

Study on the Adaptability of Jurassic Nitrogen Foam Cone Pressing

Xiujun Tang^{1a*}, Xiao Li^{1b}, Chen Yang^{1c}, Ling Li^{1d}

¹No. 7 Oil Production Plant of Changqing Oilfield

Abstract. Aiming at the problems of bottom water coning and oil well flooding caused by the large impact of the early production strength of the Jurassic bottom water direct contact well in the Seventh Oil Production Plant. Carry out research on nitrogen foam control bottom water coning technology, mainly including: ① laboratory test to optimize foam system suitable for Jurassic system of No. 7 Oil Production Plant, determine injection concentration and optimal gas-liquid ratio; ② The nitrogen foam injection timing and shut in time were optimized by numerical simulation method; ③ Summarize the field tests that have been carried out, and determine the optimal combination of parameters suitable for the Jurassic nitrogen foam pressure cone of No. 7 Oil Production Plant.

1 Introduction

The development of bottom water in some Jurassic reservoirs is greatly affected by the initial liquid production strength, and the bottom water coning is fast. For the wells with high liquid production strength, the continuous optimization has been carried out year after year. A total of 271 parameter wells have been adjusted down. The water cut rise rate has slowed down after the liquid control production, but the trend has been uncontrollable. There is an urgent need to carry out research on methods for inhibiting bottom water coning. At present, scholars at home and abroad have proposed a variety of methods for inhibiting bottom water coning: changing the oil well working system method, producing water to eliminate coning method, injecting air pressure coning method, chemical pressure coning method, and drilling diaphragm [1-6]. Nitrogen foam pressure cone is a kind of chemical water plugging, which has the plugging characteristics of "plugging the big without plugging the small, water without plugging the oil" [7]. High pressure injection of nitrogen and foaming agent into the bottom water cone can suppress the bottom water and increase the formation pressure, achieve the purpose of water control and oil increase in this well, and promote other wells in the well cluster to take effect. Pang Zhanxi used numerical simulation to optimize nitrogen foam parameters [8], and

conducted field tests in Bohai Oilfield [9], Changqing Oilfield [10], and achieved certain results.

2 Screening and evaluation of nitrogen foam system

The evaluation methods of foam system mainly include orifice plate hitting method, Ross Miles method, airflow generation method, pouring method, Waring Blender method, etc. The Ross-Miles method was selected to evaluate and study the foaming performance and stability of the foaming agent. The salinity of the formation water in the test area is basically between 15000mg/l and 50000mg/l, and the indoor upper limit is simulated water with the simulated salinity of 50000mg/l.

2.1 Performance evaluation of foaming agent

The selected foaming agent has a foaming volume of 260ml for foam and a half-life of 135.5 minutes for foam under the condition of 10MPa and 62 °C. The foam generated by the foam system under high pressure is particularly dense and has better stability. From the scatter diagram of mass concentration and half-life, it can be seen that the optimum concentration is between 0.5% and 0.7%(See Figure 1). With the increase of pressure, the foaming ability and foam stability of foam become stronger(See Figure 2).

^atangxj_cq@petrochina.com.cn, ^blix2_cq@petrochina.com.cn, ^cyc7_cq@petrochina.com.cn, ^dliling4_cq@petrochina.com.cn

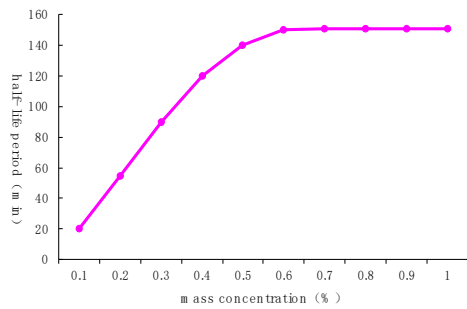


Figure 1. Gas-liquid ratio 65 °C, 10MPa foaming agent concentration change curve.

