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Study on Remaining Oil at High Water Cut Stage of the Offshore Strong Bottom Water Reservoir

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Abstract

C oilfield is a heavy oil field developed by horizontal wells and single sand body in Bohai oilfield. The edge and bottom water of the reservoir is active and the natural energy development mode is adopted. The comprehensive water cut of the oilfield was 95.3%, which had entered the stage of high water cut oil production. Some reservoirs were limited by crude oil viscosity and oil column height. Under the condition of existing development well pattern, some reserves were not produced or the degree of production was low, and the degree of well control was not high, so there is room for tapping the potential of remaining oil. This paper studied the rising law of water ridge of horizontal wells in bottom water reservoir by reservoir engineering method, and guided the infilling limit of horizontal wells in bottom water reservoir. At the same time, combined with the research results of fine reservoir description, the geological model was established, the numerical simulation was carried out, and the distribution law of remaining oil was analyzed. Through this study, we could understand the law of water flooding and remaining oil in the high water cut period of bottom water heavy oil reservoir, so as to provide guidance for the development strategy of this type of reservoir in the high water cut period.

Keywords

Bohai Oilfield, Heavy Oil Reservoir, Flooding Law, Remaining Oil

1. Introduction

The research on remaining oil has always been the focus of attention in the middle and late stage of oilfield development. For continental sedimentary strata, the reservoir characteristics are complex, and with the impact of oilfield development process on them, the underground oil-water relationship is more complex, and the distribution characteristics of remaining oil are also complex, which makes the research of remaining oil more difficult. According to the previous research experience, the remaining oil research mainly focuses on the following six contents (Chen et al., 2018): 1) describe the types and distribution laws of remaining oil in the reservoir. Dong Dong et al. and Dou Songjiang et al. studied the types and distribution of remaining oil in fluvial facies reservoirs and complex fault block reservoirs, and put forward suggestions on their supporting potential tapping measures. It is found that the main types of remaining oil are macro remaining oil with reservoir scale remaining oil characteristics and onlooker remaining oil in pore structure; 2) The formation and distribution patterns of remaining oil are characterized and the controlling factors are analyzed. The research in this field needs to be combined with geological and development characteristics. Through the research on the formation, location and mode of remaining oil distribution, the remaining oil can be classified, described and predicted (Dou & Zhou, 2003). 3) Geological synthesis method, logging interpretation, numerical simulation, seismic monitoring, well testing and other methods to describe and predict the remaining oil (Wang et al., 2004; Nie et al., 2004). 4) Fine interpretation of high-precision structural model, division of sequence stratigraphy, characterization of reservoir configuration, study of reservoir macro heterogeneity, classification of flow units and other applications in the study of remaining oil (Yin et al., 2006; Wang et al., 2015). 5) Predict the distribution characteristics of remaining oil. Taking Machang oilfield as an example, Yin Taiju and others predicted the distribution of remaining oil in high water cut period in complex fault block area, and put forward that the remaining oil prediction includes well point remaining oil prediction and inter well remaining oil prediction (Hu et al., 2012; Chen et al., 2012). 6) Description of residual oil distribution characteristics after tertiary oil recovery measures (Yin et al., 2004; Wang et al., 2018).

This paper studies the rising law of water ridge of horizontal wells in bottom water reservoir by reservoir engineering method, and guides the infilling limit of horizontal wells in bottom water reservoir. At the same time, combined with the research results of fine reservoir description, the geological model is established, the numerical simulation is carried out, and the distribution law of remaining oil is analyzed.

2. Study on Water Flooding Law of Sand Body

C is the bottom water reservoir. Since 2011, 14 new road wells have been drilled, 5 have been flooded and 9 have not been flooded. It can be seen from the water flooded situation that for such bottom water reservoirs, with the passage of production time of production wells, the surrounding oil-water interface gradually increases and the water flooded thickness becomes larger; At the same time point, the closer to the production well, the greater the flooded thickness. The average water cut in the upper 6 m of the oil layer is less than 75%, the average water cut in the lower 6 m is more than 75%, and the water flooding in the lower part is serious.

The direction of water inflow is the surrounding edge and bottom water. With the progress of production, a pressure drop is formed near the well area, the surrounding edge and bottom water gradually advances to the well area, and the production well is easy to form a water cone (**Figure 1**).

