Analysis of water flooded characteristics Qualitative analysis of factors affecting water flooding Horizontal well

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Abstract. In production practice, water flooding is mostly used in oil recovery in China, and water flooding occurs in oilfields due to improper artificial water injection. We must understand the flooded characteristics to take remedial measures for flooding timely. In addition, compared with vertical wells, horizontal wells have the advantages of high recovery index, low production pressure difference, long waterless production period, and so on. Therefore, this paper will also make a brief analysis of the influencing factors of horizontal well flooding. Therefore, the analysis of the above two aspects can be used to adjust and adjust the oil field plan.

1. Introduction
The research on the controlling factors of water flooded degree of horizontal wells is not only an inevitable problem in the development and production of Daqing Oilfield, but also one of the key factors to maintain the continuous production of the oilfield. In order to guide the development and production of oil and gas in the study area, the water flooded status, main controlling factors and distribution characteristics of remaining oil in different sandstone blocks of Xingnan oilfield are summarized.

2. Analysis of water flooded characteristics

2.1. Classification of water flooded grades
Correct classification of flooded zones is very important for better evaluation of flooded zones, there are different ways of partitioning from different angles, in the practical application of oilfield, many factors should be considered, choose one Dividing method as main line, combined with other methods to comprehensively divide the flooded period of water flooded zone. In this paper, the division of water flooded zones is based on the data of oilfield production, combining time factor and logging response characteristics, according to the China National Petroleum Company standard, the water flooded level is divided into oil layers \( f_w \leq 10\% \), weak water flooded \( 10\% < f_w \leq 40\% \), medium water flooded \( 40\% < f_w \leq 60\% \), strong flooding \( 60\% < f_w \leq 80\% \), strong water flooded \( 80\% < f_w \leq 90\% \), super strong flooding \( f_w > 90\% \) six levels.

2.2. Logging response characteristics of water flooded zone
(1) The variation characteristics of spontaneous potential. The upper part of the reservoir is a positive rhythm reservoir of fluvial facies, argillaceous cementation, relatively loose, the reservoir heterogeneity is serious, most flooded zones have bottoms, characteristics of water flooding in the middle and lower parts, and cause the baseline shift under natural potential, the amplitude of natural potential gradually...
decreases, even from negative to positive. According to the actual situation of fresh water injection at the beginning of oilfield and fresh water recharge by sewage later, the variation of natural potential amplitude and baseline offset in water flooded zone the following theoretical explanations can be made\(^2\), the lower part of the sandstone reservoir has been flooded, water salinity in mixed formation water flooded zone \(C_{W3} < \) initial formation water salinity \(C_{W2}\) , formation water salinity of surrounding rock \(C_{W1}\), mud filtrate salinity \(C_{mf}\), at this time, the electromotive force of the three interfaces is: Electromotive force at the interface between sand and mudstone at the upper part
\[
S_{P1-2} = k_1 (\lg C_{W1}/C_{mf} - \lg C_{W1}/C_{W2}) + k_2 \lg C_{W2}/C_{mf} \\
= (k_1 + k_2) \lg C_{W2}/C_{mf}
\]
(1)

Submergence in the middle electromotive force at interface with non flooded surface
\[
S_{P1-2} = k_2 (\lg C_{W3}/C_{mf} - \lg C_{W2}/C_{mf} + \lg C_{W2}/C_{W3}) = 0
\]
(2)

Electromotive force at the interface between sand and mudstone at the bottom
\[
S_{P3-4} = k_1 (\lg C_{W1}/C_{mf} - \lg C_{W1}/C_{W3}) + k_2 \lg C_{W3}/C_{mf} \\
= (k_1 + k_2) \lg C_{W3}/C_{mf}
\]
(3)

In the formula: \(K_1\) is the diffusion adsorption electromotive force coefficient of mudstone; \(K_2\) is the diffusion electromotive force coefficient of sandstone.

Therefore, the natural potential baseline offset of watered out layer should be
\[
\Delta S_p = S_{P1-2} - S_{P3-4} = (k_1 + k_2) \lg C_{W2}/C_{W3}
\]
(4)

It can be seen from the above formula that the magnitude of the baseline offset of natural potential is mainly determined by the ratio of formation water salinity before and after flooding. And it has nothing to do with the salinity of mud filtrate, at the same time, we can see that the greater the CW2/CW3 ratio is, the greater the delta \(\Delta S_p\) is, that is to say, for freshwater flooded reservoirs in oilfields, the larger the baseline migration, the higher the water flooded degree of reservoirs. If the middle or all of the reservoir is flooded, the baseline of SP will not be offset, but the amplitude of SP will change, even from negative anomaly to positive anomaly.

