Experimental Study on Saturation Distribution of Heterogeneous Reservoir

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Abstract—Polymer flooding has a large-scale promotion in Daqing oilfield, this paper prepared two-dimensional heterogeneous model according to the typical reservoir in Daqing oilfield and did the experiments of water flooding and polymer flooding with the method of three tubes parallel, monitored the oil saturation distribution in the process of displacement timely by using the advanced saturation monitoring method. The results show that, the recovery rate was 30.35% in the water flooding stage and improve the degree of recovery to 8.28% in the polymer flooding stage. The mainstream channels in the high permeability layer was formed and occurred the phenomenon of fingering in each layers after water flooding, the remaining oil is mainly distributed in the medium and low permeability layer. The polymer advanced to the high permeability layer and increased the injection pressure and the amount of liquid absorption of the medium and low permeability layer after polymer injection, the distribution of remaining oil mainly in low permeability layer after polymer flooding.

Keywords-saturation distribution; the remaining oil; sweep efficiency; oil saturation monitoring technology; polymer flooding

I. INTRODUCTION

It has made a lot of achievements in the research of theory and technology of polymer flooding at home and abroad especially in the Daqing oilfield, it has formed a relatively complete series matching technology of reservoir, engineering, technology in polymer flooding, achieved three leaps which from laboratory research to the pilot experiment and at last to the industrial field experiments[1-4], but the current block which has entered into or about to enter the subsequent water flooding stage, need to take further measures to improve the flooding effect, enhanced oil recovery and economic benefits, while the key to solve this problem is to study the distribution of residual oil[5-8]. Analysis the displacement situation by the monitoring system of oil saturation to the typical block in Daqing oilfield[9-10]. The distribution of residual oil is particularly important in the process of displacement and to clarify the distribution of the remaining oil is conducive to the follow-up development adjustment [11-12].

II. EXPERIMENTAL DESIGN

The experimental water is the simulated formation water of Daqing oilfield which salinity is 6778mg/L; The experimental oil is the simulation oil and the oil viscosity is 9.8mPa·s when the temperature is 45 degrees; the physical model which are used in the experiment are quartz sand epoxy cemented heterogeneous saturation monitoring cores which specifications are 300 x 300 x 10mm and electrode arranged different permeable layer and permeability of each layer is respectively 200, 1000, $1800\times10^{-3}\mu m^2$; The experimental polymer is ordinary medium molecular weight polymer with the concentration is 1000 mg / L and the viscosity is 42 MPa • s; The experimental temperature are conducted under the condition of 45 ° C; The injection speed: 3 ml/min. The experiment adopts the form parallel and the experimental diagram as shown in figure 1. The experimental scheme is water flooding to the moisture content of 98% + 0.6PV polymer flooding + subsequent water flooding to the moisture content of 98%.

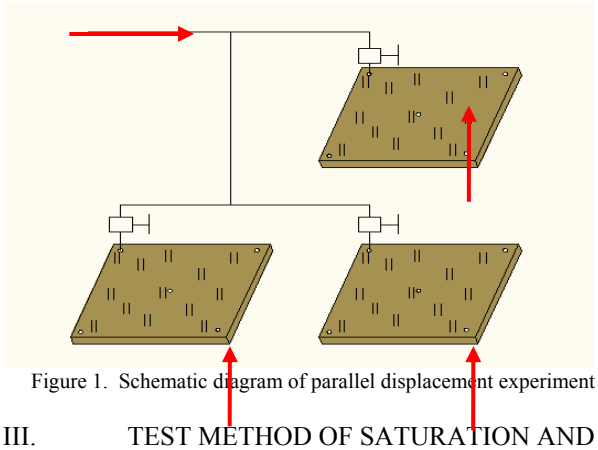


Figure 1. Schematic diagram of parallel displacement experiment

III. TEST METHOD OF SATURATION AND EXPERIMENT RESULTS AND ANALYSIS OF DISPLACEMENT

Saturation monitoring literature shows that the rock electricity experiment is the widest method to monitor oil saturation which the theoretical basis is Archie, the function relation between the resistivity of the two points of the reservoir rock and the moisture content is the core idea and the oil saturation can be determined judged by the resistivity after finds the relations [13-14].

This paper adopts the oil saturation monitoring technology based on the above theory; real-time monitoring to the oil saturation of electrode which lay in the two-dimensional physical model in the process of experiment by the real-time monitoring system, the electrodes which were arranged divided the two-dimensional physical model into different grid. It can grasp the spread situation of the monitoring points through the change of oil saturation. The oil saturation is lower than the initial value monitoring points at the end of a displacement stage which believed that point is affected [15]. It can calculate displacement efficiency data combined with macroeconomic recovery. Statistics and analysis to the displacement stage according to the spread and oil displacement efficiency of the stage in water flooding and polymer flooding, the macroscopic oil displacement effect are shown in table 1, and the oil displacement efficiency are shown in table 2.

