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Analysis on the variation law of polymer flooding index in the first and second oil reservoirs of Daqing Oilfield

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Abstract: With the development of oilfield exploitation in China, in-depth understanding of the change of polymer flooding injection-production index can effectively alleviate the contradiction of polymer flooding and improve the production efficiency. Based on this, taking Daqing oilfield as an example, this paper makes a detailed analysis on the classification of polymer flooding stages and the prediction methods of development indicators for the first and second oil layers, and mainly discusses the variation rules of injection-production indicators in the process of polymer flooding for the first and second oil layers, in order to provide reference for others.

Key words: Daqing Oilfield; Reservoir polymer; Flood injection-production index; Change rule

1. Introduction

Since 1995, polymer flooding in Daqing oilfield has made great achievements. By the end of 2014, the unimplemented reserves of the first and second oil layers in Daqing Oilfield were 91 million tons and 1.257 billion tons respectively. It can be seen that the polymer injection potential of class I oil reservoir is gradually decreasing. In order to maintain the high yield state of the oil field and the existing scale of polymer flooding, the development object has been transferred from class I oil reservoir to class II oil reservoir. Compared with the first type oil reservoir, the second type oil reservoir has more thickness and lower permeability, and has serious problems such as plane and longitudinal heterogeneity. At present, due to the deterioration of the physical properties of the polymer injected reservoir, it is impossible to guide the polymer flooding adjustment work based on the research rules of the first type reservoir. Therefore, in order to effectively alleviate the contradiction of polymer flooding, it is necessary to quantitatively describe the variation law and difference of polymer flooding injection-production indexes in the first and second oil layers, and deepen the understanding of the development law of polymer flooding.

2. Polymer flooding stage division

According to the variation characteristics of the comprehensive water-cut curve of polymer flooding, polymer flooding can be divided into five stages: non-effective stage, water-cut decline stage, water-cut low value stage, water-cut recovery stage and subsequent water flooding stage [1]. Except the stage of low water cut value, all the other stages have clear division principles. In the analysis and adjustment of field dynamics, effective measures are usually taken to prolong the water-cut low value period when the water cut reaches the lowest point and enters the stage of water-cut low value. However, different oil production plants have different standards for when the water-cut low value period ends. It has been reported that when the polymer dosage reaches 165-210mg /L·PV, all mining indexes in polymer flooding will appear the inflection point of rapid change, and this point is considered as the key point of polymer flooding. If polymer injection continues, the block will enter the stage of low water content.

Prediction method of polymer flooding development index

At present, the prediction methods for a class of reservoir development indicators mainly include water flooding increment method, water flooding decline method, normalization method, polymer flooding flow tube method, numerical simulation method, displacement characteristic curve method and so on. Among them, the calculation process of water flooding increment method and water flooding decline method is relatively simple, but can be used to calculate short-term oil increase, or predict the recovery factor and production after polymer flooding. The normalization method is mostly used in the process of oilfield development planning, which can give reasonable water flooding decline production. The polymer flooding flow tube method requires high accuracy and fast calculation speed in polymer flooding process, but it has poor prediction effect on the late recovery of water content in a few blocks. The numerical simulation method is mainly used for the prediction of dynamic indicators, because there is a large deviation between the predicted results and the actual values, so it can only be used as a reference. The displacement characteristic curve method mainly reflects the dynamic characteristics of the block through the actual dynamic development data. It is simple and reliable to use it for polymer flooding development index prediction [2].

Through long-term practice, it is found that there are obvious differences in the geological characteristics and the reflection of polymer driving state between class I and Class II reservoirs, but the displacement characteristic curve method is still applicable to individual stages of polymer flooding of class II reservoirs, and the prediction accuracy is high. At the same time, when the cumulative oil production reaches a certain level, it can form a linear relationship with the logarithm of cumulative liquid production, and the theoretical equation is as follows:

$$\lg L_P(\mathrm{t}) = a + bN_P(t) \text{ type} \quad (1)$$

In Equation (1); $L_P(\mathrm{t})$ Represents the accumulated liquid production at a certain time, 104t; $N_P(t)$ Represents the accumulated oil production at a certain time，104t；aRepresents constants related to rock and fluid properties; B is the constant related to well pattern layout and geological conditions.

