

Comparative experiment analysis of functional polymers flooding after polymer flooding

In view of a certain block of First Production Plant in Daqing Oilfield, this paper conducted physical simulation experiments of three hydrophobic associated polymers flooding which is in two conditions that equal concentration and equal viscosity after polymer flooding. As a result, injecting equals the multiples of pore volume under equal concentration. Enhanced recovery effect range: 20.73% of Huading I hydrophobic associated polymer flooding is the largest; 12.22% of Haibo BI hydrophobic associated polymer flooding is the most un-conspicuous. Injected equal the multiples of pore volume under equal viscosity. Enhanced recovery effect range : 20.73% of Huading I hydrophobic associated polymer flooding is the largest; 14.48% of Haibo BI hydrophobic associated polymer flooding is still the most un-conspicuous. Combined with the indoor experimental result, it can be seen that the poly table agent of Huading I is the best of the three kinds in driving the residual oil after polymer flooding, and its effect is the most obvious.

Key words: *Physical simulation experiments, hydrophobic associated polymers, equal concentration, equal viscosity, enhanced recovery effects.*

1. Introduction

Recently, main blocks of most oilfields in China have begun to enter into development phase with high water cut stage or extra high water cut stage in an all-round way[1], the reservoir still have a large number of disposable remaining oil[2], it is research direction how enhanced recovery effects and its degree of reserve recovery[3]. The polymer is the main material of the three oil recovery. There are many ways to synthesize polymers. Such as solvent-switch techniques have been widely used for preparing polymer vesicles as most amphiphilic block copolymers are not directly soluble in water [4-6]. At home

and abroad many scholars study this direction.

In the context, polymer flooding is the most commonly applied chemical enhanced-oil-recovery technique [7]. the hydrophobic associated polymers, light molecular weight and reversible assemble, regarded as a new oil displacement agent. It possesses high viscosity, anti-mechanical shearing, anti-biodegradation, anti-oxidative degradation, the salt resistant and temperature resistant. It not only applies to various low permeability reservoir, but also applies to reservoir under various degree of mineralization conditions and injected allocating sewage directly. Hydrophobic associated polymer flooding is more economical and environment of a high-efficiency one element of chemical flooding which possess a better developable future. Hydrophobic associated polymer has dual nature which has ability of mobility control and emulsify reinforced dissolution oil. Increasing flooding solution viscosity with polymers provides a favourable mobility ratio, compared to brine flooding, and hence improved volumetric sweep efficiency [8]. It can expand sweep area as well as enhance displacement efficiency which is a new technology of enhanced oil recovery after polymer flooding. A part of oil field has begun to make proactive experiment about some hydrophobic associated polymers, and the result obtain very conspicuous effect of reduced water yield and increased oil yield, but it is imbalance development about field experiment and knowledge of theory [9]. Even with current floods, a broad range of polymer viscosities are injected, with substantial variations from a base-case design procedure [10]. Reported and literature is relative few about hydrophobic associated polymers specially about optimize the best one among diverse hydrophobic associated polymers in a certain block of oil field, that severely restricted development and application of hydrophobic associated polymers in oil field development.

Therefore, aimed at the current conditions of reservoir and the present situations of mining in a certain block of First Production Plant in Daqing Oilfield, based on the similar condition, the development of physical modal, simulating driving process of chemical flooding, three different kinds of hydrophobic associated polymers under equal concentration

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and equal viscosity conditions, and the contrast tests on the physical simulation experiments have been carried on after polymer flooding. Combining with the contrast of economic property, the effect of enhancing the recovery efficiency of three different kinds of hydrophobic associated polymers flooding after polymer flooding was studied.

2. The experiment design

2.1 THE PHYSICAL MODEL

In this paper, the physical model is cemented epoxy resin quartz artificial homogeneous core gas permeability is $1500 \times 10^{-3} \mu\text{m}^2$, the size of model: L=30cm, W=4.5cm, H=4.5cm. Designing the physical model meet the principles of dynamic similarity and motion similarity in the displacement experiments.