The numerical simulation shows that the flooded thickness is 0 - 5 m, and the flooded thickness of new drilling is 1.2 - 3.3 m, which is basically consistent.

On the plane, the water flooded types of sand bodies are divided into two types, of which the two types are mainly located in the west of the work area. Type 1 is mainly edge water inrush bottom water coning, and type 2 is mainly bottom water coning (**Figure 2** and **Figure 3**).

3. Study on Residual Oil in Sand Body

The control factors of water flooding law are relatively complex, which can be roughly divided into underground and aboveground. Among them, underground factors mainly include reservoir development, rhythm, sedimentary microfacies type, interlayer distribution, etc., while aboveground factors include oilfield development and production mode, production operation system, etc. These factors jointly control the distribution of water flooded layer in longitudinal and plane.

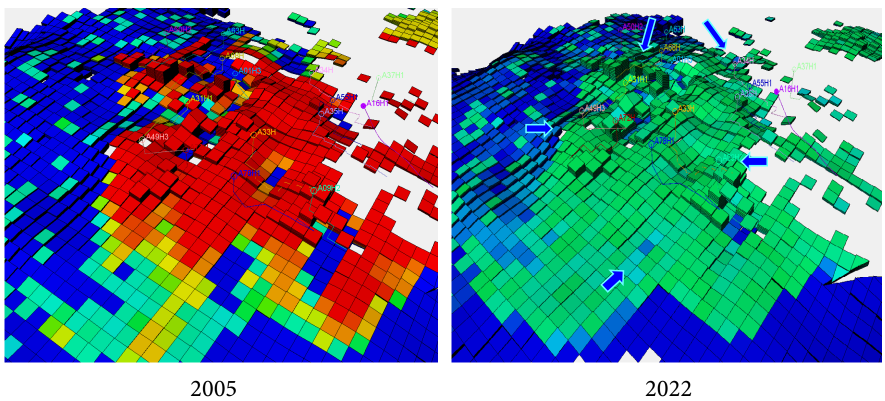

Figure 1. Variation of oil saturation.

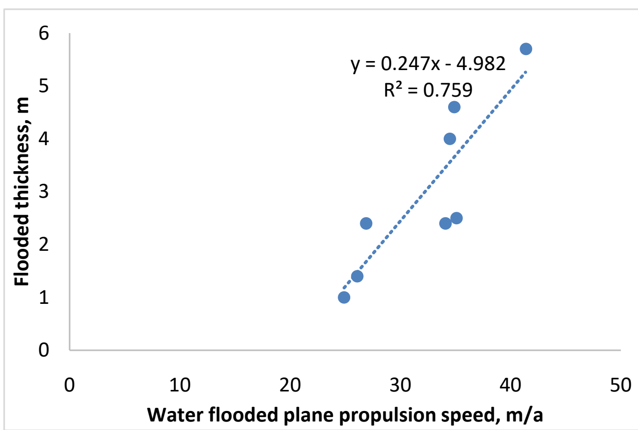

Figure 2. Water flooding law—type 1.

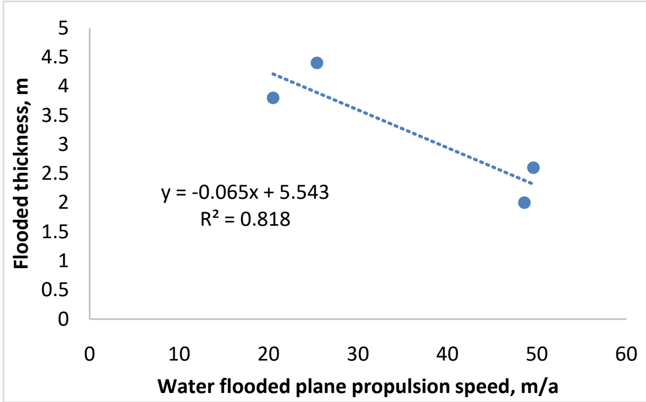

Figure 3. Water flooding law—type 2.

1) Sand body rhythm factor

C oilfield is a fluvial reservoir, and the channel sand body is characterized by positive rhythm. According to the rhythm type of water flooded wells and the statistics of water flooded parts, it can be seen that the water flooded parts are mainly at the bottom of positive rhythm and homogeneous rhythm.

