Experimental study on constant pressure of polymer flooding in second-class reservoirs

Hongmei Ji

The Seventh Operation Area of No. 6 Oil Production Plant of Daqing Oilfield Co. Ltd. Heilongjiang Daqing 163000 China

Abstract. At present, the second-class oil layer has become the main polymer flooding replacement layer in the Lamadian Oilfield. The second-class oil layer has low permeability, low connectivity and serious heterogeneity. The results of the polymer flooding laboratory experiments are quite different from the field flooding effect. Polysystem design provides better guidance. Based on theoretical and field data analysis, this paper adopts constant pressure injection method. After the experimental injection fluid is seepage through a 1.5m long core, the core flooding experiment is carried out, that is, the problem of excessive pressure rise in polymer flooding is controlled, so that the injection fluid is closer to the oil layer. state of the injected system. The constant pressure polymer flooding experiment was used to establish the matching relationship between the polymer system and oil layers with different permeability, which effectively guided the design of the on-site polymer injection system. At present, indoor polymer flooding core experiments generally adopt the constant speed mode, without controlling the injection pressure. However, due to the influence of permeability, connectivity and other factors, the injection pressure increases greatly, and the reservoir water absorption is difficult, which leads to a great difference between the experimental results and the field effect. In order to make the indoor core experiment closer to the actual field injection state and better guide the design of polymer flooding scheme, it is urgent to optimize and improve the experimental method.

Keywords: Polymer flooding, constant pressure injection mode, oil displacement experiment

1. Problems Existing in Constant-speed Injection Displacement Method

1.1 The pressure rise of constant velocity polymer flooding is too large

A core with a permeability of about 0.5 μm2 and a length of 0.3 m was selected, and the constant-speed injection method was used to inject 25 million molecular weight clear water to prepare a polymer solution with a concentration of 1500 mg/L and 2000 mg/L, respectively. The experimental results are shown in Table 1:

Table 1 Experimental data of constant velocity polymer flooding

Polymer system	Solution processing	Water drive		Poly flooding		Total recovery ratio (%)
		Pressure (atm)	Recovery ratio (%)	Pressure (atm)	Recovery ratio (%)	
25 million 1500mg/L	Mechanical shear	1.35	40.23	3.75	36.78	77.01
25 million 2000mg/L	Mechanical shear	1.40	39.58	4.23	41.65	80.14

The experimental results show that the injection pressure of polymer flooding is about 3 times that of water flooding, far exceeding the fracture pressure of the oil layer in the field. Due to the ultra-high pressure, the injected fluid is forced to enter the layer with low permeability, transforming the unrecoverable part into the oil layer that can be driven, resulting in a high recovery rate and a large gap with the actual field.

1.2 The displacement fluid does not conform to the actual situation on site

Before the polymer solution is injected into the formation, it will be biodegraded due to the existence of various bacteria in the injection allocation system. During pipeline transportation, chemical degradation will occur due to the existence of oxygen and iron in water. When passing through the pump and gate, it will produce mechanical degradation; Therefore, in the process of injection allocation, the ground viscosity loss of polymer solution reaches 20% ~ 30%. When the polymer solution is injected into the formation, it is affected by the borehole shear, and the viscosity loss is about 15%.

In traditional oil displacement experiments, in order to simulate the above process, the displacement fluid is sheared to make the viscosity loss rate reach 40% to 50%. However, this method ignores the shear effect of the polymer when it seeps in the formation, which is also the main reason for the inconsistency between the laboratory experimental recovery factor and the field.

2. Determine the experimental method of constant pressure oil displacement

When the constant-speed oil displacement method is adopted, the pressure gradient at both ends of the core is much larger than that between injection-production wells of polymer flooding, which leads to a great difference between the indoor core experiment results and the field effect. Aiming at this problem, a constant-pressure oil displacement experiment method is proposed.

2.1 The constant pressure flooding experimental device can effectively control the injection pressure

According to the ideal gas equation of state, PV = NRT, the experimental process meets equations (1) and (2):

$$P1V1=P2V2 \tag{1}$$

$$V2=V1+\Delta V \tag{2}$$

Where: P1-initial pressure, MPa; ; V1-initial gas volume, ml; P2-pressure during the experiment, MPa; ; V2-gas volume during the experiment, ml; ΔV— the volume change of gas in the liquid storage tank during the experiment, that is, the volume mL of displacement fluid used in the core displacement experiment.