2.2 THE EXPERIMENT MATERIALS

In this experiment, the simulation oil is mixed with kerosene oil according to certain proportion, and the viscosity is 9.8 mPa·s under condition of 45°C; The hydrophobic associated polymers used in this experiment is Huading I, Huading II and Haibo BI. The price of three hydrophobic associated polymers is 15000yuan/t.

2.3 THE EXPERIMENTAL PROGRAMMES

In this paper, the equal concentration and equal viscosity experiments both contain three comparison tasks. The equal concentration experiments mainly include by injecting the

same dosage and concentration of three hydrophobic associated polymers after the basic polymer flooding experiment scheme (Medium molecular weight polymer flooding to 0.6PV); The equal viscosity experiment mainly include by injecting the same dosage and viscosity of three hydrophobic associated polymers after the basic polymer flooding experiment scheme (Medium molecular weight polymer flooding to 0.6PV).

3. The experiment results analysis

3.1 THE RESULT OF EQUAL CONCENTRATION EXPERIMENTS

Table 3 shows that porosity of homogeneous core is 25.68%~26.50%, range of oil saturation is 67.08%~70.44%. These basic data shows that the comparability of man-made core is nice, it is appropriate that man-made cores are used in the equal concentration comparison experiments of three hydrophobic associated polymers.

In the experiments of equal concentration, 68.9 mPaos, 61 mPaos, 56 mPa·s is viscosity of three hydrophobic associated polymers, Huading I, Huading II, Haibo BI, respectively. Table 3 shows that recovery degree of Huading I flooding is 20.73%, accounting for 27.31% of ultimate recovery efficiency; recovery degree of Huading II flooding is 14.19%, accounting for 20.3% of ultimate recovery efficiency; recovery degree of Haibo BI flooding is 12.22%, accounting for 17.83% of ultimate recovery efficiency. These data shows: Recovery degree of Huading I flooding after polymer flooding is not only the

TABLE 1: THE CONTENT OF EQUAL CONCENTRATION EXPERIMENTAL PROGRAMMES

Programme	Water flooding	Polymer flooding	Water flooding	Slug of hydrophobic associated polymers	Follow-up water flooding
1	More than 98% of water content	Common medium molecular weight polymer (1000mg/L 0.6PV)	More than 98% of water content	0.15PV protective slug (Huading I, high concentration:1500mg/L)+0.9PV Huading I flooding (1000mg/L, viscosity:68.9 mPa·s)	More than 98% of water content
2				0.15PV protective slug (Huading II high concentration:1500mg/L)+0.9PV Huading II flooding (1000mg/L, viscosity:61 mPa·s)	
3				0.15PV protective slug (Haibo BI high concentration:1500mg/L)+0.9PV Haibo BI flooding (1000mg/L, viscosity:56 mPa·s)	

TABLE 2: THE CONTENT OF EQUAL VISCOSITY EXPERIMENTAL PROGRAMMES

Programme	Water flooding	Polymer flooding	Water flooding	Slug of hydrophobic associated polymers	Follow-up water flooding
1	More than 98% of water content	Common medium molecular weight polymer (1000mg/L 0.6PV)	More than 98% of water content	0.15PV protective slug (Huading I, high concentration:1500mg/L)+0.9PV Huading I flooding (1000mg/L, viscosity:68.9 mPa·s)	More than 98% of water content
2				0.15PV protective slug (Huading II high concentration:1500mg/L)+0.9PV Huading II flooding (1100mg/L, viscosity:68.9 mPa·s)	
3				0.15PV protective slug (Haibo BI high concentration:1500mg/L)+0.9PV Haibo BI flooding (1180mg/L, viscosity:68.9 mPa·s)	

TABLE 3: THE CONTRATIVE RESULT OF EQUAL CONCENTRATION EXPERIMENT ($1000 \times 10^{-3} \mu\text{m}^2$)

