The research on the change of the development Index in high concentration polymer after polymer flooding

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Abstract. In order to study the change principle of development biddingafter polymer flooding，the coefficient of drag and residual resistance factorare measured by flow test, and the reasonable injection rate is obtained by the injectability evaluation experiment.Oil displacement experiment is carried out in different types of wellsin large scale simulation physical model of high molecular weight polymer with relative molecular weight of 25 million, the results show that the reconstruction of well pattern can greatly reduce the residual oil saturation and ease the pressure of injection continued rise; with the concentration of polymer flooding increases, the conformance efficiency of middle and low permeability layerare improved; after the reconstruction of well pattern, the remaining oil located near the diversion line and the original oil well get utilized,displacement characteristicshas improved significantly.

1. Introduction

Polymer flooding is applied to several blocks in Daqing Oilfield to enhance oil recovery[1]. It shows that stimulation effect and economic benefit are obvious [2]. Nevertheless, oil recovery ratio is only about 10% in oil reservoir and half of the crude oil is present at the same time[3]. 25 million ultra-high molecular weight and high-concentration polymer flooding is a new technology for after polymer flooding, which has a good application effect. For ultra-high molecular weight and high-concentration polymer, there exists the problems such as high injected pressure and difficulties in injection, and has been a matter of great urgency. In the paper, microelectrode and large-scale three-dimensional physical mode are used. High-concentration viscoelastic polymer flooding after polymer flooding in large-scale three-dimensional physical mode is applied to study changes of sweep efficiency and distribution of remaining oil [4]. And Laboratory displacement experiment of different displacement experimental programs are carried out to compare the effect of enhancing oil recovery of different experimental solutions[5].

2. Determination of resistance factor and residual resistance factor

Resistance factor and residual resistance factor of polymer are determined by flow experiment. After polymer flooding, subsequent water flooding is applied in oil reservoir until water cut is 92%. Then resistance factor and residual resistance factor of 25 million ultra-high molecular weight polymer solution at different concentrations in oil reservoir are determined. Measurement results are shown in Table 1 and injection pressure variations of polymer in Fig.1.

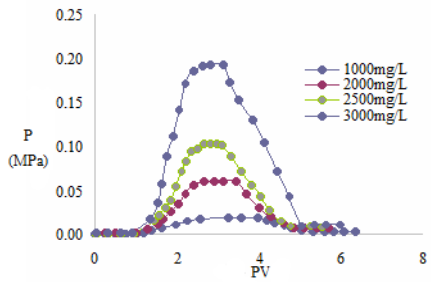

Fig. 1 the difference of the injection pressure difference of different concentrations of polymer

The resistance coefficient and residual resistance coefficient determination experiment results show that, the residual resistance coefficient caused by low concentration (1000 mg / L) polymer is low. When the concentration reached 2000 mg/L, with the concentration increasing, increasing the residual resistance coefficient is increased. After the concentration is more than 2500mg / L, the residual resistance coefficient increases slowly.

Table 1 experimental results of resistance coefficient and residual resistance coefficient

The classes and properties of polymer			The effective permeability of core /$10^{-3}\mu m^2$	The water penetration rate of core after polymer flooding/$10^{-3}\mu m^2$	coefficient of drag	residual resistance factor
molecular weight	concentration /mg/L	viscosity /mPa.s				
2500 ten thousand	1000	45.0	299.9	44.76	40.9	6.7
	2000	95.0	224.9	18.59	101.3	12.2
	2500	241.0	270.0	13.64	257.5	19.8
	3000	391.0	244.3	11.16	352.4	21.9

3. Injection capability evaluation experiment

According to the measurement result of resistance coefficient and residual resistance coefficient, the polymer of different concentration launch injection capacity evaluation experiment. From the injection capacity evaluation results show that high concentration polymer can be injected. From the view of polymer flow characteristic curve, 1000mg / L polymer has good injection capacity. Whereas concentrations exceeded the 1000mg / L, polymer injection pressure differential is large. Meanwhile taking into account the residual resistance coefficient of various polymers and the corresponding concentration, the injection speed should be selected between 0.250mL/min and 0.30mL/min.