To ensure that the pressure remains unchanged after the experiment starts, it is necessary to ensure that ΔV is negligible. Therefore, V1 is infinitely enlarged to make it much larger than ΔV (the maximum value of ΔV during the core experiment is generally 150mL).

During the experiment, the volume of the liquid storage tank used is 500ml, and 300ml of displacement liquid is prepared, that is, the volume of gas in the liquid storage tank is 200ml, and the volume of displacement liquid used in the core displacement experiment is 150ml. When three 40L gas buffer tanks are added in front of the liquid storage tank,

$$V1=120L+200mL=120.2L \tag{3}$$

$$V2=V1+\Delta V=120.2L+150mL=120.35L \tag{4}$$

$$V1/V2=120.2/120.35=0.999 \tag{5}$$

That is, the gas volume change can be neglected, that is, the pressure is constant. Therefore, we have designed a constant pressure oil displacement experimental device which consists of six parts: gas pressure stabilizing source, liquid storage tank, pressure detection device, core displacement device, produced fluid collection device and data automatic monitoring and recording device.

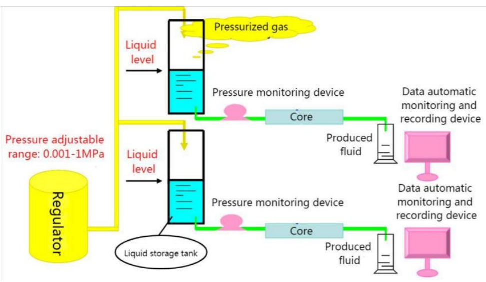

Fig. 1 Constant pressure experimental device

The method realizes the controllable injection pressure during the core flooding process. This set of equipment can not only carry out a group of core displacement experiments alone, but also can connect several groups of cores in parallel to carry out multiple groups of core experiments at the same time. requirements, which can greatly improve work efficiency. The experimental system meets the design requirements, can work stably for a long time, and meets the needs of the core constant pressure injection experiment.

2.2 Determination of pressure gradient in constant pressure oil displacement experiment

Based on the pressure test data of injection-production wells (Figure 2), the injection-production pressure difference of different oil layers is calculated, and the average pressure gradient between wells is 0.1 ~ 0.15 MPa/m.

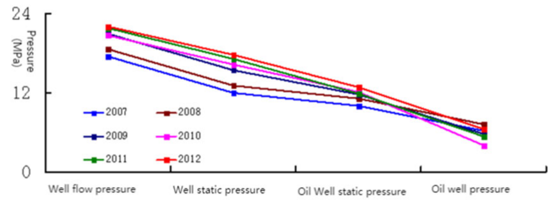

Fig. 2 Injection-production pressure difference curve of a polymer injection block

From the influence curve of advancing distance on pressure drop (Fig. 3), it can be seen that the pressure gradient in the near well zone of the injection well is large and the pressure gradient in the far well zone is small. In order to meet the experimental requirements of different schemes, the indoor constant pressure injection experimental pressure gradient is finally determined to be 0.01 ~ 0.15mpa/m.

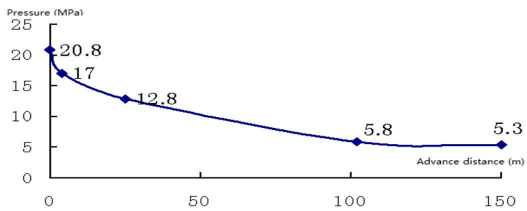

Fig. 3 The influence curve of the propulsion distance on the pressure drop in the simulation experiment

2.3 After the displacement fluid percolates through the core for 1.5m, the system performance conforms to the field practice

The polymer solution will be subjected to shear action in the process of reservoir seepage, but the magnitude of this action is not consistent. Because the pores of oil layer are selective and destructive to the size of polymer molecules, near the injection end of oil layer, the pores will firstly shear and degrade the macromolecule polymer in solution, so that it can meet the needs of pore radius. At this time, a large pressure gradient is formed near the injection end, and the fluid will lose a large driving energy. The polymer molecules entering the deep part of the oil layer gradually adapt to the pores of the oil layer, the molecular weight distribution is more uniform, and the properties gradually tend to be stable.