Programme	Permeability measured with gas ($\times 10^{-3} \mu\text{m}^2$)	Oil saturation (%)	Porosity (%)	Recovery degree of water flooding (%)	Recovery degree of polymer flooding (%)	Recovery degree of hydrophobic associated polymer flooding (%)	Total recovery efficiency (%)
1: injected 0.9PV Huading I hydrophobic associated polymer (1000mg/L, viscosity: 68.9mPa·s)	1554	67.08	26.50	33.70	21.49	20.73	75.92
2: injected 0.9PV Huading II hydrophobic associated polymer (1000mg/L, viscosity: 61mPa·s)	1509	70.44	26.17	34.73	20.97	14.19	69.89
3: injected 0.9PV Haibo BI hydrophobic associated polymer (1000mg/L, viscosity: 56 mPa·s)	1487	69.23	25.68	35.19	21.11	12.22	68.52

TABLE 4: THE CONTRASTIVE RESULT OF EQUAL VISCOSITY EXPERIMENT ($1000 \times 10^{-3} \mu\text{m}^2$)

Program	Permeability measured with gas ($\times 10^{-3} \mu\text{m}^2$)	Oil saturation (%)	Porosity (%)	Recovery degree of water flooding (%)	Recovery degree of polymer flooding (%)	Recovery degree of hydrophobic associated polymer flooding (%)	Total recovery efficiency (%)
1: injected 0.9PV Huading I hydrophobic associated polymer (1000mg/L, viscosity: 68.9 mPa·s)	1554	67.08	26.50	33.70	21.49	20.73	75.92
2: injected 0.9PV Huading II hydrophobic associated polymer (1100mg/L, viscosity: 68.9 mPa·s)	1543	69.13	26.67	30.36	25.98	17.68	74.02
3: injected 0.9PV Haibo BI hydrophobic associated polymer (1180mg/L, viscosity: 68.9 mPa·s)	1553	70.81	26.50	33.42	24.47	14.48	72.37

biggest of the three kinds of hydrophobic associated polymers, and the contribution for total recovery efficiency is the largest. Because of the viscosity of Huading I hydrophobic associated polymer is the biggest among the all under condition of equal concentration. The ability of adjusting entry profile and reducing water/oil mobility contrast of Huading I is better than that of Huading II and Haibo BI, leading to ability of expand sweep area of Huading I is better than the other two hydrophobic associated polymers. So, the range of enhance recovery efficiency of Huading I is obvious bigger than the scope of that of the other two hydrophobic associated polymers.

The following is oil displacement experimental curve of three kinds of hydrophobic associated polymers.

Injection end pressure, withdrawal water and oil of production end are both changing as water/oil front goes forward during the experiment. The relation diagram of the multiples of pore volume injected, comprehensive water cut, shunt efficiency, and pressure as follow Figs.1 to 3. The three figures illustrate and show, the water content gradually rises up when actuating pressure, the pressure does not gradually

decline until main stream line is formed; Recovery efficiency shows escalating trend after polymer flooding, the water content shows obvious downswing as effect of polymer flooding. At the same time, injected polymer makes viscosity of water increasing, and leading to phenomenon that adsorb and jam of rock interior porosity, for the foregoing reasons, resulting in the pressure rise up. During follow-up water flooding, the recovery efficiency has enhanced because residual polymer plays an important role in flooding; When hydrophobic associated polymer flooding, it protects slug of high concentration displaced firstly, in case of main slug is diluted by the formation solution during the follow-up flooding, and having an effect of piston propulsion, and advantaging to main slug easy to impel to reservoir. As can be seen from Figs.1 to 3, water content of Huading I shows the most obvious downswing, the Huading II is second, Haibo BI is the worst. To sum up, Huading I than other two hydrophobic associated polymers possess operate quickly and obvious effect of enhance displacement characteristics.

3.2 THE RESULT OF EQUAL VISCOSITY EXPERIMENTS

Table 4 shows that porosity of homogeneous core is

26.50%~26.67%, range of oil saturation is 67.08%~70.81%. These basic data show that the comparability and repeatability of man-made core is nice, it is appropriate that man-made cores are used in the equal viscosity comparison experiments of three hydrophobic associated polymers.