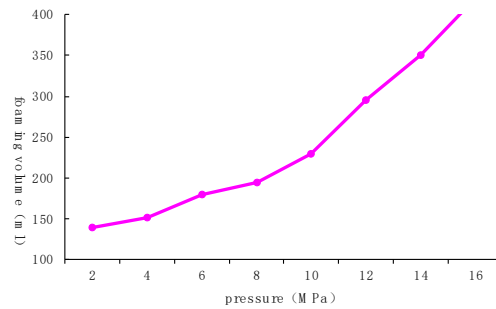


Figure 2. Effect of pressure on foaming ability of foam system (65 °C).

2.2 Evaluation of salt resistance and thermal stability

The salt resistance test of the foaming agent was carried out at 65 °C from 50000 mg/l, 100000 mg/l and 150000 mg/l. At high temperature and high salinity, the brine shows clear and transparent liquid, indicating that the system has good salt resistance. At the same time, the thermal stability of the solution was evaluated at a constant temperature of 120 days. There was no precipitation, turbidity and phase separation in the solution, and its half-life changed little, indicating that the thermal stability of the system was good.

2.3 Oil water selectivity evaluation of foam system

In the laboratory, 1%, 5%, 10% and 15% simulated oil were added into the prepared foam agent solution, and Ross Miles method was used to evaluate its half-life, which were 47/min, 40/min, 26/min, 8/min, and no foaming. The test data shows that with the increase of oil content, the half-life of foam is significantly reduced, especially when the oil content is greater than 5%, which indicates that the system has good oil-water selectivity,

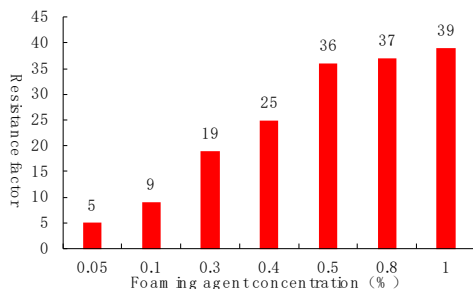


Figure 3. Resistance factors at different foaming agent concentrations.

2.4 Evaluation of foam dynamic plugging performance and optimization of injection parameters

As a selective plugging agent, foam has large flow resistance and high apparent viscosity in porous media, which can effectively plug the flow of gas and water phases and has plugging and profile control effect on the formation. This time, the concentration, gas-liquid ratio and injection method of foam system are optimized to evaluate its plugging ability.

2.4.1 Foam plugging capacity under different concentrations

The higher the foam concentration, the greater the resistance factor. When the concentration increases to 0.5%, the foam resistance factor increases slightly with the increase of foaming agent concentration, so 0.5% is the lowest injection concentration of foam system(see Figure 3).

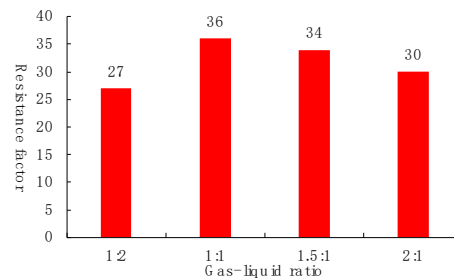


Figure 4. Resistance factor at different gas-liquid ratios.

2.4.2 Foam plugging capacity under different gas-liquid ratios

Gas liquid ratio has a great influence on the plugging ability of foam. According to the comprehensive analysis of the plugging experimental results of the four gas liquid

ratios, the plugging ability of foam is best when the gas liquid ratio is about 1:1(see Figure 4).

2.4.3 Foam plugging capacity under different injection modes

The resistance factor (41) of foam in gas-liquid mixed injection mode is higher than that in alternative injection

mode (36). The main reason is that gas-liquid mixed injection mode has sufficient gas-liquid contact and good foaming effect. Therefore, gas-liquid mixed injection mode shall be adopted as far as possible on site.

