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Numerical simulation of polymer flooding in water flooding reservoir

Xiaofei Sun*, Qingquan Zhang, Zhiyi Teng, Xueqian Wang, and Jiaming Cai

School of Petroleum Engineering, China University of Petroleum (East China), Qingdao, China

Abstract. Different influencing factors in the process of polymer flooding have different degrees of influence on the development effect, so it is necessary to carry out the dynamic prediction of polymer flooding before implementing the development scheme. In this study, the reservoir model of C Block is established and the production performance is fitted. The fitted reservoir model is used to study the influence of polymer concentration, injection time, injection rate multiple and injection timing on the development effect of C Block. The results show that the cumulative oil production increases gradually with the increase of polymer concentration, and combined with the principle of economic development, there is an optimal polymer concentration in C Block, which is 0.15 wt%; With the increasing of injection time and injection rate multiple, the cumulative oil production and incremental oil production (compared with water flooding) show an increasing trend; For injection timing, the earlier polymer injection is more conducive to obtaining higher cumulative oil production and oil increment. The cumulative oil production under the optimal development scheme of C block is 23.8494×104 m3, which is 1.5042×104 m3 higher than that of water flooding.

1. Introduction

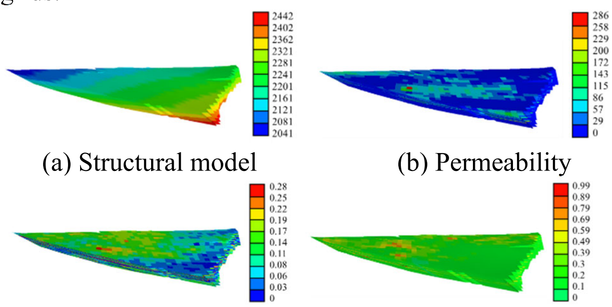
At present, most oil fields in eastern China have entered the late stage of high water cut development, and the existing water flooding cannot excavate more remaining oil [1]. So improving oil recovery at a small economic cost is the main task at present. In China, polymer flooding is one of the most mature and widely used EOR methods in tertiary oil recovery technology [2]. Polymer flooding is to inject polymer solution into the oil reservoir and increase recovery by changing mobility ratio and increasing sweep efficiency [3, 4].

The C Block has experienced the stages of natural energy development, initial water injection and subdivided water injection development. In 2017, the production of injection-production adjustment reached the peak. It is urgent to carry out the research on polymer flooding scheme to improve oil production. Therefore, in order to scientifically develop reservoirs, it is necessary to evaluate the stimulation effect of the scheme before the implementation scheme [5]. In this paper, the CMG-SRATS software is used to study the development effect of different influencing factors of polymer flooding. Finally, the development effect under the optimal scheme is predicted, so as to provide theoretical basis and guidance for the implementation of polymer flooding in future.

2. Reservoir model

2.1 Establishment of geological model

Based on seismic, logging and reservoir test data, the geological model (grid and reservoir properties) established by petrel software was imported into CMG-SRATS software. The reservoir structure and properties are shown in Fig.1. The model has 47×25×25 (29375) grids.



(a) Structural model (b) Permeability

(c) Porosity (d) Oil saturation

Figure 1. Numerical simulation model of C block.

2.2 Establishment of fluid model

In order to fully simulate the mechanism of enhanced oil recovery by polymer flooding, three components are defined in the fluid model of CMG, including oil, water and polymer. The fluid model not only defines the basic properties of oil and water, but also considers some special properties of polymer, such as viscosity, residual

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* Corresponding author: 1209475702@qq.com

resistance factor and so on. Table 1 shows the rock and fluid properties in the model.

Table 1. Rock and fluid properties in the model

Reservoir	Value	oil	Value	Polymer	Value
Depth, m	2170	Density, g/cm^3	0.96	Density, g/cm^3	1.008
Pressure, MPa	21.7	Viscosity, mPa·s	8.5	Viscosity, mPa·s	209.3
Temperature, °C	80	Volume factor	1.035	Residual resistance factor	2

2.3 Establishment of production dynamic model

Production dynamic model is the dynamic presentation of reservoir development process and production situation. Based on the production parameters of C Block, the production dynamic model is established. In order to ensure that the established reservoir model can better reflect the actual reservoir conditions and complete the study of polymer flooding development effect, the cumulative oil production and water cut are taken as the fitting target, and the history matching is carried out by adjusting the relative permeability curve and other reservoir parameters. The results of history matching are shown in Fig.2. It can be seen from Fig.2 that the fitting accuracy of actual production data and model data is high, which provides a reliable reservoir model for subsequent program prediction research.