As shown in Table 4, comparing the equal viscosity comparison experiments of three hydrophobic associated polymers, the total recovery efficiency of programme 1 is 75.92%, and it is the largest. And recovery degree of hydrophobic associated polymer flooding is 20.73%, accounting for 27.31% of total recovery efficiency. In programme 2, recovery degree of Huading II flooding is 17.68%, accounting for 23.9% of ultimate recovery efficiency. In the programme 3, the total recovery efficiency of whole flooding is 72.37%, and recovery degree of Haibo BI hydrophobic associated polymer flooding is 14.48%, accounting for 20% of total recovery efficiency. Although, the total recovery efficiency of three series of experiments is litter difference, but it is much different about the three hydrophobic associated polymers' recovery degree account for ultimate recovery efficiency. In conclusion, Huading I contribute the most to the achievement of enhance recovery efficiency, Huading II is second, Haibo BI have the worst effect in all.

The following is oil displacement experimental curve of three kinds of hydrophobic associated polymers.

Figs.4 to 6 each shows the relation diagram of the multiples of pore volume injected, water content, enhance recovery range of chemistry flooding and pressure during experiment process of three kinds of hydrophobic associated polymers flooding. As seen in figures, the shape of the curve amplitude of preliminary water flooding, polymer flooding and follow-up water flooding are basically identical during process of total experiment. But curve of water cut shows increase then decrease trend, because of changing