3 Effect of water cut on oil recovery during coning

With the increase of water cut, the extent of water pressure cone to enhance oil recovery first increases and then decreases; When the water cut is low, foam is injected. Because of the high oil saturation, the foam entering the reservoir is easy to break, and the plugging effect on bottom water is weak; When the water cut is very high, foam is injected. As the bottom water has completely broken through, the enhanced oil recovery amplitude of water pressure cone decreases. It can be seen from the figure that the best effect is to carry out the cone pressure test when the water content is 90%.

3.1 Effect of water cut on oil recovery during coning

According to the actual situation, five ranges of water content are set: 70%, 80%, 85%, 90% and 95%. According to the simulation, with the increase of water content, the increase range is increased first and then decreased; Combined with the previous laboratory tests, when the oil content is 5%, the foam becomes worse, easy

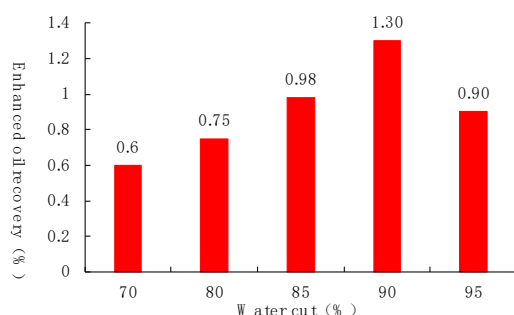


Figure 5. EOR values corresponding to different water cut.

to break, and the plugging effect is significantly weakened; When the water content is very high, it means that the bottom water has been completely coning, and the increase of oil recovery continues to decline. It can be seen from the figure that the best effect is to carry out the cone pressure test when the water content is 90%. (see Figure 5).

3.2 Effect of shut-in time on oil recovery

After the reservoir is injected with foam, the well must be closed, so that the flow field in the implementation area can be gradually balanced, and then the oil recovery can be improved. Seven ranges of 0 day, 5 days, 10 days, 15 days, 20 days, 25 days and 30 days are designed for simulation. From the simulation results, it can be seen that the maximum increase occurs after the well is closed for 15 days (see Figure 6).

3.3 Effect of different vertical/horizontal permeability ratios on enhanced oil recovery

The Jurassic reservoir is relatively homogeneous, but there is still a certain gap between vertical and horizontal permeability. Five permeability ratios are designed for simulation. From the simulation results, with the increase of the ratio, the enhanced oil recovery increases first and then decreases. When the ratio is 0.4, the enhanced oil recovery is the highest (see Figure 7).

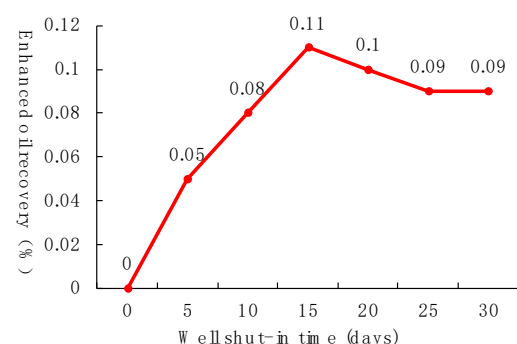


Figure 6. EOR value corresponding to different shut-in time.

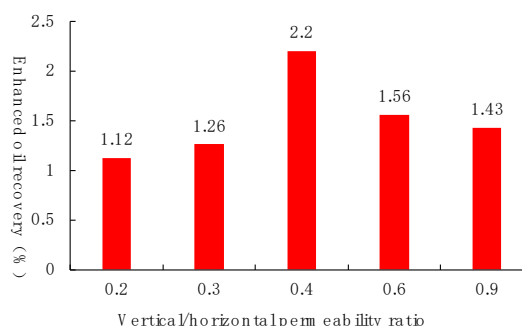


Figure 7. Figure with short caption (caption centred).

4 Field test effect

According to the reservoir structure and oil well production, three wells were selected for field test (see Table 1). The purpose of the test is to ① press the water cone downward through the strong oil-water selectivity

and Jamin effect of nitrogen foam, effectively block the upward migration of bottom water, and slow down the bottom water coning; ② The nitrogen foam is injected to

rapidly boost the pressure near the well, effectively make up the pressure deficit near the well, recover the reservoir energy, and enhance the fluidity of underground crude oil.