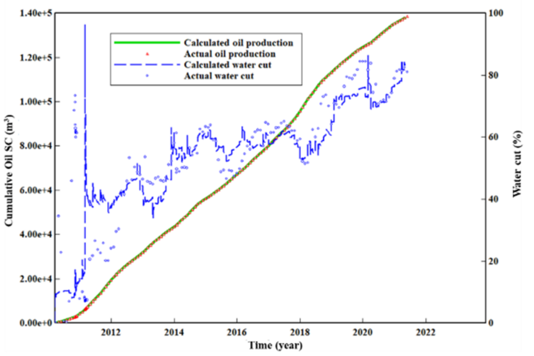

Figure 2. Historical matching results of oil production and water cut in the whole area.

3. Research on influencing factors and discussion

Combined with the field operation parameters of C Block, the development schemes under different influence parameters of polymer flooding are formulated, and the influences of polymer concentration, injection time, injection rate multiple and polymer injection timing on the development effect are studied.

3.1 Effect of polymer concentration

Table 2 and Fig.3 show the development schemes and simulation results under different polymer concentration. It can be seen from Fig.3 that with the increase of polymer concentration, the cumulative oil production and incremental oil production (compared with water flooding) increase gradually. This is because with the increase of polymer concentration, the entanglement intensity of the molecular chain increases due to the characteristic that the single molecular chain of the polymer is easy to tangle with each other. Therefore, the increase of the traction radius of the polymer molecule causes the residual oil at both ends of the pores to be dragged out, thereby increasing the volume sweep coefficient. However, when the polymer concentration increased from 0.15 % to 0.2 %, the cumulative oil production only changed 0.055×104 m3. This is due to the fact that the polymer injected in the early stage can be adsorbed and mechanically detained on the reservoir rock, resulting in the weakening of the polymer flooding ability and mobility of subsequent injection. In addition, according to the principle of economic development, the optimal polymer concentration is 0.15 wt %.

Table 2. Development schemes under different polymer concentration.

Scheme number	Injection timing year	Polymer concentration wt.%	Injection time year	Injection rate multiple
1	1	0(water flooding)	5	1
2	1	0.01	5	1
3	1	0.05	5	1
4	1	0.1	5	1
5	1	0.15	5	1
6	1	0.2	5	1

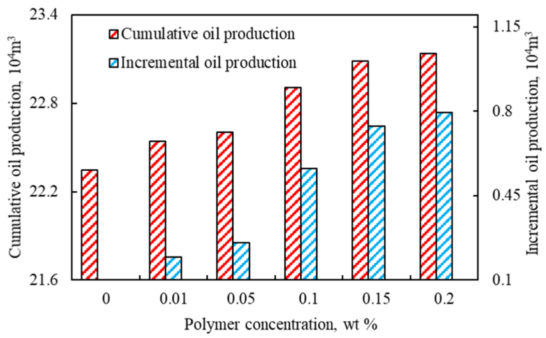

Figure 3. Simulation results under different polymer concentration.

3.2 Effect of injection time

Table 3 and Fig.4 show the development schemes and simulation results of polymer flooding under different injection time. It can be seen from Fig.4 that with the increase of polymer injection time, the cumulative oil production increased from 22.5028×104 m3 to 23.1396×104 m3. This is because the amount of polymer increases as the injection time increases. The crude oil in the pores is continuously affected and produced under the action of more polymers, thereby increasing the cumulative oil production and incremental oil production.

Table 3. Development schemes of polymer flooding under different injection time.

