Experimental Study of Oil Displacement by the Bio-enzyme at the Third Type Reservoirs of Sabei Blocks

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Abstract—**Sabei blocks are currently in the development stage with ultra-high water-cut. The remaining oil distributes scatteredly and quite a part scattered in the third type reservoirs where exists some problems such as poor producing capacity and water injection capacity, low productivity, fast rising rate of water-cut, and so on. The Bio-enzyme is a kind of chemical agent produced by microbial technology. It has the high capability of releasing hydrocarbon from the surface of reservoir rock particles, and can change the wettability of reservoir rocks and reduce the interfacial tension, thereby to reduce the flow resistance of oil in the reservoir pores and release the crude oil from the surface of the rock particles. The lab experiments in cores by bio-enzyme solution show that this agent can increase the recovery rate by 5.0% and reduce the injection pressure by 40%. The field test results showed that the bio-enzyme can improve the physical properties of underground oil, decrease the injection pressure of water wells, increase the injection volume, improve the injection profile and establish a good injection-production drive system. The oil well production increased significantly and the composite declining rate slows down at the same time.**

Keywords-bio-enzyme; wettability; interfacial tension; recovery

I. INTRODUCTION

Sabei blocks are currently in the development stage with ultra-high water-cut. The remaining oil distributes quite scatteredly after long-term development by water flooding. A large scale distributes in the third type reservoir blocks, so it is necessary to explore this part of latent capacity by the tertiary well pattern thickening. However, the tertiary infilling wells which were perforated at the low permeable layers like the thin, poor oil layers or the noncommercial layers showed poor reservoir producing capacity, poor water injection capacity, low productivity, fast water rising rate and so on. The effect of conventional measures is not ideal for such wells. Now it is a technique cruxes that the Sabei development blocks face to improve the effect of the tertiary infilling wells and to increase the crude oil recovery rate of the third kind reservoir. Bio-enzyme is a new form of chemical agent invented combining with oil field development practice[1].

Enzyme is a new form of high efficient catalysts that can remove the hydrocarbon from the surface of the solid particles. This unplugging process is a kind of catalytic biochemistry reaction. Enzymes are initially used in the mud or the oiliness waste treatment, the oil-water separation and recycle, the clearance of environmental pollutants and so on. In the development process of oil and gas field, the enzyme has been used successfully in breaking fracturing fluid gel and cleaning the drilling fluid filter cake. Enzymes can form some chemical agents near wellbores of the oil/gas wells or inside the formations to increase production and the injection, to control water (water shutoff, profile modification) and sand[2-3]. Recently, the technology of using other chemical agents produced on the spot (such as inorganic, jelly glue, resin and so on) is under research. Because of the good performance as the excellent capacity of separating oil/gas/solid and the specificity of hydrocarbon degradation, enzymes have been used successfully to unplug the oil wells and have got good effects of relieving the organic blockage and stabilizing formations. The tests in the countries and districts such as the U.S.A, Mexico, Venezuela, Indonesia, etc. have got excellent effects[4-5].

The bio-enzyme is a kind of biological agents created by microbial technology. It is a kind of water-soluble product and has high capability of releasing the hydrocarbon from the surface of reservoir rock particles. It can change the wettability of the reservoir rock from lipophilicity to hydrophilcity, can decrease the wetting angle, so as to decrease the flow resistance of crude oil in the pores of reservoir, to release the crude oil from the surface of rock particles and from the micropores, then to get the effect of unplugging, oil displacement and enhancing the recovery rate.

II. BASIC PERFORMANCE OF THE BIO-ENZYMEE

A. Capability of Washing Crude Oil

Mix samples of the quartz sands with crude oil from DQ Oilfield fully, and then put the mixture into several bottles containing different concentrations of this bio-enzyme solution. The observed results showed that after interaction between the bio-enzyme solution and oil sand the crude oil was separated from the surface of quartz sands in the forms of oil droplets or upfloated bulks. After separation the surface of sand particles became clean and the interface of oil-water became regular. All the results illustrate the excellent performance of the bio-enzyme to wash oil.

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B. Interfacial Tension

By the Interfacial Tensiometer, the interfacial tensions were measured for field oil samples with different concentrations and salinity at different time. The test results showed that the interfacial tension was the smallest under the concentration of 0.5%. And under this concentration the interfacial tension was steady and never rebounded with time(see in table 1 and table 2). The higher the salinity, the lower the interfacial tension(see in table 3).

