CSCanada
Advances in Petroleum Exploration and Development
Vol. 11, No. 2, 2016, pp. 48-51
DOI:10.3968/8364

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

Numerical Simulation Study on the Technology of Different Nature Polymer Injection in Thin and Bad Reservoir

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Received 16 April 2016; accepted 10 May 2016
Published online 26 June 2016

Abstract
The thin and poor reservoir , as an important replacement of production decline in the later stage of oilfield development, is gradually becoming the target of three oil recovery due to the large proportion of its reserves. For Class Ⅲ and Class Ⅳ of thin and poor reservoirs with large contradiction between the layers, if the same molecular weight polymer flooding is used to drive oil, it is easy to affect the development effect because of low producing degree of poorly matched reservoir. On the basis of the fine geological model, the water cut and cumulative oil production of the simulated area were fitted by the simulation software of eclipse, and the development effect of different production schemes is analyzed and forecasted. Research results show that the effect of different layer different nature polymer injection is better than that of general polymer injection, and the effect of different stage different nature polymer injection is better than that of the different layer different nature.

Key words: Thin and bad reservoir; Numerical simulation; Different nature and different stage; Polymer flooding

Zhang, W. L., Sun, L. Y., Zhang, X. T., & Wang, J. (2016). Numerical simulation study on the technology of different nature polymer injection in thin and bad reservoir. *Advances in Petroleum Exploration and Development*, *11*(2), 48-51. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/8364
DOI: http://dx.doi.org/10.3968/8364

INTRODUCTION

With the development of oilfield, most of the oil field has entered the high water cut period, class Ⅲ and class Ⅳ of thin and poor reservoir become the main object of oilfield exploration and development at present due to its considerable reserves[1-2]. Improving the recovery efficiency of thin and poor reservoir has become the most important research focus in the study. Practice has proved that high concentration and high molecular weight polymer solution has a strong ability to drive oil. However, it is easy to be blocked in the thin oil layer due to the high heterogeneity, low permeability, strong adsorption and carrying capacity of the polymer, so that polymer solution flows into the reservoir of high permeability and good connectivity[3-5]. Through the numerical simulation of experimentation area, this paper compares and analyses the effect of water flooding, general polymer injection, polymer injection different layer and different nature[6], and polymer injection different stage and different nature[7].

1. GEOLOGICAL SURVEY OF EXPERIMENTATION AREA

The formation of experiment zone is gentle, the maximum dip is less than 1.5 degree, and The micro structure fluctuation is not big, the entire block can be regarded as flat ground. The thin and poor reservoir permeability is generally lower than 300×10^{-3} μm^2, of which class Ⅲ reservoir permeability is generally within the range of 100×10^{-3}~300×10^{-3} μm^2, and class Ⅳ reservoir permeability is generally lower than 100×10^{-3} μm^2. Reservoir is mainly the development of the non channel sand with the effective thickness below 1 m and the development of the outer untabulated reservoirs. The total oil area of the experimentation area was 0.6 km^2, which accounted for 1/5 of total oil block. In addition, there is no fault block. Well pattern apply of 5-spot well pattern, and the injection production well spacing is about 100 m.

2. THE CONSTRUCTION OF GEOLOGICAL MODEL

2.1 Principle of Grid Construction

(a) X-Y coordinate system is used in Grid system, of which X direction runs east to west and is parallel to the direction of the based injection production well. Grid is uniform and rectangular shape.

(b) In order to ensure the production authenticity of four-boundary mesh in the simulation process, we add 2 rows empty grid with no attribute Outside the well grid.

2.2 Grid Partition Result

In accordance with the modeling requirements, we applied of 25 m × 25 m model to build the grid In plane. So grid number is 49 × 56. In the longitudinal direction, 40 sedimentary layers were established according to the different of sedimentary period of microfacies and sedimentary environment. In the whole reservoir geological model, the total number of grids is 109,760.

2.3 Grid Attribute Assignment

In this part, it is necessary to assign the value for these attributes of permeability, porosity, saturation and so on.

3. HISTORY MATCHING OF NUMERICAL SIMULATION

After the geological model was established, the History fitting need to do according to the known production dynamic data. the water cut of the field is about 90% at present. Cumulative oil production is 512.23×10^4 t. The fitting result of water cut and cumulative oil production are shown in Figures 1 and 2.