(2) Characteristics of resistivity variation curve. After reservoir flooding, the injected water is mixed with the original formation water, so the resistivity \(R\) of the mixed water will depend on the salinity of the original formation water and the injected water and the amount of injected water, for example, the oil field belongs to freshwater + sewage reinjection flooded type, so its resistivity is relatively large, and the resistivity changes of the flooded layer produced during different water injection periods are different, so we use Archie formula to preliminarily explore the resistivity changes. It is known by Archie formula
\[
R_t = ab R_z/\phi^n S_w^n
\]
(5)

Formula: \(R_t\) is the resistivity of mixed formation in watered out zone
\(\phi\) and \(\phi\) are water saturation and porosity respectively.

According to the upper formula, the resistivity of watered out layer is determined by the combination. Fresh water was injected into the development process, and later the wastewater was reinjected, therefore, it belongs to the freshwater flooding type as a whole. With the continuous injection of injected water into the reservoir to drive out the crude oil in the formation, on the one hand, the water saturation of the reservoir keeps increasing and the water productivity is not short rising; on the other hand, the injected fresh water continuously dissolves the salt in the formation and exchanges with the bound water in the reservoir, so although the injection is carried out the salinity of the water has increased, but the salinity of the mixed formation water is decreasing, the salinity of mixed formation water keeps increasing until the salinity of injected water is close to that of mixed formation water and tends to dynamic equilibrium. Therefore, in the early stage of oil field flooding, with the increase of water saturation when fresh water enters the reservoir, the resistivity equation obviously
decreases. The results of theoretical analysis and laboratory analysis show that when the reservoir is flooded to a certain extent, the salinity of mixed formation water decreases to the extent that its influence on resistivity exceeds that of water saturation due to desalination, so the resistivity will increase. In addition, the decrease of the amplitude of microelectrode curve and the increase of acoustic time difference can be used to assist in the identification of flooding, which is not discussed in detail here.

2.3. Qualitative analysis of flooding[3]
Generally speaking, the degree of water flooding of an oil reservoir increases gradually with time, following the rule of oil reservoir weak water flooding medium water flooding strong water flooding even water flooding. Therefore, in the early stage of oilfield development, there should be more cases of oil reservoir, weak water flooding and medium water flooding. In the middle and later stages of development, the situation of higher water flooding degree is the overwhelming majority, so the water flooding degree can be roughly distinguished from the development history and logging time.

The process of qualitative identification of flooded zones in the study area is divided into three periods according to time: before 1990, 1990-1994 and after 1994. Then, according to the amplitude change of SP curve and baseline migration, combined with the variation characteristics of conductivity, resistivity and microelectrode curves, comprehensive consideration is made, and the influence of geological factors such as sedimentary microfacies, micro-structure and the configuration relationship of adjacent wells are taken into account to determine the water flooding range degree. Qualitative analysis of water flooded grade for logging two interpretation reference. In the course of the study, the principle, rule and experience of distinguishing water flooded level in seven districts are preliminarily summarized, and on this basis, the distinguishing mode of water flooded layer is summarized.

(1) oil layer
According to the standards promulgated by China National Petroleum Company, the moisture content of oil layers $f_w \leq 10\%$, the oil layer is not flooded or the water flooded is very light. Therefore, the baseline of SP does not migrate, and its anomalous amplitude is large, resistivity value is large, inductive conductivity is small and smooth, and microelectrode amplitude difference is large. In the study area, the majority of pure oil reservoirs appeared before 1990, while the occurrence of pure oil reservoirs after 1990 is less. At the same time, most of the pure oil reservoirs are distributed in the marginal and core beach microfacies of the river bed subfacies, but rarely in other facies zones.

(2) Weak water flooded layer
Moisture content of weak water flooded layer $10\% < f_w \leq 40\%$, in the study area, the negative migration of SP baseline in weak flooded layer has the greatest probability, and the offset is smaller, the negative anomaly amplitude of SP decreases, and the resistivity decreases. For thick layer, the shape of induction curve changes from smooth to smooth, while for thin layer, the difference of the amplitude of circular peak microelectrodes decreases. From the time point of view, the probability of occurrence of circular peak microelectrodes is the highest in 1989-1991, less after 1992, and the probability of occurrence of weak flooding in marginal beach microfacies. This indicates that the injected water first flooded along the large radius of pore throat and good reservoir properties.