C. Change of the Rock wettability by Bio-enzyme

Cut the quartz into the test chips with length of 3cm, width of 1.5cm, thickness of 0.5cm and polish them with metallographic abrasive papers. Because the primary component of the sandstone was quartz, the quartz can be used instead of sandstone. It is a little water wettability originally. Put the test chip into the diluted crude oil for immersion at normal temperature. Then take them out and put it into a container with clean kerosene horizontally. Put a small droplet of water on the test chip and measure the contact angle of bio-enzyme by the optics projection method.

In the process of interaction between the quartz test chip and the bio-enzyme solution, the water droplet was becoming less height and longer, while the contact angle decreases gradually(Table 4). The results showed that the hydrophilcity of the test chip became stronger and the lipophilicity of the test chip became weaker. After the interaction, the enzyme molecules attached to the surface of quartz test chip and the wettability of the surface of quartz test chip can be changed in short time.

D. Experiments of Oil Displacement by the Bio-enzyme

The core oil-displacement experiments showed that the recovery rate of water flooding increased by 5.0% after injection of bio-enzyme solution by 0.5PV for different concentrations(see in table 5). Comparing the injection pressure between the steady water flooding about 0.754MPa and the following number about 0.429MPa, the injection pressures have been reduced by 43.1％(Figure 1).

III. EFFECT OF THE FIELD TEST

A. Introduction of the Testing Area

The field test was performed at the thin reservoir of the group GAO Ⅰ of some tertiary infilling adjustment wells. The average thickness of the sandstone perforated at each well is 13.2m and the effective thickness perforated is 4.1m with the average permeability is 0.111μm^2。 The average daily liquid production is 12.0t while the daily oil production is 2.1t with the composite water-cut of 82.4%. The pilot well group has some features, the first of which is the low initial water-cut, the fast rising speed of water-cut at the later stage. These features stand for the major puzzles of the tertiary infilling well pattern. At the early stage the daily oil production of the central oil well was 4t with the water-cut of 55.6％. Recently the daily oil production is 2t with the water-cut of 82.6％ which is higher than the water-cut of the tertiary infilling wells of the entire block by 6.5%. The yearly water-cut increases by 13.5%. The second one is the low oil production of unit effective thickness, and the cumulative value is 417t/m, 13.1％ lower than the value of the entire block. So the pilot well group has a certain oil potential. The third is the high pressure level. Aiming at such problems the pilot well group is suitable for verifying the adaptability of bio-enzyme flooding in the tertiary infilling wells at Sabei systematically.

B. Implementation of the Testing Programs

In December 2007, with the original working system of the water injection wells, the bio-enzyme was flooded by the continuous injection method. Firstly, 0.03PV of water was injected; then 0.5PV of the bio-enzyme solution was injected subsurface to displace oil with the concentration of 0.8%.Till the February 2008, the all the injection work has been finished. The cumulative injection of the bio-enzyme was 120.4t.

C. Evaluation of the Field Test

1.Improvement of the injection effect at water wells

After the injection of bio-enzyme, Water could be injected in 2 water wells that had never absorbed water originally; the injection pressure of 4 injection wells decreased at the same time; the injection volume increased; and the injection profile has become better somewhat. The results show that a favorable injection-production driven system has been established. The average injection pressure of individual injection well decreased from 12.8MPa to 12.1MPa after injection of the bio-enzyme and the average injection volume of individual well increased by 16m^3. The average scale of water absorbing capacity for every injection well increased by 14.18 from 19.15% to 33.33%. Good effect has been achieved.

2.Obvious Increment of Oil Production

The average daily oil production of individual oil well increased from 2.1t to the peak value of 3.6t while the water-cut decreased by 0.8 percent. The daily oil production of the central wells increased by 1.0t at the best stage while the water-cut decreased by 6.1. The cumulative oil increment by now achieved 2796t.

3.Improvement of Pressure Level

The average flow pressure is 3.7MPa originally while it became 4.7MPa after the field test. It can be seen from the well testing data of central oil well N-2-351-30 that the reservoir pressure resumed from 8.04MPa to 10.92MPa, which means the recovery of the formation pressure. The flow coefficient increased from 0.015μm^2•m/mPa•s to 0.078μm^2•m/mPa•s.

4.The Composite declining rate slows down

Before the bio-enzyme flooding test, the average monthly composite decline of the 8 oil wells in the testing block is 1.75t. Then this value became 1.2t after the bio-enzyme flooding. So the composite declining rate slowed down by 2.23%.

5.Improvement of the Physical Properties of the Crude Oil

As can be seen from complete analysis with the oil samples underground, the bio-enzyme flooding test improved the physical properties of crude oil that the viscosity, the paraffin

content and the gel content all decreased somewhat(see in table6).