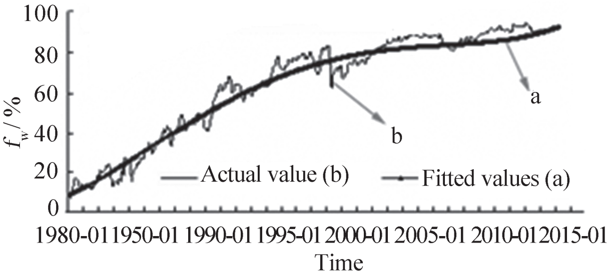

Figure 1
Fitting Curve of Water Cut in Overall Block

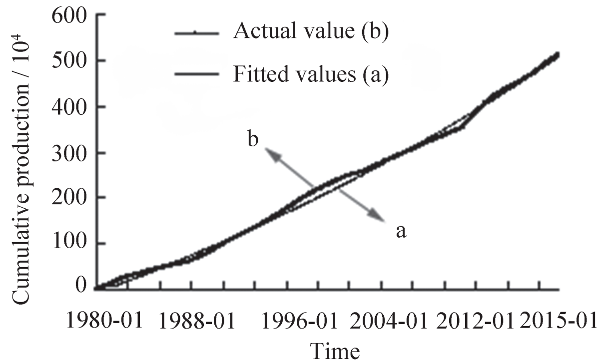

Figure 2
Cumulative Oil Production Fitting Curve in Overall Block

4. SCHEME AND SCHEME PREDICTION

On the basis of fine history matching, 8 sets of production scheme was formulated and forecasted, of which there are 2 sets of water flooding schemes that take Class Ⅲ and Class Ⅳ reservoirs as object respectively in Table 1. Table 2 shows two sets of general polymer injection schemes. Table 3 shows three sets of different layer polymer injection schemes. In addition, there still is a set of polymer injection scheme of different nature and different stage. Finally, we forecasted these 8 sets of schemes.

Table 1
Water Flooding Scheme

Scheme	Reservoir	Permeability (10^{-3} μm^2)	Downtime
1	Class Ⅳ	< 100	Until the water cut is 98%
2	Class Ⅲ	100~300	Until the water cut is 98%

Figures 3 and 4 are the prediction results of Scheme 1 and Scheme 2. The stage recovery percent of Scheme 1 is 7.2% until the water cut is 98%, and the stage recovery percent of Scheme 2 is 9.5% until the water cut is 98%. Recovery percent of polymer flooding of Scheme 1 is lower than the Scheme 2. It is not only because of the lower permeability of Class Ⅳ reservoirs than Class Ⅲ, but also because of the Class Ⅳ reservoirs heterogeneity is more serious. It leads to poor reservoir performance.

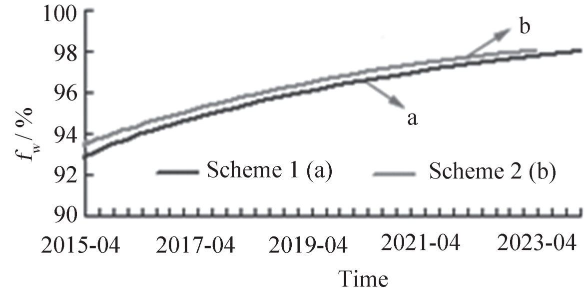

Figure 3
Water Cut Prediction Curve of Scheme 1 and Scheme 2

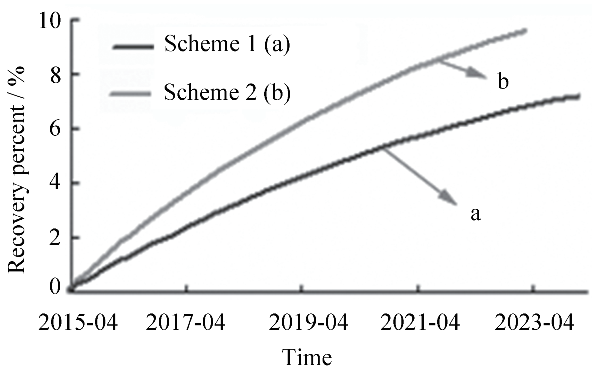

Figure 4
Stage Recovery Percent Prediction Curve of Scheme 1 and Scheme 2

The scheme prediction results are as follows: Stage recovery percentage of Scheme 3 is 13.5% until water cut is 98%, stage recovery percentage of Scheme 4 is 14.1% until water cut is 98%.

The scheme prediction results are as follows: The stage recovery percentage of entire block is 15.12%, 20.28%, 16.4% respectively for Scheme 5, Scheme 6 and Scheme 7 until water cut is 98%, of which Class Ⅲ reservoirs is 18.9%, 23.4%, 17.3% respectively, and Class Ⅳ reservoirs is 12.6%, 18.2%, 15.8%. From the figure we can see that the stage recovery percentage of Scheme 5 is greater than that of Scheme 3 and Scheme 4. It is because that different polymers are adopted for different reservoirs in Scheme 5 of different layer different nature polymer flooding. It makes the injected polymer and oil layer match better and solves the contradiction between the layers. The results showed that the displacement efficiency of different layer different nature polymer injection is better than that of general polymer injection. By comparing the Scheme 5, Scheme 6 and Scheme 7, we can find that, with the increase of polymer molecular weight, the stage recovery degree is firstly increased and then decreased.