A. *The Overall Experimental Results*

TABLE I. RESULTS OF EOR BY WATER FLOODING AND POLYMER FLOODING

	Stage of recovery degree / recovery（%）			
Stage	**Low permeability layer**	**Medium permeability layer**	**High permeability layer**	**The whole**
Water flooding stage	6.02	21.13	56.05	30.35
polymer flooding stage	9.09	14.83	2.07	8.28
The total recovery rate	15.11	35.96	58.12	38.63

It can be seen from the table 1 that the overall recovery was 38.63% when injection 0.6 PV ordinary medium molecular weight polymer after water flooding to moisture content of 98% and the extent of the use of high permeability layer is much higher than that of the medium and low permeability layer.

TABLE II. RESULTS OF SWEEP EFFICIENCY AND OIL DISPLACEMENT EFFICIENCY AT THE END OF WATER FLOODING AND POLYMER FLOODING

Coefficient	**Stage**	**Low permeability layer**	**Middle permeability layer**	**High permeability layer**	**overall**
Swept efficiency（%）	water flooding	13.01	41.00	90.10	48.08
	polymer flooding	37.52	67.02	90.55	65.04
The oil displacement efficiency（%）	water flooding	46.30	51.50	62.20	63.20
	polymer flooding	40.30	53.71	64.20	59.42

It can be seen from the sweep situation (table 2) that the sweep efficiency of high permeability layer in the water flooding stage is as high as 90%, while the sweep efficiency of low permeability layer is not to 15% and the effect of use is very poor; the sweep efficiency of medium and low permeability layer started to rise substantially after injection 0.6PV polymer, so as to improve the overall recovery efficiency of model.

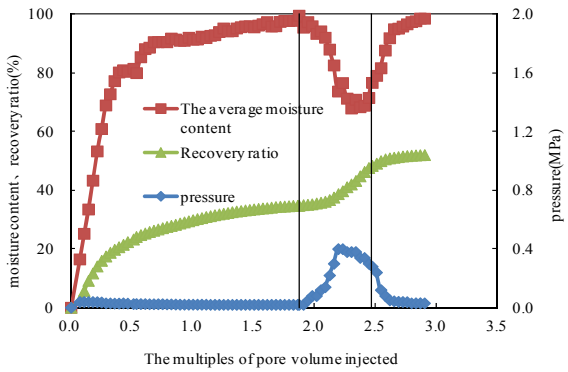


Figure 2 . Relation curve between injections the multiples of pore volume injected, the average moisture content, recovery, and pressure

It can be seen from the Fig .2 that the injection pressure instantly increases at the beginning of displacement, the cores of oil began to decline with the increase of water injection and the overall moisture content gradually increased, at the same time the pressure is gradually reduce with the resistance of core fluid reduce. The pressure dropped steadily when the moisture content of water flooding reach to 98%. The pressure gradually increased and the average moisture content began to decline with the polymer flooding, indicating that polymer flooding began moving the oil film which did not spread

and drag out by water flooding and thus the overall recovery rate is also rising rapidly.

B. The Distribution of Oil Saturation

We can obtain the distribution of oil saturation at different stages of flooding by the real-time monitoring system of oil saturation to real-time monitoring in the process of the displacement.

