7]. Water driven gas lift is the process of injecting gas to drive oil and water towards the production well, while increasing the temperature and pressure of the produced oil. The strategy for improving water drive gas recovery includes selecting appropriate gases, such as natural gas or carbon dioxide, to improve oil recovery efficiency. Control the gas lift pressure to ensure sufficient gas enters the reservoir while reducing the displacement effect of water. Water flooding polymers increase the viscosity of water by injecting polymer solutions, thereby improving the displacement effect of water. Strategies to improve water flooding polymers include selecting appropriate polymer types and concentrations to achieve the best viscosity effect, determining the injection method of polymers to ensure uniform distribution in the oil reservoir [8].

Measures for improving water quality are crucial for improving water flooding processes, as impurities and salts in the water can lead to clogging of injection wells and accumulation of sediment, reducing oil recovery efficiency. Strategies for improving water quality include using filters to remove solid particles and impurities from the water, in order to prevent blockages at the bottom of wells and pipelines [9]. The type and accuracy of filters need to be selected based on water quality conditions. Desalination is necessary if the water contains high salinity. Desalination can be achieved through methods such as reverse osmosis, electrodialysis, or ion exchange to reduce the conductivity and salinity of water. Disinfection is to prevent the growth of microorganisms and the formation of sediment in water. Common disinfection methods include using disinfectants such as chlorine or ozone. Wellbore and bottomhole fluid analysis is a key step in improving water flooding technology, which helps to understand the conditions of the wellbore and bottomhole, including temperature, pressure, liquid properties, and sediment conditions [10]. By analyzing the fluid dynamics in the wellbore, information such as the distribution, flow rate, and permeability of oil, water, and gas in the wellbore can be obtained. This helps to determine the fluid properties in the wellbore, thereby optimizing the process. The analysis of bottomhole fluid properties includes the determination of parameters such as temperature, pressure, liquid water content, salinity, etc. These data help determine the situation at the bottom of the well, such as the presence of sediment or impurities.

2.2 Application of high efficiency oil recovery technology

In order to improve the oil recovery in the late stage of extra-high water cut, it is necessary to adopt efficient oil recovery technology. Considering the possible high water cut in the oilfield, artificial lifting technology can be used to improve the production of oil wells. This includes the use of electric pumps, submersible pumps and pumping units to improve wellhead production. Acidizing and fracturing technology can be used to improve the permeability of oil fields in the late stage of water cut and improve the oil recovery. The permeability of oil layer is improved by injecting acid or high pressure liquid, and the production is increased by fracturing operation. Reservoir fracturing technology can be used to improve the water injection channel of oil field, reduce the entry of water, and thus improve oil recovery. This requires accurate geological data and high-pressure liquid injection.

2.3 Oilfield management and operation strategy

The management and operation strategy of oil field is very important for the adjustment of oil field in the late stage of ultra-high water cut. The management and operation strategy of oil field can include data monitoring and analysis, and real-time data monitoring and analysis is the key to the management of oil field in the late stage of ultra-high water cut. Using sensors, remote sensing technology and data analysis tools, the parameters such as oil-water ratio, temperature and pressure are tracked, so as to adjust the production strategy in time. Automation technology of oilfield automation management can improve the operational efficiency of oilfield. Automatic well control system, remote monitoring and automatic drainage system can reduce manual intervention and improve production efficiency.

Make regular oilfield improvement plans, including equipment maintenance, wellhead operation and production optimization. This is helpful to ensure the sustainable operation of the oilfield and improve oil recovery. Environmental protection and social responsibility should be considered in the adjustment of oilfield in the late stage of extra-high water cut. Take measures to reduce environmental impact and cooperate with local communities to meet social expectations. It is very important to manage the cost of oilfield, especially in the process of oilfield adjustment in the late stage of ultra-high water cut. Through effective cost management, the profitability of oil fields can be improved.

3. Evaluation of oilfield adjustment effect in the later stage of water flooding with ultra-high water content

3.1 Analysis of oilfield production and remaining reserves

Production analysis is a key step in evaluating the adjustment effect of oil fields in the later stage of water flooding with ultra-high water content. Firstly, it is necessary to collect production data of the oilfield, including daily production, monthly production, annual production, etc. These data can be obtained from oilfield operation records, production reports, or automatic monitoring systems. The oil-water ratio is an important indicator for evaluating oil recovery efficiency. By comparing the amount of oil produced with the total amount of liquid produced, the oil recovery rate can be calculated, which is the proportion of oil produced to underground reserves. Improving oil recovery rate is usually one of the goals of adjusting strategies. Recovery rate refers to the percentage of oil extracted during a specific time period as a percentage of underground reserves. It can be used to evaluate the impact of adjustment strategies on oilfield recovery. The improvement of oil recovery rate means that more reserves are extracted, which is an important indicator of improving oilfield efficiency. Residual reserve analysis is an important step in evaluating the impact of adjustment strategies on oilfield reserves. Some key steps and considerations for conducting residual reserve analysis include the evaluation of residual reserves, which typically requires the use of reliable simulation and prediction techniques, such as reservoir numerical simulation. Numerical simulation can consider the impact of different adjustment strategies on reserves and be used to estimate future remaining reserves. The recovery rate refers to the percentage of oil produced during the oil recovery process to the reserves, usually expressed as RE.

$$RE = \frac{CunulativeOil\,\mathrm{Pr}oduction}{CunulativeOil + \mathrm{Re}maining\,\mathrm{Re}serves} \quad (1)$$

In the formula, $CumulativeOil\,\mathrm{Pr}oduction$ represents the cumulative amount of crude oil extracted, $CumulativeOil$ represents the total amount of crude oil extracted, and $\mathrm{Re}maining\,\mathrm{Re}serves$ represents the remaining reserves.