Table 2
General Polymer Injection Scheme

Scheme	Reservoir	Permeability (10^{-3} μm^2)	Polymer concentration (mg/L)	Molecular weight (10^4)	Stop polymer injection time	Downtime
3	Class Ⅲ Class Ⅳ	<300	600	400	Until the polymer injection amount is 1pv	Until the water cut is 98%
4	Class Ⅲ Class Ⅳ	<300	1,000	1,000		

Table 3
Polymer Injection Scheme of Different Layer Different Nature

Scheme	Reservoir	Permeability (10^{-3} μm^2)	Polymer concentration (mg/L)	Molecular weight (10^4)	Stop polymer injection time	Downtime
5	Class Ⅲ	100~300	1,000	1,000	Until the polymer injection amount is 1 pv	Until the water cut is 98%
	Class Ⅳ	<100	600	400		
6	Class Ⅲ	100~300	1,000	1,400		
	Class Ⅳ	<100	600	800		
7	Class Ⅲ	100~300	1,000	1,800		
	Class Ⅳ	<100	600	1,200		

Scheme 8: Polymer injection scheme of different stage different nature. Class Ⅲ and Class Ⅳ reservoirs are all shot open in this scheme. Firstly, the general polymer injection, whose polymer injection parameters are same to that of Class Ⅲ reservoirs in Scheme 6, is adopted until the polymer injection amount is 1 pv; then the general polymer injection, whose polymer injection parameters are same to that of Class Ⅳ in Scheme 6, is adopted until the polymer injection amount is 1 pv; finally, it turns the water flooding until the water cut is 98%.

As shown in Figures 5 and 6, the stage recovery percentage of scheme 8 is 21.16% until water cut is 98%, of which Class Ⅲ reservoir is 24.4%, and Class Ⅳ reservoir is 19.1%. The stage recovery percentage of each layer is larger than corresponding layer of Scheme 6. The reasons are as follows, compared with Class Ⅲ reservoirs of Scheme 6, lower permeability layers which is close to Class Ⅳ reservoirs in Class Ⅲ of Scheme 8 is better displacement; compared with Class Ⅳ reservoirs of Scheme 6, higher permeability layers which is close to Class Ⅲ reservoirs in Class Ⅳ of Scheme 8 is better displacement. But because the amount is relatively small for these two kinds of layers, the stage recovery percentage of different stage different nature polymer flooding scheme is only about 1% than that of different layer different nature polymer flooding scheme. In conclusion, it is better than different layer different nature scheme for different stage different nature one in Class Ⅲ and Class Ⅳ reservoirs.

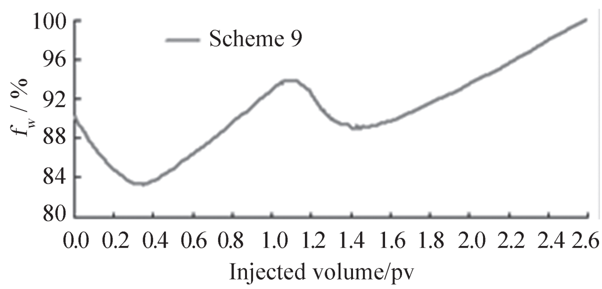

Figure 5
Water Cut Prediction Curve of Scheme 5

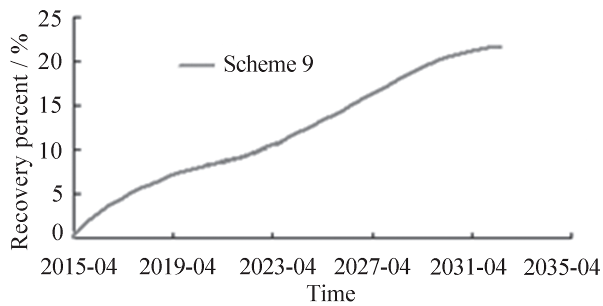

Figure 6
Stage Recovery Percent Prediction Curve of Scheme 9

CONCLUSION

(a) Because of heterogeneity is serious in Class Ⅲ and Class Ⅳ reservoirs, it will have poor results for single polymer flooding. Different layer different nature polymer injection makes the polymer and layer match better by injecting polymer of different concentration and different molecular weight to different layers.

(b) In different stage different nature polymer flooding of Class Ⅲ and Class Ⅳ reservoirs, the pores get more adequate displacement by injecting different concentrations and different molecular weight polymer at different stages. In addition, synergistic effect is produced by superposition of different polymer injection stage. It makes better effect of reservoir production than different layer different nature polymer flooding.

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