IV. CONCLUSION

(1) The Bio-enzyme is a kind of biological agents produced by microbial technique with high ability of releasing hydrocarbon from the surface of the reservoir rock particles. It can change the wettability of reservoir rocks and reduce interfacial tension, thereby to unplug pores and enhance the oil recovery.

(2) The core oil-displacement experiments show that the bio-enzyme solution can enhance the recovery rate by 5.0% and made a decline of the injection pressure by 43.1%.

(3) The field test shows that the Bio-enzyme solution can improve the physical properties of the crude oil underground, make the injection pressure of water wells decline, increase the injection volume, improve the injection profile and establish good injection-production driven system. The production of oil wells increases obviously and the composite declining rate slows down at the same time.

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Table 1 Relationship between IFT and the concentration of bio-enzyme solutions

Concentration of Bio-enzyme/%	0.2	0.5	2.0	6.0	10.0
IFT/(10^{-1}mN/m)	4.88	2.01	2.52	7.15	9.50

Table 2 The relationship between the IFT and time

Time /min	20	40	60	80	100	120	140
IFT/ (10^{-1}mN/m)	2.34	2.50	2.28	2.63	2.52	2.40	2.83

Talbe 3 Relationship between the IFT and salinity (Bio-enzyme: 2%)

Salinity/ (mg/L)	200	800	2000	5000	8000
IFT /(mN/m)	1.28	1.14	0.55	0.47	0.39

Table 4 Changes of the contact angle

Time(min)	contact angle/°	
	Quartz test chip	Limestone test chip
0	94.35	133.64
5	8.89	132.49
300	2.62	124.77
1800	0	115.76

Table5 Results of core oil-displacement experiments at lab by Bio-enzyme flooding

Cores	Gas permeability /(10^{-3} μ m^2)	Concentration of bio-enzyme /%	Recovery rate of water Flooding/%	Recovery of Bio-enzyme /%	Total recovery rate /%
Artificial D-4	53.7	2	48.5	4.5	53
Artificial D-5	53.7	5	49	4.4	53.4
Artificial 2	98	8	55.9	5.8	61.7
Natural 2	73	2	34.8	3.8	38.6
Natural 5	33.8	2	44.1	5.3	49.4
Natural 6	6.3	2	24.3	6.8	31.1
Nonhomogeneity 3	49.1	2	48.9	6.1	55
Average				5.2	

Table 6 The complete anlysis data sheet of oil sample

Well ID	Before Bio-enzyme flooding					After Bio-enzyme flooding					Difference				
	Density (k g/m^3)	Viscosity (mPa·S)	Freezing Point (℃)	content of wax (%)	content of gel (%)	density (k g/m^3)	Viscosity (mPa·S)	Freezing point (℃)	Content of wax (%)	content of gel (%)	density (k g/m^3)	Viscosity (mPa·S)	Freezing point (℃)	content of wax (%)	content of gel (%)
B2-350-29	869.7	79.54	32	31.6	13.32	901	30.41	33	23.4	13.6	31.3	-49.13	1	-8.2	0.28
B2-351-30	892.9	41.91	30	23.2	14.62	872.7	30.56	32	15.6	18	-20.2	-11.35	2	-7.6	3.38
B2-351-32	867.2	28.11	30	27.3	15.68	868.2	25.06	31	17	20	1	-3.05	1	-10.3	4.32
B2-360-30	882.7	29.47	30	27.18	12.85	864.9	26.14	31	24	24	-17.8	-3.33	1	-3.18	11.15
B2-360-32	881.4	32.55	33	25.52	16.45	892.8	22.25	34	20	16.4	11.4	-10.3	1	-5.52	-0.05
B2-361-31	871.9	29.35	31	29.45	12.1	868.8	28.83	33	25.4	22.2	-3.1	-0.52	2	-4.05	10.1

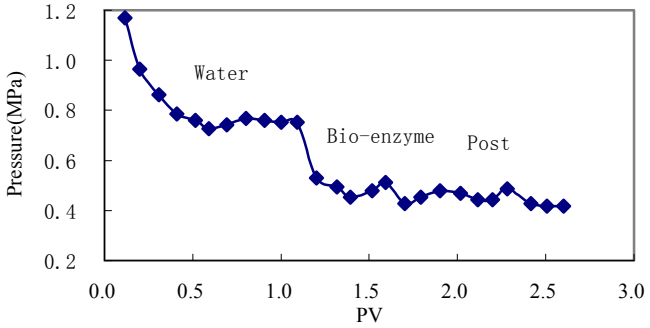

Fig.1 The pressure history of bio-enzyme flooding