Differential transformation is performed on Equation (1), Prediction model of The moisture content at a certain time can be obtained $f_W(t)$：

$$f_W(t) = 1 - \frac{1}{2.3aL_p(t)} \text{ type} \quad (2)$$

In Equation（2），Once the cumulative fluid production at a certain time is determined, the water cut at that time can be predicted. Therefore, the water cut can be predicted through the displacement characteristic curve.

3. Variation law of injection-production index in polymer flooding process

3.1 Injection pressure

When the polymer solution begins to enter the medium and low permeability layer, it means that the layer is about to be used and the water content will decrease significantly. In the water-cut decline stage, the injection pressure of the first and second oil reservoirs will rise rapidly due to the increase of viscosity of displacement fluid, and the rising rate of injection pressure will significantly slow down or tend to be stable in the middle and late period [3]. Table 1 makes a detailed statistics of injection pressure increase in 13 blocks of the first and second oil layers in Daqing Oilfield. The results show that the pressure of blank water flooding stage is low and the allowable injection pressure of oil layers is high because the conditions of the first and second oil layers are good and the burial depth is large. Therefore, in the whole polymer flooding process, The injection pressure and the increase of injection pressure of the first type oil reservoir are obviously higher than that of the second type oil reservoir.

Table 1. Injection pressure increase at different stages in the first and second oil reservoirs

Reservoir types	Injection pressure increase /MPa		Average pressure throughout polymer flooding /MPa
	Water cut period	Low water content and rising period	
A class of reservoir	4.04	0.39	12.10
The second class reservoir	*3.15*	*0.25*	*10.90*

3.2 Apparent water absorption index

In different stages of unit polymer dosage, the apparent water absorption index decline rate of polymer flooding in the first and second oil layers is also different, and the specific situation is shown in Table 2. Because the injection volume of the first and the second oil reservoirs is large in the water-cut decline stage, and the injection pressure is just in the rising stage, but has not reached the peak, the decreasing speed of water absorption index is obviously large. In the period of low water content, the decline rate of apparent water absorption index will slow down. In the water cut recovery stage, the apparent water absorption index will decrease further, or even slow down. Although the formation conditions of the second type oil layer are poor and the average injection pressure is obviously lower than that of the first type oil layer, but the amount of polymer solution is relatively short, so the apparent water absorption index and decline rate of the second type oil layer are relatively lower than that of the first type oil layer [4]

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Table 2. Changes of water absorption index decline rate in different stages of the first and second oil reservoirs

Reservoir types	Rate of decrease of water absorption index /%		
	Water cut period	Low water cut stage	Water recovery period
A class of reservoir	4.00	0.94	0.58
The second class reservoir	*0.86*	*0.15*	*0.04*

3.3 Liquid producing index

Table 3 shows the calculation results of the decline rate of the liquid production index of polymer flooding in the first and second oil layers at different stages of unit dosage. Through data analysis, it can be seen that the decline rate of the liquid production index of polymer flooding in the first and second oil layers varies greatly in different stages. At the same time, the matching effect of class I oil layer and polymer solution is better, which can significantly improve the liquid production capacity of class I oil layer, and the liquid production index is significantly higher than that of class II oil layer. In the water-cut decline stage, the industrial index decline rate of the second oil layer is relatively large. In the period of low water cut value, the decline rate of industrial index of the second type oil layer will decrease obviously. In the stage of water cut recovery, the decline rate of the liquid production index of the second oil layer tends to be gentle.