In order to study the change law of the system performance during the seepage of the polymer solution in the oil layer, 6 cores with a permeability of about 0.5μm2 and a length of 0.3m were connected in series, that is, the cores with a total length of 1.8m were injected to simulate the difference between the mechanical and blasthole shearing. The system polymer solution, the pressure, viscosity, molecular weight and viscoelasticity of the polymer solution after passing through each core were measured.

2.3.1 The viscosity of polymer solution tends to be stable after 1.5m seepage in the reservoir

In a series of cores with a total length of 1.8m, polymer solutions with molecular weights of 25 million, 2000mg/L, 19 million and 2200mg/L are injected respectively. Record the change of viscosity of polymer solution with advancing distance. It can be seen from Figure 4 that with the increase of advancing distance, the viscosity loss rate gradually decreases, and when advancing to 1.5m, the viscosity gradually tends to be stable.

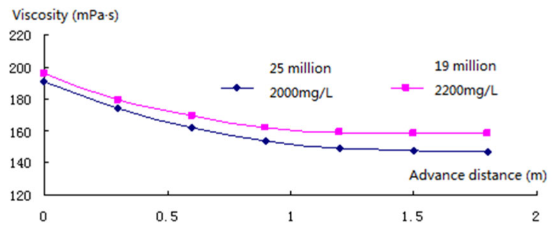

Fig.4 Variation of polymer solution viscosity with advancing distance

2.3.2 The molecular weight of polymer solution with different molecular weight tends to approach gradually after percolation of 1.5m in the reservoir

25 million 1,500 mg/L, 19 million 1,800 mg/L and 12 million 2,000 mg/L polymer solutions were prepared, and their viscosities were all around 200 MPa s. After 1.5 m series core seepage, the molecular weights were reduced to 9.11 million, 7.73 million and 6.25 million respectively. The molecular weight degradation rates were 63.6%, 59.3% and 47.9%, respectively.

Prepare 25 million 2000 mg/L and 19 million 2200 mg/L polymer solutions, the viscosity is about 300 mPa s, after 1.5 m of series core seepage, the molecular weight is reduced to 10.62 million and 9 million respectively; the molecular weight degradation rates are 57.5% and 52.6%. The experimental results show that the molecular weight of different molecular weight polymer systems with similar viscosity tends to be close after 1.5m core seepage.

2.3.3 The elastic change of polymer solution tends to be stable after 1.5m seepage in oil layer.

In the range of shear rate from 0.1s to 500s-1, the first method phase stress difference curves of the polymer solution after seepage in cores with different lengths were measured, and the elastic change of the polymer system was investigated. The experimental results show that the elastic change tends to be stable after the seepage of the polymer solution through the 1.5m core at low shear rate.

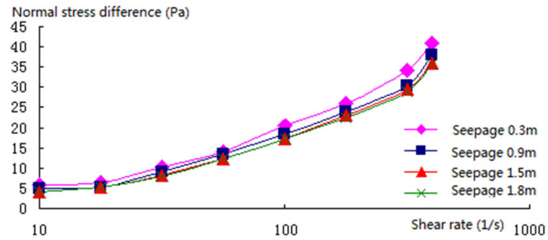

Fig. 5 Variation of first normal stress of polymer with advancing distance

To sum up, after 1.5m core seepage, the viscosity and elasticity of polymer solution tend to be stable, and the molecular weight tends to be close to each other. Therefore, on the basis of simulating mechanical and borehole shear, the polymer solution can be infiltrated into the core for 1.5m, which can meet the actual situation on site and be used as core injection fluid.

3. Application effect of polymer constant pressure flooding experiment

Using the constant pressure polymer flooding method, the effects of polymer molecular weight, concentration and different water quality on the seepage ability of polymer system are deeply studied, and the matching relationship chart between polymer system and reservoirs with different permeability is drawn, so as to provide basis for on-site polymer flooding scheme design.

3.1 Study the matching relationship between polymer system and oil layers with different permeability.

By carrying out constant pressure experiments, the effects of polymer molecular weight, concentration and different water quality on the seepage capacity of the polymer system were studied in depth, the matching relationship between the polymer system and the oil layers with different permeability was improved, and the design of the polymer flooding injection system was effectively guided.

Through the research on the seepage ability of polymer system under reservoir conditions, find out the polymer system that meets the field injection production pressure difference, can be injected in low permeability reservoir, and has certain seepage resistance in high permeability reservoir, give full play to the ability of polymer system to expand wave and volume in reservoir, so as to determine a reasonable polymer flooding system.