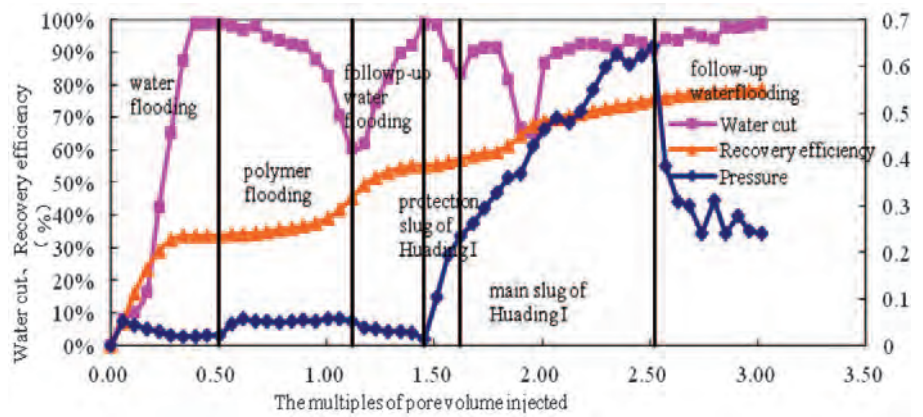


Fig.1 The Relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Huading I

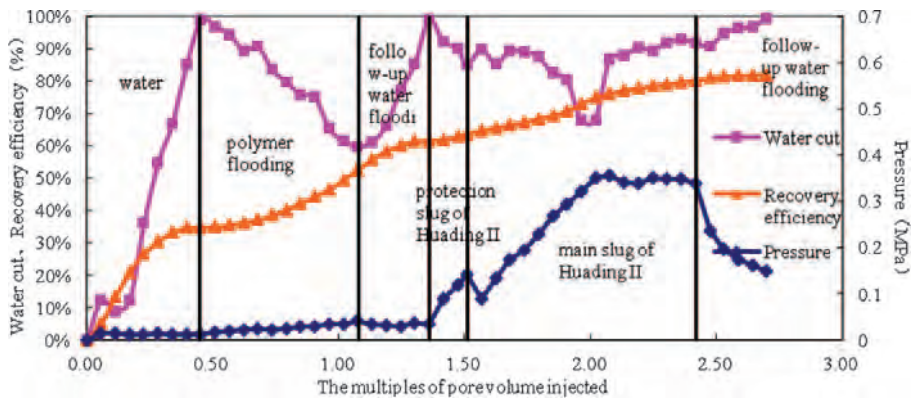


Fig.2 The relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Huading II

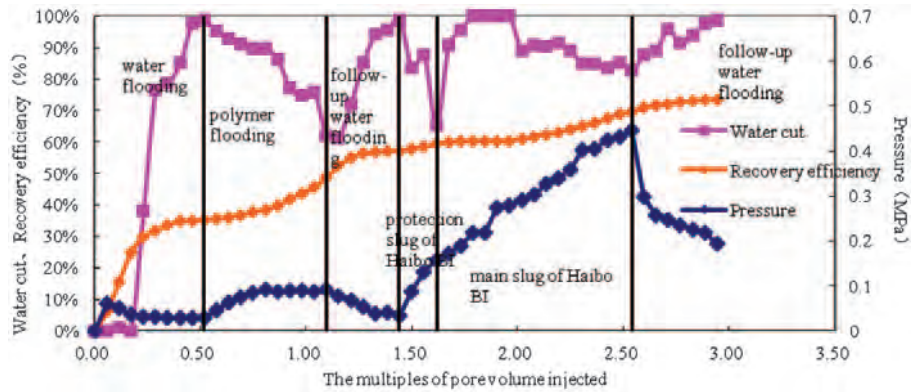


Fig.3 The Relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Haibo BI

chemistry reagent lead to a phenomenon of response lag. After injected main slug of hydrophobic associated polymers, water cut of Huading I shows fall firstly than other two hydrophobic associated polymers tests, it illustrates that Huading I response quickly for enhance recovery effect. Comparing with three kinds of hydrophobic associated polymers flooding, water cut of the three hydrophobic