4. One dimensional vertical heterogeneous core flooding experiment

By carring out oil displacement experiments on one-dimensional vertical heterogeneous artificial cores of three layers. The permeability and porosity of the low permeability layer are $300\times10^{-3}\mu m^2$ and 24%, and that is $700\times10^{-3}\mu m^2$and 26% in middle permeability layer, and that is $1100\times10^{-3}\mu m^2$ and 30.5% in high permeability layer respectively the efficiency of high-concentrotion polymer after polymer flooding had been evaluated.

By using 25 million molecular weight polymer, the flooding experiment was carried out by injecting concentration of 2000, 2500 and 3000mg/L under different injection pore volume:

（1）Under the condition of the same amount of polymer, the maximum recovery rate corresponding to the optimum concentration.

（2）On the condition of the same concentration, the recovery increase amplitude of high concentration polymer flooding is larger with the increase of the injection pore volume and the injection concentration

5. Oil displacement experiment of large scale simulation physical model

According to the geological characteristics of the second piece in the north of PuI reservoir, combined with the experimental zone reservoir conditions, physical parameters and the existing well pattern arrangement ,we arrange and refactor the well pattern ,design the large-scale simulation of physical model which is proportional to the vertical heterogeneity and horizontal homogeneous .Five point method is chosen to set up a plane model which has 1 injection well and 4 production wells, the model size is: 4.5cm×60cm×60cm, the permeability of each layer is respectively $300\times10^{-3}\mu m^2$、$700\times10^{-3}\mu m^2$ and $1100\times10^{-3}\mu m^2$. In the plane model, each middle and low permeability layer is separately distributed 8 pairs of electrodes in order to acquire the oil water front data, so there are 128 electrode detection points in total.

5.1 Experiment scheme

The model of water flooding turned into polymer flooding when the water cut reached 92%.After the ordinary polymer flooding, we can carry out high molecular weight high concentration polymer flooding experiment, monitor the injection pressure and the change of water cut, calculate the recovery, and research the difference of frontal advance and the change of sweep coefficient of polymer flooding and high concentration polymer flooding after polymer flooding by using real-time monitoring oil water front technology.

5.2 The change of stage recovery percent and injection pressure

The displacement experimental results of physical modeling show that the degree of reserve recovery of high concentration polymer flooding is closely related to the injection production method. Well network reconfiguration can reduce the residual oil saturation to a greater extent, the high concentration polymer flooding stage recovery dgree is higher than the two productions- two injection methods which has the same concentration, which is 1.43 and 1.49 percentage points respectively.

5.3 Conformance efficiency and migration of oil water front

The conformance efficiency of different schemes and different displacement stages are shown in table 2.

Table2 the results of the determination of the sweep coefficient of different solutions and different displacement stages

Displacement scheme	conformance efficiency					
	Water drive stage		Common polymer flooding		High concentration polymer flooding	
	Low	Middle	Low	Middle	Low	Middle
after Common polymer flooding inject 2000mg/L	0.165	0.334	0.520	0.824	0.768	0.923
after Common polymer flooding inject 2500mg/L	0.184	0.350	0.516	0.840	0.790	0.965
Well pattern reconstruction +2000mg/L	0.170	0.348	0.523	0.832	0.795	0.972
Well pattern reconstruction +2500mg/L	0.162	0.344	0.518	0.825	0.815	0.984

The results show that high concentration polymer flooding, following the ordinary polymer flooding, can increase the sweep coefficient of middle and low permeability layers, and the higher the concentration, the bigger the sweep coefficient.

In the real-time monitoring system of water/oil front,we determine the migration of water/oil front of different layers and points of longitudinal heterogeneous plane model in different polymer flooding and different injection production modes. As shown:

(1) Under the condition of the original well pattern, remaining oil can be informed in diverting stream line of the common polymer flooding and the high concentration polymer flooding. The distribution of remaining oil in the low permeability layer is significantly larger than that in the middle layer.

(2)After the well pattern is reconstructed, the remaining oil located in the distribution line and the vicinity of the original well net oil well in the middle and low permeability layers gets tapped, and the oil displacement efficiency is improved obviously.

6. Summary

(1) For similar permeability cores, with the increase of polymer concentration, the resistance coefficient and residual resistance coefficient of polymer solution increase.

(2) For the same amount of polymer, there is the best concentration that is correspond to maximum recovery percent.

(3）No matter which well pattern, when high concentration polymer solution is injected, it can

significantly improve the recovery percent of polymer flooding. But the recovery percent of the high concentration polymer flooding is still closely related to the injection-production pattern.

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