(3) Medium water flooded layer
Water content in middle water flooded middle layer $40\% < f_w \leq 60\%$, the abnormal spontaneous potential in the middle flooding period is smaller than that in the weak flooding period, the resistivity decreases, the peak is obvious, the value of inductive conductivity increases, the sawtooth is obvious, and the difference of microelectrode amplitude decreases. From the time point of view, the probability of occurrence of the abnormal spontaneous potential in 1990-1991 is the greatest, and it still occurs from 1992 onwards. Most of the sedimentary facies are marginal beach microfacies. The probability of flooding in this area is the smallest and the duration is the shortest.

(4) Strong watered out zone
The water content range of strong watered out zone is $60\% < f_w \leq 80\%$, the baseline of SP shifts
to negative direction, and its abnormal amplitude decreases. Compared with reservoir, the resistivity decreases obviously, the value of induced conductivity increases, the shape sharpens, and the amplitude difference of microelectrode decreases. From the time point of view, the probability of occurrence is the greatest from 1990 to 1993, and it hardly appeared before 1989. The sedimentary facies belt is dominated by marginal shoal microfacies. At the same time, a considerable part of natural dike microfacies reservoirs are flooded. It is proved that with the process of water injection, injected water has gradually injected into reservoirs with poor physical properties and began to displace oil from poor reservoirs.

(5) Waterflooded layer
The water content range of strong water flooded layer is $80\% < f_w \leq 90\%$, at the same time, the amplitude of SP decreases, the resistivity value decreases, and the amplitude difference of microelectrodes decreases obviously. From 1990 to 1994, the probability of occurrence is the greatest.

(6) Strong water flooded layer
Water content of $f_w > 90\%$ is very strong water flooded layer, at this time, due to the strong flooding degree, the baseline offset of SP decreased, and the abnormal amplitude of SP decreased significantly. There are even positive anomalies. From time to time, the probability is greater after 1993. The main facies zones are edge beaches, but the super-strong water-flooded zones in the microfacies of natural levees account for a considerable proportion, indicating that injection water has displaced most of the oil in poorer reservoirs.

3. Dynamic factors affecting water flooding in horizontal wells

Through numerical simulation, it is known that the important factors affecting water flooding of horizontal wells are the length of horizontal section, the vertical heterogeneity of reservoir, the trajectory of horizontal section, the oil-water viscosity ratio and so on.

The numerical results of the influence of horizontal section length on the flooding performance of horizontal wells show that, under certain conditions of fluid production, with the increase of horizontal section length, the production pressure difference decreases, the bottom water advances evenly, the sweep efficiency is high, the production period of anhydrous production and cumulative production of anhydrous oil increase, and the water cut rises slowly after water breakthrough, and the water drive effect is better.

The numerical simulation results of reservoir vertical heterogeneity (positive rhythm, reverse rhythm, compound rhythm) on horizontal well waterflooding performance show that positive rhythm reservoir has the fastest water breakthrough, and reverse rhythm and compound rhythm reservoirs are equivalent to physical interbeds, and the development effect is good.

The numerical simulation results of the influence of horizontal section trajectory on the waterflooding performance of horizontal wells show that the waterless period of horizontal wells in the lowest position in the middle of the horizontal section is the shortest, while the waterless period of the following section in the horizontal section is the longest in the upper part and the toe section in the lower part of the horizontal section is the longest, and the development effect is better.

The numerical simulation results show that with the decrease of oil-water viscosity ratio, the water-free production period and cumulative production of horizontal wells increase, and the development effect is very good. When the oil-water viscosity ratio is 1, the fluid is similar to piston displacement, and the bottom water advances uniformly. The sweep efficiency and anhydrous recovery are high, and the development effect is very ideal.

4. Conclusion and conclusion
When the oilfield floods, the natural potential decreases and the baseline deviation, and the natural potential amplitude decreases or even changes from negative anomaly to positive anomaly.

At the initial stage of oilfield flooding, with the increase of water saturation when fresh water
enters the reservoir, the resistivity decreases obviously. When the reservoir is flooded to a certain extent, the water salinity of mixed reservoir decreases to the extent that its influence on resistivity exceeds the water saturation, the resistivity increases.

The influencing factors of water flooding in horizontal wells are the length of horizontal section, the vertical heterogeneity of reservoir, the trajectory of horizontal section, the oil-water viscosity ratio and so on.

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