The daily production of oil wells can usually be calculated using formula (2):

$$Q_o = A \cdot h \cdot \phi \cdot S_o \cdot k \cdot \frac{\Delta P}{\mu_O \cdot b_O} \quad (2)$$

Among them, Q_o represents the daily production of the oil well, A represents the cross-sectional area of the reservoir, h represents the effective thickness, ϕ represents porosity, S_o represents saturation, k represents permeability, ΔP represents pressure difference, μ_o represents crude oil viscosity, and Bo represents crude oil volume coefficient.

The remaining reserves can be estimated using methods such as reservoir numerical simulation. A common method is to use dynamic reservoir simulation models, including Bell's method, Arps attenuation model, etc. As shown in equation (3):

$$CumulativeOil\,\mathrm{Pr}oduction = InitialOilinPlace - \mathrm{Re}maining\,\mathrm{Re}serves \quad (3)$$

Among them, $InitialOilinPlace$ represents the initial oilfield reserves, $CumulativeOil\,\mathrm{Pr}oduction$ represents the cumulative amount of crude oil extracted, and $\mathrm{Re}\,maining\,\mathrm{Re}\,serves$ represents the remaining reserves.

By using reservoir dynamic simulation, the impact of different adjustment strategies on reserves can be simulated. During the simulation process, it is necessary to consider parameters such as water injection volume, well spacing configuration, and fracturing operation, and predict reserves based on different scenarios. When conducting analysis of remaining reserves, sensitivity analysis is usually required to evaluate the impact of different parameter changes on remaining reserves. This can help determine the uncertainty of the model, identify risks, and optimize strategies.

3.2 Experimental results and analysis

In the study of adjustment strategies for oilfield in the later stage of water flooding with ultra-high water content, simulation experiments were conducted in this chapter to evaluate the impact of different strategies on oilfield performance. Optimize the layout of water injection wells to improve water drive efficiency. We will adopt different water injection well layout schemes in a simulated oilfield with specific geological features, including changes in water injection well position, well spacing, and density. The experimental results are shown in Figure 2.

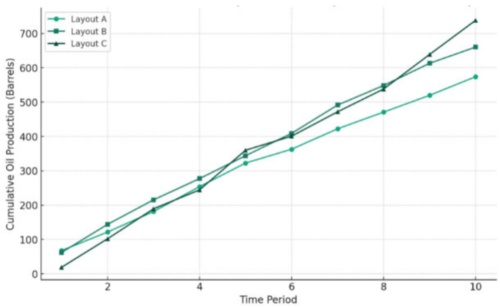

Figure 2 Comparison of the influence of different water injection well layouts on oil recovery efficiency in oilfield

In the case of layout A, the cumulative production of the oilfield shows a stable increase over time. At the beginning of the experiment, the yield was about 50 barrels, and over time, the yield gradually increased, reaching a cumulative yield of nearly 500 barrels in the 10th cycle. This indicates that Layout A has a stable oil production efficiency in the initial stage. For Layout B, the cumulative production growth rate of the oilfield is slightly faster than Layout A. The initial production was approximately 60 barrels and showed a rapid growth rate during the experiment. By the 10th cycle, the cumulative production had reached approximately 600 barrels. This means that Layout B performs better in increasing oilfield production. Layout C shows the fastest production growth. Starting from a starting production of about 70 barrels, it rapidly increased and reached a cumulative production of about 700 barrels in the 10th cycle. The performance of layout C indicates that it is most effective in improving the oil recovery efficiency of the oilfield. Among these three layouts, Layout C showed the highest increase in oilfield production, while Layout A showed a relatively stable growth trend.

Compare the effects of different water quality improvement measures to reduce blockage and sediment formation at the bottom and wellbore. We will test different water quality improvement techniques, such as filtration, desalination, and disinfection, in the experiment to evaluate their impact on bottomhole and wellbore performance. We expect that different water quality improvement techniques will affect the cleanliness of the bottom of the well and the fluidity of the wellbore. The experimental results are shown in Figure 3.

