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Research Article

Evaluation of Water Flooding Development Effect by Using Water Storage Rate and Water Flooding Index

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Abstract: Because the edge water is not active and natural energy field is not sufficient, it is quite difficult to develop the low permeability reservoir. The formation pressure can be supplied through water flooding which is the core development technology for low permeability reservoir. However, the evaluation of water flooding development effect plays a vital role to further improve the development effect and enhance the final recovery. In this article, the theoretical calculation formula of two indicators including water storage rate and water flooding index were listed out, their relationship to water cut were analyzed respectively, and the reason to cause the difference between theoretical value and actual value was pointed out. Finally, these two indicators were used to evaluate the water flooding effect with X oilfield.

Keywords: Water storage rate; Water flooding index; Water cut; Development effect evaluation.

INTRODUCTION

A large number of oil field production practice shows that the energy supplement is particularly important for low permeability oil fields. However, the development effect of low permeability reservoir is not ideal, and there are some shortcomings such as the increasing pressure of water injection, the shortage of oil supply, the rapid decline of production, the low oil recovery rate and the low oil recovery [1]. If the formation energy can not be supplemented in time, the formation pressure will be significantly reduced, the production capacity of the rapid reduction of production, and ultimately lead to a low recovery rate. After the development of water injection, the formation energy is supplemented, which can significantly improve the secondary recovery. Therefore, we must continue to improve the oilfield water injection development evaluation system, the establishment of scientific and rational indicators of the system.

WATER STORAGE RATE, WATER DRIVE INDEX, MOISTURE CONTENT ANALYSIS

Analysis of relationship between water retention and moisture content

The water storage rate and water flooding index are two important indexes which reflect the development effect of water injection field. It is directly related to the factors such as oil injection and comprehensive water cut [2]. The water storage rate refers to the ratio of the difference between the water injection amount and the water collection amount in the water injection development field. Namely: water retention = (cumulative water injection - cumulative water production) / cumulative water injection. The water storage rate mainly indicates the level of water use efficiency, and its connotation is the efficiency of maintaining the energy of the formation layer [3]. The higher the value of the water storage, the higher the degree of water use, the better the development effect. According to the definition of water retention, the water storage rate is calculated as:

$$C_p = [(Q_i - Q_w) / Q_i] \times 100\% \quad (1)$$

The expression of the injection ratio is：

$$Z = Q_i / (Q_w + Q_o \times \frac{B_o}{\rho_o}) \quad (2)$$

Then：

$$C_p = 1 - 1/[Z(1 + \frac{Q_o}{Q_w} \times \frac{B_o}{\rho_o})] \quad (3)$$

By moisture content：

$$f_w = \frac{Q_w}{Q_w + Q_o} \quad (4)$$

Then：

$$C_p = 1 - 1/[Z(1 + \frac{1 - f_w}{f_w} \times \frac{B_o}{\rho_o})] \quad (5)$$

In the formula：

Q_i ——Cumulative water injection；

Q_w ——Accumulated water production；

Q_o ——Accumulated oil production；

Z ——Injection ratio；

B_o ——Crude oil volume factor；

ρ_o ——Crude oil ground density。

From the above formula, according to the different Z value, draw the water retention rate and moisture content of the curve shown in Figure 1.

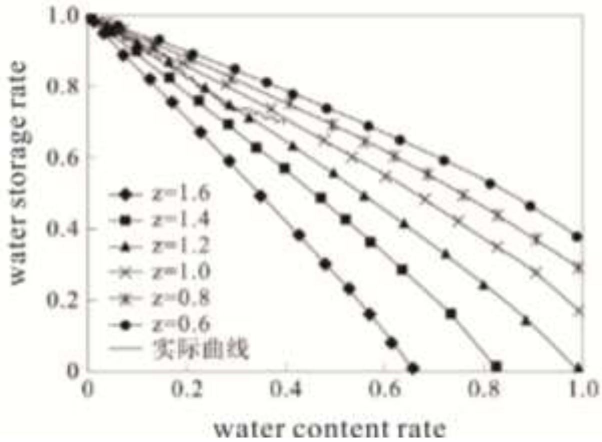

Fig-1: The relationship curve of water storage rate and water cut

Analysis of the relationship between water flooding index and moisture content

The water flooding index is defined as the amount of water discharged per ton of oil produced in the ground. Water flooding index = (water injection - water production) / oil production. The greater the water flooding index, the greater the required water injection. According to the definition of water flooding index, the water drive index is calculated as:

$$S_p = (Q_i - Q_w)/(\frac{B_o}{\rho_o} \times Q_o) \quad (6)$$

By the expression of the ratio can be obtained:

$$S_p = Z + (Z - 1)(\frac{\rho_o}{B_o} \times \frac{Q_w}{Q_o}) \quad (7)$$

Defined by moisture content:

$$S_p = Z + (Z - 1)(\frac{f_w}{1 - f_w} \times \frac{\rho_o}{B_o}) \quad (8)$$

From the above formula, according to the different Z value to draw the water drive index and the water content of the relationship between the curve shown in Figure 2.

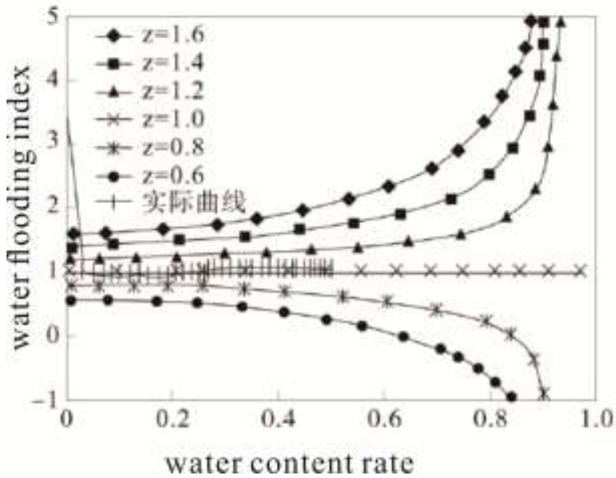

Fig-2: The relationship curve of water flooding index and water cut

Relationship between theoretical value and actual value of water retention and waterflooding index

In the practice of production, the theoretical value and actual value of water storage rate and water flooding index are often different. Resulting in the calculation of the accumulated water retention and cumulative water drive index below the theoretical value of two main reasons [4]:

One of them is in the early stages of oilfield development. The intrusion of the edge and the bottom water is equivalent to injecting water into the reservoir, but in the calculation, although the total water production has increased, it has not been included in the accumulated water.

The second is in the early stages of oilfield development, injection and production imbalance, more liquid production, less injection, then take measures to reduce pressure mining. It can be seen that the actual value of the two indicators will be lower than the theoretical value.

Resulting in cumulative storage rate and cumulative water drive index higher than the theoretical value of the main four reasons [5]: First, to make up for the pressure deficit or pressure recovery stage, injection and production ratio greater than 1.0; Second, the overflow of water injection; Third, due to the poor connectivity of the reservoir as a whole, resulting in water injection effect is not obvious; Fourth, due to the measures of onset, into the water spread volume has expanded, the development effect is obvious. Therefore, when the actual value of water storage and water flooding index is higher than the theoretical value, the influence of reservoir pressure and change of injection and production ratio on the two indexes should be taken into account. If the actual value of the two indicators is higher than the theoretical value, it is proved that the pressure is large, leading to the overall connectivity of the reservoir is poor. Under normal circumstances, the two indicators decreased less, or curve upturned trend, then it is proved that the measures have been effective.

When the oil field is in the high water period or especially high water cut period, the two indexes of water storage rate and water flooding index have universal applicability to the evaluation of development effect, and can guide the oil field to adjust the tapping measures according to the actual situation. However, when the edge of the water intrusion is not taken into account, the corresponding static geological parameters should be used to calculate, which can weaken their impact on the accuracy of the indicators.