Table 1. Basic parameters of test well.

WELL	Design consumption		Actual consumption		Initial pressure	Maximum pressure	Climbing pressure
	Foaming agent	Nitrogen	Foaming agent	Nitrogen			
	(m ³)	(Nm ³)	(m ³)	(Nm ³)	(Mpa)	(Mpa)	(Mpa)
A	200	40000	200	40600	10	16	6
B	350	55000	350	59750	9	15	6
C	400	75000	400	76000	16	21.5	5.5

Take Well C as an example. The structure is - 65m, and the average structure of the surrounding wells is - 75m. It is located at the high part of the reservoir structure. The oil layer is 7.7m, the permeability is 33.88mD, the oil saturation is 63.9%, and the reservoir condition is good. The oil layer of the well is in direct contact with the bottom water and is exploited with natural energy. After 12 months of production, the water content gradually rises, and after 48 months, it is flooded. Analysis shows that the initial liquid production strength is 2.1m higher ³/ D.m (reasonable liquid production strength 0.6m ³/ d. M), resulting in water flooding of the bottom water coning into the oil well, which meets the conditions of nitrogen foam coning.

In the process of nitrogen foam cone pressing, in order to extend the validity period, the entire sand layer thickness is considered, the high-strength foam system is selected, and the gas-liquid ratio is appropriately increased to force the water cone downward. According to the volume method, the preliminary design injection volume is 850m³, including 400m³ of foam liquid and 450m³ of nitrogen (gas liquid ratio 1.13:1), which is equivalent to 5 × 10⁴Nm³, another 2.5 gas injection × 10⁴Nm³, the initial design of the pressure expansion period of the closed well is 7-10 days, but according to the implementation experience of the two wells A and B, the effect is better when it is actually used for 15 days. After the implementation of nitrogen foam cone pressing in November 2019, the daily oil production of a single well remained at about 1.1t, an increase of 0.4t compared with that before the water cut rose. Up to now, the cumulative oil production has been 1130.76t, and the test effect is good(see Figure 8).

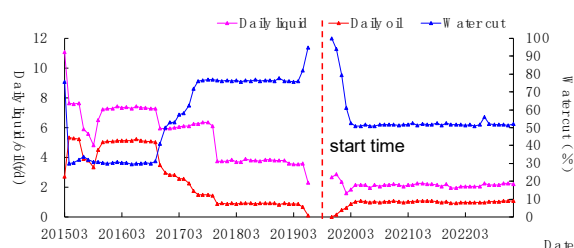


Figure 8. Production curve of Well C.

Summarize the experience of implemented wells and combine the well selection conditions. In Block A of No. 7 Oil Production Plant, three well groups were selected to carry out nitrogen foam coning test to explore a new way

for Jurassic reservoir to control bottom water coning and supplement energy.

5 Conclusion and understanding

(1) After the nitrogen foam cone is used, the production curve of the oil well presents a zigzag shape, which indicates that the nitrogen foam is constantly broken and regenerated. It bubbles when encountering water and breaks when encountering oil, which can play a role in inhibiting bottom water.

(2) The indoor experiment shows that when the concentration of foaming agent is 0.5%, the gas-liquid ratio is 1:1, and the gas-liquid mixed injection method is adopted, the effect is better. During the test, in order to improve the effect, the gas-liquid ratio can be increased to 1.12~1.3:1.

(3) The numerical simulation shows that when Kv/Kh is 0.4, water content is 90%, and the well is shut in for 15 days, the effect of cone pressure test is the best.

(4) It is recommended to jointly implement integral cone pressing with blocks or multiple well groups. It can improve the pressure system at the bottom of the well. Under the effect of nitrogen expansion and energy increase, the remaining oil between wells can be effectively used, and the oil increase effect of the measure wells and surrounding wells can be significantly improved.

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