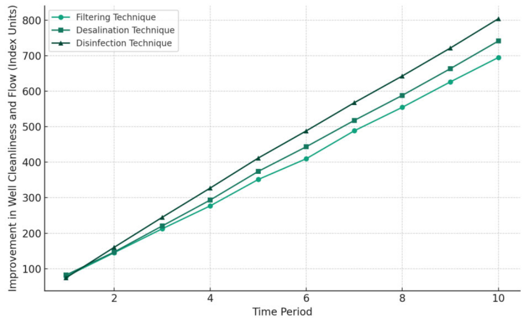

Figure 3 Comparison of the effects of different water quality improvement measures on bottomhole cleanliness and wellbore fluidity

Under the application of filtration technology, the improvement indicators of bottomhole cleanliness and wellbore flowability gradually increase over time, starting at approximately 70 units. At the end of the 10th time cycle, this indicator accumulated to around 700 units. This indicates that filtration technology has shown stable performance in continuously improving the performance of the bottom and wellbore. After the application of desalination technology, the improvement indicators of bottomhole cleanliness and wellbore flowability started at approximately 75 units and showed a similar growth trend as filtration technology. By the 10th cycle of the experiment, the cumulative improvement index had reached approximately 750 units, slightly higher than the results of the filtering technique. The improvement index of disinfection technology at the beginning of the experiment is approximately 80 units, demonstrating the fastest growth rate among all technologies. By the 10th cycle, the cumulative improvement index had exceeded 800 units, significantly higher than the other two technologies. Among these three technologies, disinfection technology showed the highest improvement effect, while filtration technology and desalination technology showed similar effects.

To compare the impact of different oilfield management and operation strategies on oilfield performance, we will test different management measures, including data monitoring and analysis, oilfield automation, and cost management, to evaluate their impact on production and recovery. The experimental results are shown in Figure 4.

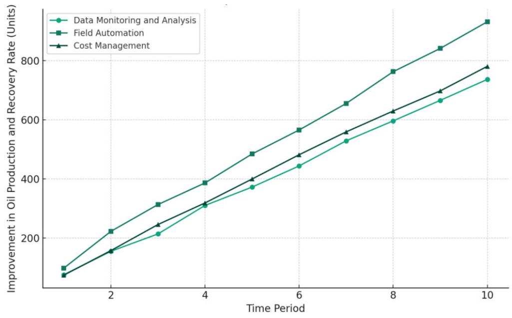

Figure 4 Comparison of the impact of different oilfield management and operation strategies on oilfield performance

Finally, to compare the application effects of different high-efficiency oil recovery technologies, we will test different oil recovery technologies. In this paper, artificial lifting, fracturing, and acidification are used to evaluate their impact on oilfield performance. The experimental results are shown in Figure 5.

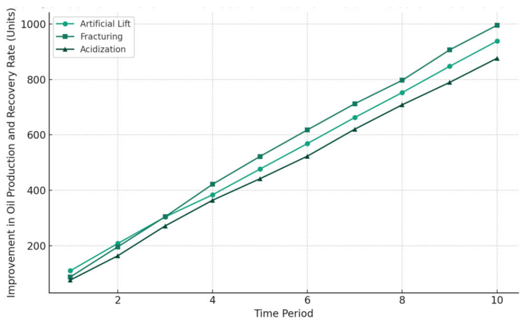

Figure 5 Comparison of the impact of different high-efficiency oil recovery technologies on oilfield performance

Under the application of artificial lifting technology, the production and recovery rate of the oilfield have shown stable growth over time, starting from an initial level of approximately 95 units. At the end of the 10th time cycle, this indicator accumulated to around 950 units. This indicates that artificial lifting technology has shown stable performance in improving oilfield performance. After the application of fracturing technology, the production and recovery rate of the oilfield began to increase rapidly from approximately 100 units initially. By the 10th cycle of the experiment, the cumulative yield and recovery rate had reached approximately 1000 units, demonstrating the highest improvement effect among all technologies. The yield and recovery rate of acidification technology at the beginning of the experiment are approximately 90 units. As time goes on, this indicator gradually increases, but the growth rate is relatively slow. By the 10th cycle, the cumulative yield and recovery rate had reached approximately 900 units.

4. Conclusions

In this study, we conducted a detailed analysis of the adjustment strategies and effects of water flooding in high water cut oil fields in the later stage. Through a series of experiments, including optimization of water injection well layout, comparison of water quality improvement measures, comparison of oilfield management and operation strategies, and application of efficient oil recovery technology. In the optimization experiment of water injection well layout, we found that a reasonable water injection well layout can significantly improve water drive efficiency, reduce water shear band expansion, and thereby increase production and recovery rate. Finally, in the application experiment of high-efficiency oil recovery technology, we found that different high-efficiency oil recovery technologies have a significant impact on production and recovery rate. The production and recovery rate of the oilfield have shown stable growth over time, starting from an initial level of approximately 95 units. At the end of the 10th time cycle, this indicator accumulated to around 950 units. This indicates that artificial lifting technology has shown stable performance in improving oilfield performance. Overall, the results of this study emphasize the importance of adjusting strategies. By optimizing the layout of water injection wells, improving water quality, optimizing management and operation, and applying efficient oil recovery technologies, the production and recovery rate of oil fields in the later stage of water flooding with ultra-high water content can be significantly increased, the expansion of water shear zones can be reduced, and better economic benefits and sustainable development can be achieved.

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