Table 3. Change of decline rate of production index in different stages of the first and second oil reservoirs

Reservoir types	Rate of decrease of water absorption index /%		
	Water cut period	Low water cut stage	Water recovery period
A class of reservoir	4.00	0.94	0.58
The second class reservoir	*0.86*	*0.15*	*0.04*

3.4 Mass concentration of produced liquid polymer

Generally, when the polymer dosage reaches 400-500mg/L·PV, the polymer mass concentration in the produced liquid of a class of oil reservoir can reach the maximum value, which is significantly faster than the previous increase rate of polymer mass concentration [5]. When the slope of the statistical curve is 1.7, the mass concentration of polymer tends to be stable. In the process of polymer injection, the concentration of polymer material in the second type oil reservoir rises slowly, and the subsequent rise rate also decreases obviously. In the polymer injection process of the second type oil reservoir, this value rises slowly, and in the later period, the rise rate drops slightly. According to the statistics of the whole process, the slope of the curve of accumulation mass concentration reaches 0.7. According to the analysis of the results, the specific changes of the produced polymer concentration are closely related to the conditions of the reservoir itself and the concentration of the injected polymer. In addition, in order to further characterize the mass concentration of polymer injected will have an impact on the mass concentration of polymer extracted, pr is introduced to characterize the difficulty of polymer slug breakthrough [6], namely:

$$\rho_r = \rho_{OP} / \rho_P \text{ type} \quad (3)$$

In Equation (3): ρ_{OP} Represents the mass concentration of polymer in produced liquid, mg/L; ρ_P Represents the mass concentration of polymer injected, mg/L.

By comparing the two types of oil reservoirs ρ_r : the first type ρ_r <0.6 and the second type ρ_r <0.4, it is found that the polymer slug of the first type is easier to break through than that of the second type. Therefore, the mass concentration of injected polymer should be appropriately increased in the scheme design.

3.5 Combined moisture content

Through the statistics of the comprehensive water cut data of 180 oil Wells in 3 blocks of the first and the second oil reservoirs in Daqing oilfield, it is found that the water cut curves of the two reservoirs are obviously different. First of all, from the point of view of water content curve shape, U shape has the best effect. The second type is √ type, and the water content rises relatively slowly in the water cut recovery stage: V type and straight line have poor effect on the whole. Among them, U type, √ type, V type and straight type are the most, accounting for 44.6%, 28.9%, 26.5%. The U type only accounts for 14.7%, the √ type accounts for 40.5%, and the V type and straight type accounts for 44.8%. It can be seen from the above that the water content of one type of oil reservoir decreases greatly and the period of low water content lasts longer. The water content of the second type oil layer decreases slightly under unit dosage, and the rise rate of water content in the later stage is relatively slow and the span is large. For details, see Table 4.

Table 4. Comparison of comprehensive water cut indexes of the first and second oil reservoirs

Reservoir types	Average moisture content decreases the most /%	Polymer dosage at low water content stage / (mg·L-1·PV)	Curve shape of water content	Rate of moisture reduction	Rate of moisture recovery
A class of reservoir	16.8	240	U	0.07	0.03
The second class reservoir	11.2	210	√	0.04	0.01

3.6 Oil production

In polymer flooding at different stages, for one, the second type reservoir of daqing oil field oil production statistics, the ratio of total oil produced to systematically according to the results and a decline in water cut stage and low stage formation and its oil production accounts for 57% of the total oil production, while the second type reservoir in aqueous rally, oil production accounts for only 60% of the total oil production, and oil production peaks relative lag. Therefore, effective measures are taken to improve polymer flooding effect during water cut recovery period.

At the same time, this study also specifically for north A piece of oil field development process are simulated, and the specific simulated on different vertical sedimentary unit P17 poor (development) and the P12 poor (development), and the plane of different sedimentary facies of oil production, such as river sand with the river sand, simulation results show that the development of poor reservoir, oil production are lagged significantly.

4. Conclusion

Through the analysis of industrial polymer flooding block in-situ data, a quantitative description, for each stage of polymer flooding, oil injection pressure, depending on the water injectivity index, producing fluid index and other indicators of change rule, in is in low water cut period, a reservoir has the highest percentage of oil production distribution, and the second type reservoir in aqueous rally distribution ratio is higher. At the same time, the numerical simulation results of jingbei A block show that the oil production of the reservoir with poor conditions will lag significantly in the peak period. When the polymer dosage reaches 165-210mg/L·PV, the inflection point of rapid change of various mining indicators will appear, and the corresponding water content decrease is 2/3 of the maximum water content decrease. Comprehensively identified as the key point of polymer flooding, polymer injection can continue, and the block will enter the stage of low water content.

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