Scheme number	Injection timing year	Polymer concentration wt.%	Injection time year	Injection rate multiple
1	1	0.2	1	1
2	1	0.2	2	1
3	1	0.2	3	1
4	1	0.2	4	1
5	1	0.2	5	1

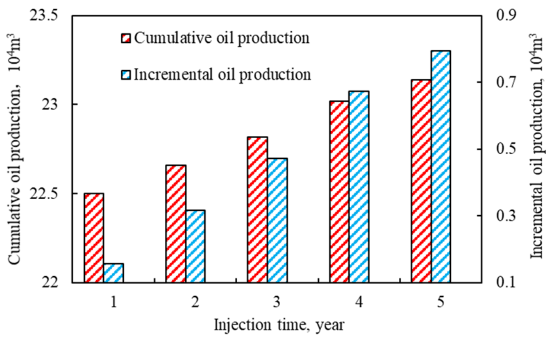

Figure 4. Simulation results under different injection time.

3.3 Effect of injection rate multiple

Fig.5 shows the simulation results of polymer flooding under different injection rate multiples (0.6~1.4). It can be seen from Fig.5 that with the increase of injection rate multiple, both cumulative oil production and incremental oil production show an increasing trend.

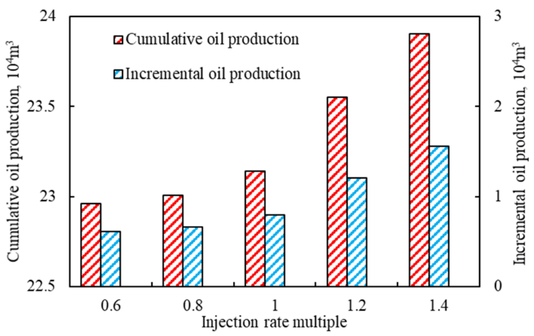

Figure 5. Simulation results at different injection rate multiples.

3.4 Effect of polymer injection timing

Table 4 and Fig.6 show the development plan and simulation results under different polymer injection timing. It can be seen from Fig.6 that the earlier polymer injection is more conducive to obtaining higher cumulative oil production and oil increment. When the injection starts in the first year, the cumulative oil production can reach 23.196×104m3, which is 0.7944×104m3 higher than that of water flooding. This is because the early injection can give full play to the role of polymer and increase the amount of crude oil affected.

Table 4. Development schemes under different injection timing.

Scheme number	Injection timing year	Polymer concentration wt.%	Injection time year	Injection rate multiple
1	1	0.2	5	1
2	2	0.2	5	1
3	3	0.2	5	1
4	4	0.2	5	1
5	5	0.2	5	1

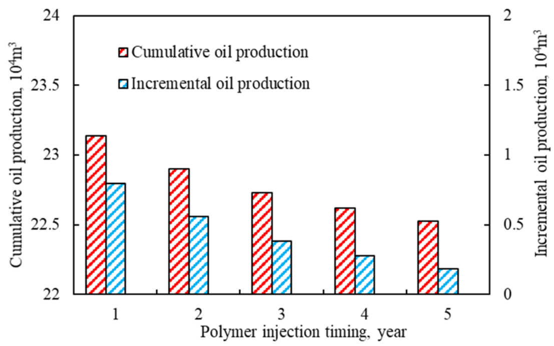

Figure 6. Simulation results under different polymer injection timing.

3.5 Prediction of optimal development scheme

Combined with the influence of different polymer flooding parameters and the principle of economic development, the optimal development scheme is shown in table 5. The cumulative oil production under this scheme is 23.8494×104 m3, which is 1.5042 ×104 m3 higher than that of water flooding.

Table 5. Optimal parameters of target block.

Injection timing year	Polymer concentration wt.%	Injection time year	Injection rate multiple
1	0.15	5	1.4

4. Conclusion

Based on the relatively fine geological model and history matching, the well-fitting reservoir model is used to complete the research on the influence of different polymer flooding parameters in C Block. The development effect of the optimal development scheme is predicted, and the relevant conclusions are obtained as follows:

(1) The cumulative oil production increases gradually with the increase of polymer concentration, and the optimal polymer concentration is 0.15 wt% in the target area; With the increase of injection time and injection rate multiple, the cumulative oil production gradually increases; The earlier polymer injection is more conducive to obtaining higher cumulative oil production and incremental oil production.

（2）The cumulative oil production under the optimal development scheme is $23.8494\times10^4m^3$, which is $1.5042\times10^4m^3$ higher than that of water flooding.

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