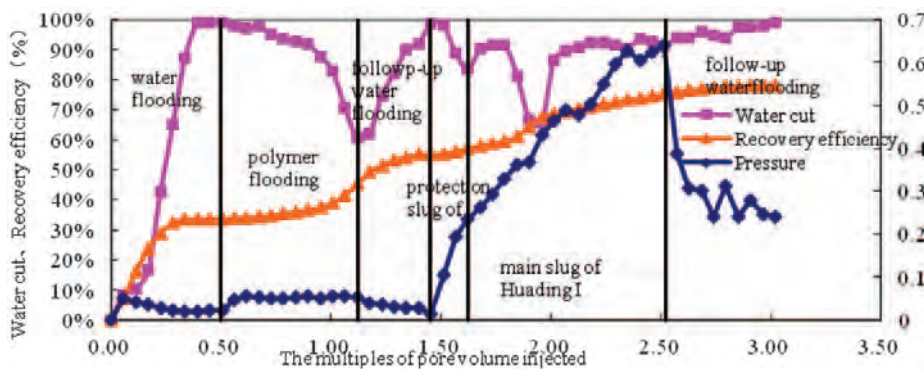


Fig.4 The relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Huading I

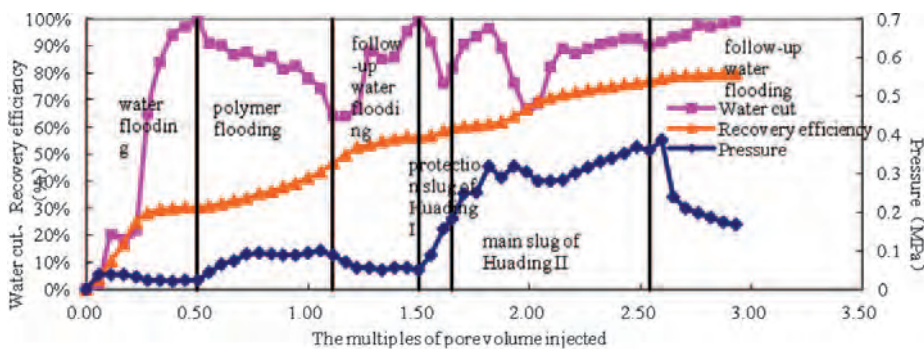


Fig.5 The relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Huading II

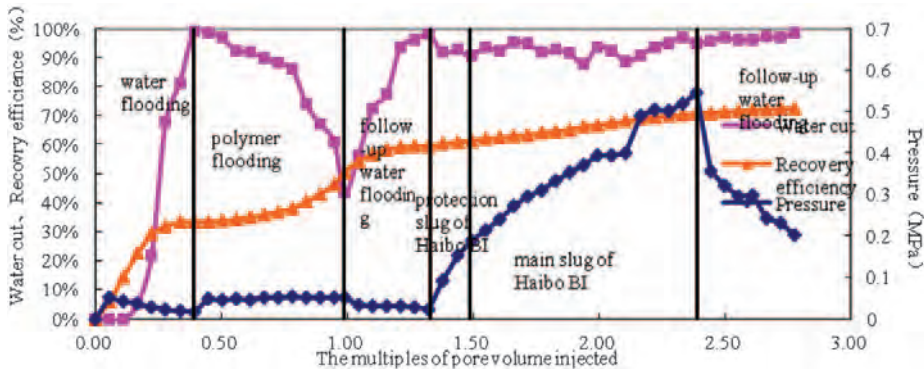


Fig.6 The relation diagram of the multiples of pore volume injected, comprehensive water cut, recovery efficiency and pressure of Haibo BI

associated polymers flooding decrease obviously, especially Huading I hydrophobic associated polymer. And in the stage of low water cut of Huading I flooding has a very obvious sustained duration, meanwhile recovery of stage of Huading I flooding rise is the most obvious in the all, but its pressure rise also is the fastest in the stage of three kinds of hydrophobic associated polymers flooding, this is due to Huading I produces large viscosity resistance, so the flooding need to start-up pressure is bigger. In the stage of Huading II flooding, the water cut emerges declining trend, but no sustained duration. The water cut just shows a change

of the slow fluctuation in the stage of the Haibo BI flooding. Therefore, comparing with displacement characteristics of three kinds of hydrophobic associated polymers flooding, the Huading I is the best, Haibo BI is the worst.

Comparing with displacement experimental data of three kinds of hydrophobic associated polymers flooding, the concentration of Huading I is the lowest, but its displacement characteristics is the best under equal viscosity condition. That is because Huading I has great inner molecular structure compared to other two hydrophobic associated polymers, leading to displacement characteristics of Huading I is very obvious. Comparing Fig.2 and Fig.4, Fig.3 and Fig.5, it is found that the concentration is larger, the viscosity is larger at the same time and its displacement effect is better, thereby explained viscosity is main factor influencing the hydrophobic associated polymers displacement characteristics, recovery of Huading II whose concentration is 1100mg/L increase by 3.49% than that of whose concentration is 1000mg/L, recovery of Haibo BI whose concentration is 1180mg/L increase by 2.26% than that of whose concentration is 1000mg/L. So concentration and viscosity are both main factors influencing the enhance recovery of hydrophobic associated polymers, and concentration is linked to clocking in viscosity.

Besides, three kinds of hydrophobic associated polymers' market price are almost the same, comparing with the contrast experiments of equal concentration and equal viscosity, the comprehensive analysis reveals that Huading I have preferable displacement characteristics and applied to the field practice.

4. Conclusions

- (1) Under different concentration of hydrophobic associated polymers conditions, the concentration larger, the viscosity is larger and the range of recovery efficiency improvement is larger.

- (2) In physical simulation experiments of equal concentration and equal viscosity, low water cut stage in Huading I flooding is earlier than other two hydrophobic associated polymers flooding and keep a long time.
- (3) In same level of core permeability, three kinds of hydrophobic associated polymer flooding after polymer flooding each can enhance oil recovery. In this paper, three kinds of hydrophobic associated polymer to improve range of enhance ultimate recovery, Huading I is the largest, and Haibo BI is the least obvious.
- (4) In physical simulation experiments of equal concentration and equal viscosity, in this paper, three kinds of hydrophobic associated polymer, degree of reserve recovery of Huading I slug is 20.73%, but degree of reserve recovery of other two hydrophobic associated polymers are far less than 20%, even degree of reserve recovery of Haibo I flooding is only 12.22% in the physical simulation experiments of equal concentration. In aspect of stage oil recovery degree contribution value to the ultimate recovery of poly table agent's flooding, Huading I type table agent is still far stronger than the other two kinds. In the contrast experiments, the maximum contribution value of Huading I type table agent is 27.3%, and the maximum contribution value of the rest four groups is only 23.9%, which is nearly 4% less than Huading I type table agent's contribution value. Combining with the contrast of economic property, Huading I hydrophobic associated polymer flooding is preferred displacement way in a certain block of First Production Plant in Daqing Oilfield.

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