1) Water flooding stage

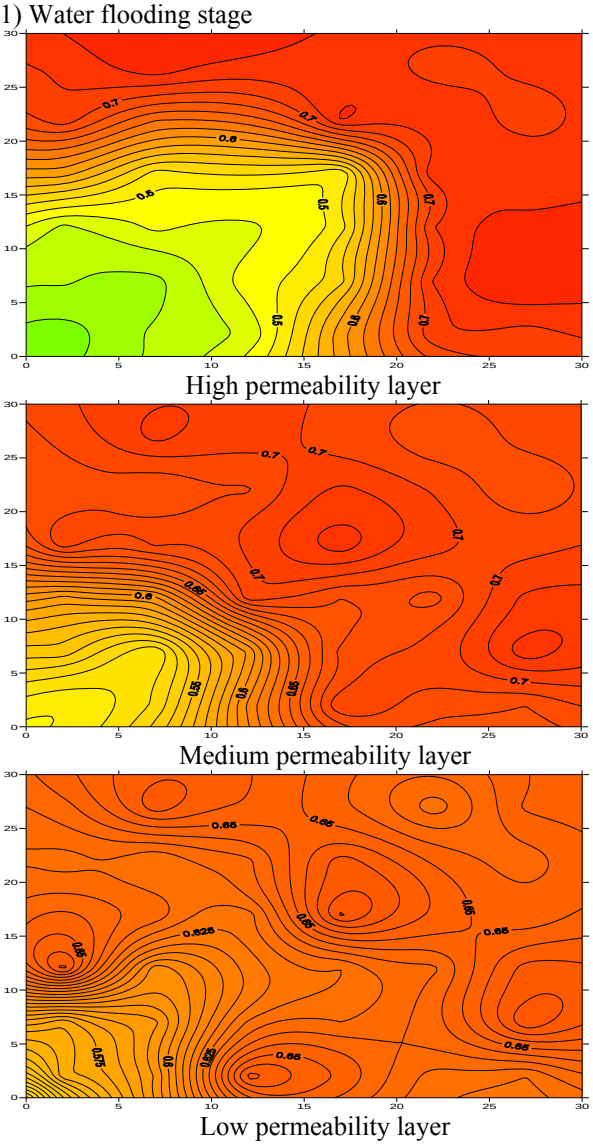
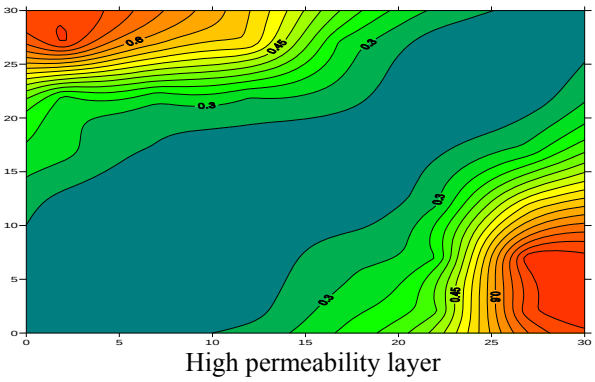


Figure 4 . Distribution of oil saturation of each layer at initial water injection phase



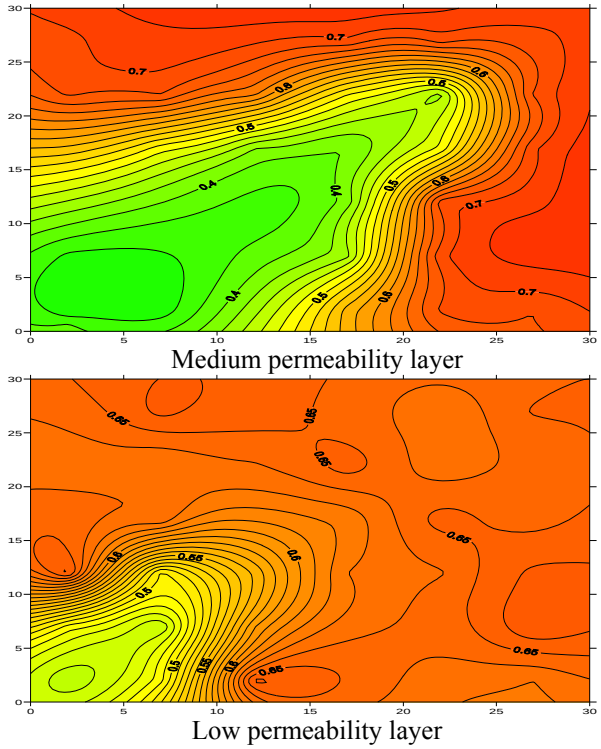
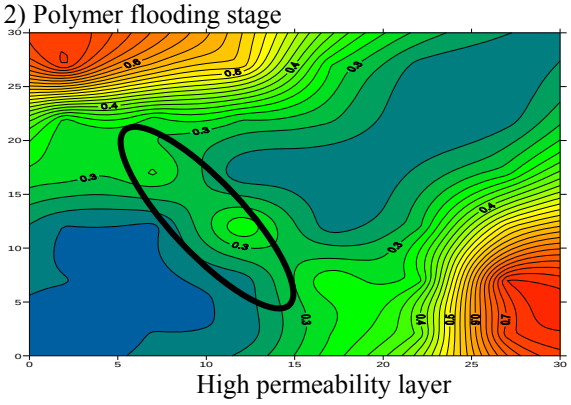
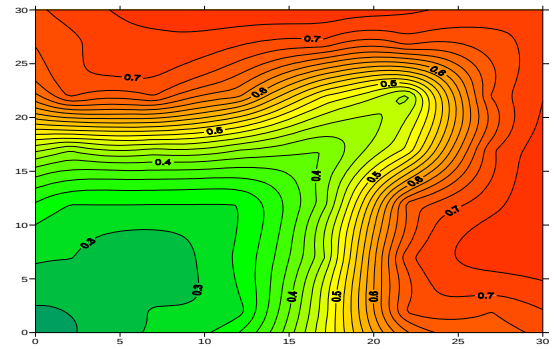