In general, the controlling effect of rhythm on water flooding is mainly caused by the difference of permeability. The bottom flooding with positive rhythm is because the permeability at the bottom is greater than that at the top, and the resistance of water migration at the bottom is small; At the same time, due to gravity, water will migrate downward, resulting in water flooding in the middle and lower part of the reservoir.

2) Reservoir type factors

The reasons for water flooding of bottom water reservoir and edge water reservoir are different: for heavy oil bottom water reservoir, in addition, the oilfield adopts the mode of horizontal well development. Flooding is mainly affected by the action of bottom water ridge. For edge water reservoirs, water flooding is mainly affected by edge water breakthrough. Different causes of water flooding lead to different distribution of Water Flooded Layers on the plane.

3) Distribution factors of genetic sand body

The type of genetic sand body and its distribution characteristics control the plane distribution of water flooded degree. Meandering river deposits mainly develop point bar, late stage channel and abandoned channel. The point bar sand body reservoir has good development, large thickness, good physical properties and good connectivity, while the abandoned channel sand body presents a semi connected body with poor physical properties at the top and slightly better physical properties at the bottom, which can form a shielding barrier on the plane for edge water reservoir.

In the middle of the point dam, especially in the water breakthrough direction, the degree of water flooding is high; However, at the edge of the point dam, close to the river channel at the end or blocked by the abandoned river channel, the degree of flooding is weak or not flooded. The well located in the middle of the point dam is flooded for 2.8 m in the water breakthrough direction, while the well located at the edge of the point dam is close to the river channel at the end of the period, which is flooded for 1 m. The well is located at the "harbor" of the abandoned river channel and is shown as not flooded.

4) Factors of liquid production and well spacing of surrounding wells

When the cumulative liquid production of the production well in the dam at the same point of the sand body is less than 50% × 10^4 m^3, there is no water flooding about 150 m away from the production well; The cumulative liquid production is 50 - 100 × 10^4 m^3, it is about 150 m away from the production well, and the flooded thickness is within 1 m; When the cumulative liquid production is 100 - 300 × 10^4 m^3. Between and 250 m, the flooded thickness is 1 - 5 m. The greater the ratio of cumulative liquid production to point dam volume, the greater the flooded thickness; When the cumulative liquid production is greater than 500 × 10^4 m^3, it is about 250 m away from the production well, and the flooded thickness reaches 10 m. To sum up, in the actual development and production, the water flooded condition of the reservoir should integrate the static data and dynamic data, find out the main influencing factors in combination with the mechanism model, and comprehensively consider other factors, so as to more accurately understand the water flooded law and serve the distribution of remaining oil and development and production.

For heavy oil bottom water reservoir, in addition, the oilfield adopts the development mode of horizontal well. Flooding is mainly affected by the action of bottom water ridge.

The remaining oil is mainly located in the undeveloped area in the middle of the work area, and the bottom water has been coning in the edge to form a water ridge. The profile of connecting wells in the crossing well shows that the lower part of the oil layer in the well area has been watered out due to the influence of the radius of the water ridge, while the well area is 97 meters away from the production well, which is greater than the effective production radius, but it is only weakly watered out.

The mechanism model studies the effective production radius, and establishes the mechanism model by using the median value of porosity and permeability, relative permeability data and high-pressure physical property data of sand body.

The mechanism model shows that with the increase of production time, when a certain number of years are reached, the outer ridge radius basically does not increase, and there is the maximum ridge radius, that is, there is the maximum effective utilization radius.

With the increase of daily liquid production, the radius of high liquid production ridge is slightly larger than that of low liquid production ridge in the same service life. When reaching a certain service life, there is also the largest effective utilization radius.

4. Conclusion

1) It can be seen from the water-flooded situation that for such bottom water

reservoirs, with the passage of production time of production wells, the surrounding oil-water interface gradually increases and the water flooded thickness becomes larger; At the same time point, the closer to the production well, the greater the flooded thickness.

2) For heavy oil reservoir with bottom water, the water flooding mode is mainly water ridge. Due to high viscosity, the radius of water ridge is 60 m.

3) The control factors of water flooding law are relatively complex, which can be roughly divided into underground and aboveground. Among them, underground factors mainly include reservoir development, rhythm, sedimentary microfacies type, interlayer distribution, etc., while aboveground factors include oilfield development and production mode, production operation system, etc. These factors jointly control the distribution of water flooded layer in longitudinal and plane.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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