Using the method of constant pressure experiment, through the experiments of 8 permeability reservoirs, 26 polymer systems and more than 500 constant pressure cores, the driving pressure difference of polymer solution in different reservoirs was determined, and the field pressure gradient and the matching relationship between polymer solution and different reservoirs were established.

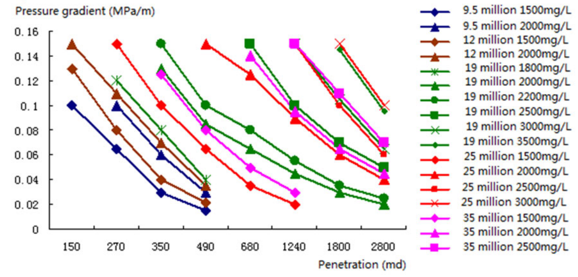

Fig. 6 Matching relationship between clear water polymer system and oil layer permeability

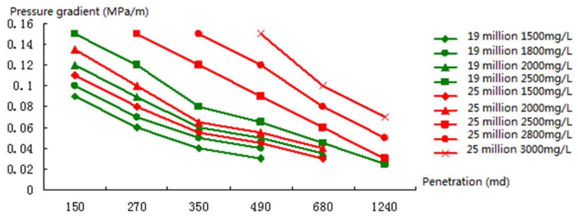

Fig. 7 matching relationship between sewage polymer system and reservoir permeability

According to this chart, it has been applied in ten polymer injection blocks in Lamadian Oilfield, and different injection concentrations of 800 ~ 2500 mg/L have been designed in combination with the development of oil layers. After optimization, the injection pressure tends to be balanced and the production degree of oil layer is further improved.

3.2 The effect of the polymer constant pressure flooding experiment is close to the field reality

Prepare 12 million 1000mg / L polymer solution with clean water, measure its initial viscosity, and conduct mechanical shear and core shear on the solution. The viscosity is 51.2mpa · s, 36.3mpa · s and 27.5mpa · s respectively. At permeability of 0.5 μ About m2, 0.3m long man-made class II heterogeneous rock core was injected with constant speed and constant pressure. The experimental results are shown in Table 2:

Table 2 Comparison of data between polymer constant pressure oil displacement experiment and constant speed oil displacement experiment

Injection scheme	Solution processing	Viscosity (mPa·s)	Water drive		Poly flooding		Total recovery (%)
			Pressure (atm)	Recovery ratio (%)	Pressure (atm)	Recovery ratio (%)	
Constant speed 12 million 1000 mg/L	mechanical shear	36.3	1.45	41.08	2.98	23.65	64.73
	Mechanical shear + core seepage	27.5	1.25	39.80	2.65	18.74	58.54
Constant pressure 12 million 1000 mg/L	Mechanical shear + core seepage	27.5	1.20	42.48	1.68	12.25	54.73

The experimental results show that under the same injection mode, after the solution passes through the core seepage, the recovery factor of polymer flooding is reduced from 23.65% to 18.74%; Under the condition of the same solution treatment method, the constant pressure oil displacement method can effectively control the pressure and reduce the polymer flooding recovery from 18.74% to 12.25%, which is closer to the field reality.

4. Application effect

Based on the experimental research results, combined with the development of sand bodies in the second-class oil layers of Lamadian Oilfield, the injection system parameters of ten blocks were individually designed. Eight injection concentrations of 25 million molecular weight and designed 800-2500 mg/L were used. After injection, the proportion of the oil layer produced thickness reached 87.3%, which was 15.1 percentage points higher than that before polymer injection. , the effect of increasing oil and precipitation is significant.

5. What do you know

(1) Using constant pressure oil displacement experiment method to carry out polymer flooding experiment can better control the injection pressure, match the actual pressure difference in the field, and improve the polymer flooding recovery ratio closer to the field reality.

(2) After the solution used in the oil displacement experiment is subjected to shearing and seepage treatment, the injected liquid can be close to the internal conditions

of the oil layer, and the experimental conditions are closer to the field reality;
(3) Through the constant pressure experiment, the matching relationship template between reservoirs with different permeability and polymer system is established, and the oil displacement system is optimized according to the chart, which can effectively improve the reservoir utilization rate;
(4) The proportion of the production thickness of the field applied oil layer increased by 15.1 percentage points, the water cut decreased by 11.9 percentage points, and the recovery factor was improved by 14.85 percentage points. The effect of increasing oil and precipitation was remarkable.

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