The practical application of X curve in X oilfield is analyzed

During the development of oilfield water injection, with the increase of crude oil production, the comprehensive water content is rising and the injected water is continuously discharged. The higher the water content, the greater the discharge water and the smaller the underground water storage [6]. From the above water drive index, the relationship between water content, we can see that when the injection ratio is 1, the water drive index is also 1, the value of water drive index does not change with the water content. It is found that when the ratio of injection is less than 1, the waterflooding index decreases with the increasing of water content. When the ratio of injection is greater than 1, the waterflooding index increases with the increasing water content The The oil field has been developed since 2001, and the formation pressure has been supplemented, and the water storage rate has a tendency to rise slowly.

X oil field before the implementation of artificial water injection, the pressure level is low, the overall effect of poor displacement, water content continues to rise, water drive index declining. After the start of artificial water injection in 2001, the formation pressure is supplemented, the water flooding index is rising, the development effect is getting better. According to the above analysis, it can be seen that the energy of the bottom water of the X reservoir is insufficient. If the natural energy is used for mining, the mining efficiency is very low, and only the artificial water injection can improve the overall development efficiency. The actual water content, water drive index and water storage rate of X oilfield are shown in Table 1.

Table 1: The actual statistics of water cut, water flooding index and water storage rate of X oilfield

f_w	0.00	0.01	0.02	0.03	0.04	0.05
S_p	4.5605	3.1508	2.1187	1.8269	1.006	1.006
C_p	1.0000	0.9800	0.9750	0.9700	0.970	0.960
f_w	0.0600	0.0700	0.0800	0.0900	0.100	0.110
S_p	0.9750	0.9550	0.9550	0.9750	0.945	0.950
C_p	0.9700	0.9600	0.9500	0.9400	0.930	0.920
f_w	0.1200	0.1300	0.1400	0.1500	0.160	0.170
S_p	0.9350	0.9450	0.9500	0.9550	0.960	0.965
C_p	0.8000	0.7950	0.7900	0.7800	0.770	0.760
f_w	0.1800	0.1900	0.2000	0.2100	0.220	0.230
S_p	0.8750	0.8800	0.8900	0.8950	0.900	0.910
C_p	0.7500	0.7400	0.7300	0.7200	0.710	0.700
f_w	0.2400	0.2500	0.2600	0.2700	0.280	0.290
S_p	1.0000	1.0050	1.0100	1.0150	1.015	1.020
C_p	0.6900	0.6800	0.6700	0.6600	0.650	0.640
f_w	0.3000	0.3100	0.3200	0.3300	0.340	0.350
S_p	1.0450	1.0500	1.0550	1.0600	1.070	1.070
C_p	0.8200	0.8150	0.8100	0.8050	0.800	0.800
f_w	0.3600	0.3700	0.3800	0.3900	0.400	0.410
S_p	1.0350	1.0400	1.0350	1.0400	1.040	1.035
C_p	0.8150	0.8100	0.8100	0.8000	0.800	0.790
f_w	0.4300	0.4300	0.4400	0.4500	0.460	0.470
S_p	1.0500	1.0450	1.0400	1.0350	1.035	1.030
C_p	1.5850	0.5850	0.5800	0.5800	0.575	0.575

CONCLUSION

(1) waterflooding development of oil fields, with the increase in the degree of recovery, comprehensive water content increased, storage rate decreased [7]. As the oil field rises as a whole, the oil displacement effect will gradually deteriorate. The size of the injection-production ratio determines the size of the water storage and the size of the water flooding index and the corresponding changes in the relationship between the application of these two indicators of the development of the effectiveness of the study, must ensure that the same drive mode.

(2) water storage rate, water drive index standard curve of water injection has a guiding significance [8]. In the process of evaluating the effect of oilfield water injection development, it is necessary to adjust the analysis method according to the change of the actual reservoir pressure and combine the other comprehensive analysis methods to get the correct conclusion.

(3) By applying the actual data of X oil field to the analysis of water storage rate and water flooding index, the conclusion of the actual water injection development effect can be obtained, which can prove the practicability of this method in the practical application of oil field.

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