Figure 4 . Distribution of oil saturation of each layer at the end of water injection

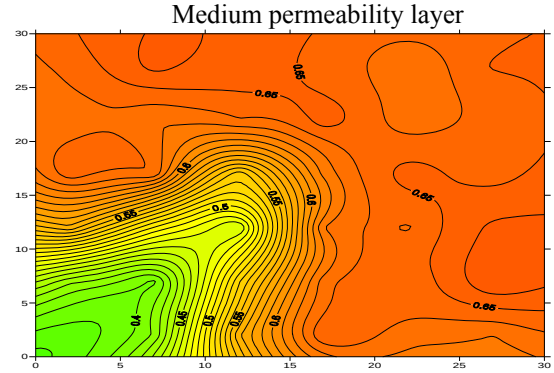
It can be seen from the Fig .3 to Fig .4 that three layers are beginning to be used, the majority of displacing agent into the high permeability layers in the stage of water flooding, each layer appear obvious fingering phenomenon with the increase of water injection, liquid amount of medium and low permeability layer gradually decreases and almost stopped produced liquid after production well see water when the high permeability layer oil-water front breakthrough, while the oil saturation of mainstream channels is relatively low under the influence of injection water flushing repeatedly in the high permeability layers, the distribution of remaining oil mainly in medium and low permeability layer after water flooding.

2) Polymer flooding stage



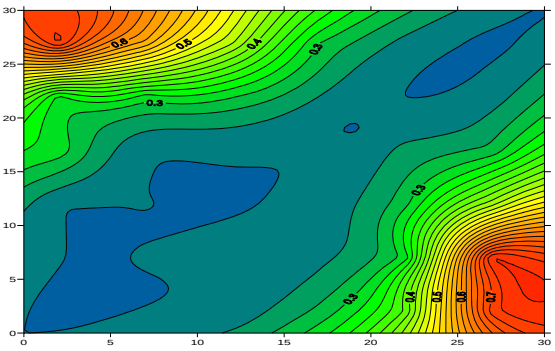


Medium permeability layer

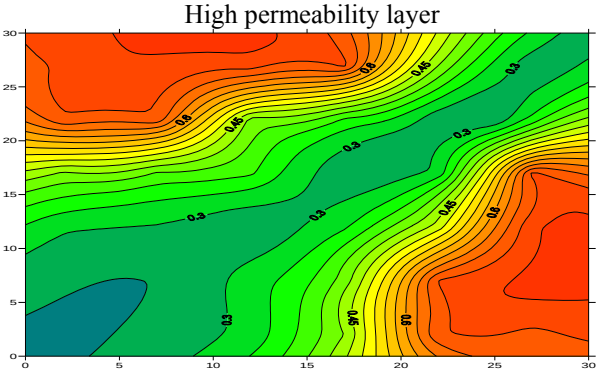


Low permeability layer

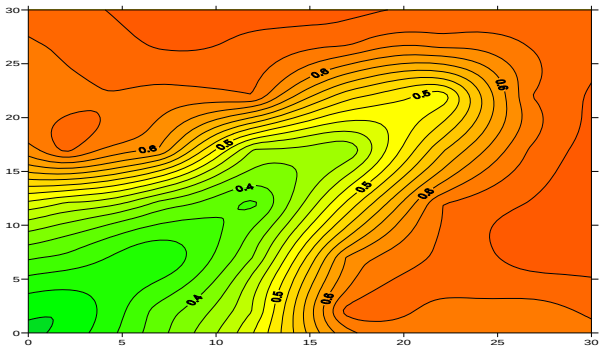
Figure 5. Distribution of oil saturation of each layer at initial polymer injection phase



High permeability layer



Medium permeability layer



Low permeability layer

Figure 6 . Distribution of oil saturation of each layer at the end of polymer injection

It can be seen from the displacement figure of continuous monitoring (Fig .5 to Fig .6) that the polymer advanced to high permeability layer when began to injection polymer, due to the high viscosity of the polymer and it can improve the mobility ratio effectively and increases the flow resistance and the injection pressure, more fluid into the low permeability layer thereby increasing the sweep efficiency of the overall model to further enhance oil recovery of the model, the medium and low permeability layer effectively used and the distribution of remaining oil mainly in low permeability layer after polymer flooding.

IV.CONCLUSIONS

1. The experiments of three tube parallel shows that: it gradually formed the mainstream channels of high permeability layer in the stage of water flooding the distribution of remaining oil mainly in medium and low permeability layer after water flooding.

2. The polymer improve the mobility ratio effectively and increased the injection pressure and the amount of liquid absorption of the medium and low permeability layer effectively used in the stage of polymer flooding, the distribution of remaining oil mainly on the both sides of the main line of the low-permeability layer after polymer flooding.

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