Study on recovery feature of the weak base ASP flooding

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Abstract. A block and B block are two weak base alkali-surfactant-polymer (ASP) flooding blocks. These two blocks have received a good effect by enhancing oil recovery over 20 percent. Based on depth analysis of the dynamic variation rule of these two blocks, summarize the exploitation characteristic, such as the injection-production capability, the section exploitation, produced chemical agents feature and scaling situations. It is concluded that the weak base ASP flooding is more suitable for industrial promotion owing to its strong injection and production ability and light scale degree. The understanding can be used for reference for the follow-up promotion of the weak base ASP flooding.

Keywords: The weak base ASP flooding; the exploitation characteristic; emulsion; scale.

1. Introduction
The ASP flooding is based on the synergistic effect of the three flooding agents, and can give synthetical play to chemical agents, which has greatly improved the efficiency of chemical agents and greatly reduced the amount of chemical agents, especially surfactants. Compared with the polymer flooding, it can further improve the oil displacement efficiency on the basis of extending swept volume. Daqing Oilfield has achieved obvious oil increasing effect and good economic benefit in the ASP flooding experimental area or industrial application. The field tests show that the weak base ASP flooding can enhance oil recovery over 20 percent higher than that of the water flooding, and it is equivalent to the strong alkali ASP flooding. In emulsifying capacity, injection and production ability and rate of recovery, the weak base ASP flooding is superior to strong alkali ASP flooding. Especially in the degree of scaling, the weak alkali ASP flooding is lighter than the strong alkali ASP flooding, which has less effect on production wells. Therefore, in the application of ASP flooding, the weak base ASP flooding should be selected.

Currently, the weak base ASP flooding has entered the promotion stage. This paper is based on A and B blocks as the focus, which deeply analyses of the dynamic variation rule of the weak base ASP flooding and provides reference for more greatly enhancing oil recovery and the follow-up promotion of weak base ASP flooding.

2. Regional General Situation
A block is a field test of weak base ASP flooding carried out by Daqing oil field in 2005, and B block is an industrial demonstration area which further enlarges the weak base ASP flooding after the A block.
The development of the oil reservoir in B block is worse than in the A block. But the two test areas have achieved the good results which enhanced oil recovery of more than 20 percent. The specific development is shown in Tab. 1.

| Block | Area (km²) | geological reserves (10⁴t) | Pore volume (10⁴m³) | Well pattern and spacing | Well number | sandstone thickness (m) | effective thickness (m) | effective permeability (µm²) |
|-------|------------|---------------------------|---------------------|--------------------------|-------------|------------------------|--------------------------|-----------------------------|
| A block | 1.21 | 116.31 | 219.21 | 5-spot pattern,125m | SII10-12 | 8.1 | 6.6 | 0.533 |
| B block | 2.83 | 266.12 | 625.26 | 5-spot pattern,125m | SII10-16 | 9.4 | 7.1 | 0.387 |

3. Recovery feature of the weak base ASP flooding

3.1. Injection features
After injecting the chemical agent, the injection pressure of the weak base ASP flooding area has always maintained a steady upward trend. The injection pressure of the pre-polymer slugs increased significantly, and the pressure increased by about 35% compared with the blank waterflooding. After the injection of ASP system, the injection pressure continued to rise steadily, but the increase rate slowed down. In the stage of subsequent polymer protection slug, the injection pressure is basically stable. The maximum increase in injection pressure during the injection of agents is 60 to 70%. The injection viscosity is greater than 30 mPa.s, and the injection rate is maintained at 0.20 to 0.25PV/a.

The specific injectivity index dramatically dropped in the pre-polymer slugs. The amplitude reduction of the injectivity from the ASP flooding to the subsequent water flooding was slowed down to the basic stability. The maximum decrease of the specific injectivity index is 25% to 40% which is 20 percent lower than strong alkali ASP flooding (58.6%) and polymer flooding of Class II reservoirs(59.0%), indicating that the injectivity of the weak base ASP flooding is stronger than strong alkali ASP flooding and polymer flooding of Class II reservoirs.

3.2. Production features
The weak base ASP flooding test showed that as the flow resistance continues to increase, the pressure transmission capacity of the oil layer decreased after the injection of the ASP system, especially after entering the effective stage, and the liquid production and the specific injectivity index also decreased.

The water content began to decrease in the injection pore volume of chemical agent around 0.09PV and the production of oil wells also decreased. At the lowest water content level, the descending speed of liquid production slow down and into the recovery period of water content, the liquid production rebounded slightly.

The specific productivity index declined fast from the early injection period to the middle of the ASP injection period and in the late injection, the decline slowed down to basic stability. In the weak base ASP flooding test, the maximum decrease in the specific productivity index was from 30% to 50% which was lower than strong alkali ASP flooding (50.6%). The weak base ASP flooding has a strong ability to produce liquid.

The lowest water content of the weak base ASP flooding is about 80%, and the water content decreases by more than 16% compared with the blank waterflooding. The low water content stability time is more than 0.40PV. The effect of oil increasing and water content decreasing is remarkable, and the enhanced oil recovery is more than 20%, see Tab.2 for details.
### Tab.2 The effect of different blocks

| Block | Water content at the end of the blank waterflooding (%) | Effective time (PV) | Water descending speed (%/0.1PV) | The lowest point of water (%) | The largest drop in water content (%) | Low water retention time (PV) | Water recovery rate (%/0.1PV) | Decrease amplitude of the specific productivity index (%) | Improved oil recovery (%) |
|-------|-------------------------------------------------------------|---------------------|-----------------------------------|------------------------------|----------------------------------------|------------------------------|------------------------------|--------------------------------|---------------------------|
| A block | 98.37                                                    | 0.125               | 11.2                              | 81.28                        | 17.09                                  | 0.43                         | 1.57                         | 31.31                           | 25.80                     |
| B block | 97.16                                                    | 0.094               | 10.57                             | 80.81                        | 16.35                                  | 0.42                         | 2.09                         | 49.68                           | 23.01                     |

### 3.3. Produced chemical agent features

Laboratory study shows that there is chromatographic separation in the process of ASP composite system migration. Field tests show that: in the weak base ASP flooding, the polymer was first produced and then the water content decreased. After the effect, alkali and surfactant were produced. Produced polymer concentration gradually increased when injection pore volume of chemical agents is more than 0.3PV. After the main slug 0.41PV, the produced concentration of alkali and surfactant increased simultaneously and reached the peak.

In terms of the time difference between the produced chemical agents of the test area, the separation chromatography of the weak base ASP flooding is not serious and the synergistic effect is good (Fig.1). The sampling from wells between oil and water wells shows that the interfacial tension can be ultra low (Fig.2) with the continuous injection of chemical agents. So the chromatographic separation is not serious and has little effect on the performance of the oil flooding system.

![Fig.1 Relative concentration of produced chemical agents of Block B](image1)

![Fig.2 Interfacial tension under of different well spacing Block B](image2)

### 3.4. Pressure features

The two test zones have taken 125m well spacing and a five spot well pattern. Compared with the blank water flooding, first, injection pressure difference curve of all stages are basically parallel after the injection of chemical agents, indicating that the chemical agent can be successfully injected into the reservoir. Second, flooding pressure difference slope increased, indicating that ASP system can drive underground low permeability reservoirs which are difficult to exploit, and the exploitation degree of oil formation section continue to improve. Third, the production pressure difference gradually amplify and the liquid supply capacity improve. (Fig.3) On the whole, the chemical agent is successfully injected into the ground, driving the remaining oil enrichment zone and producing smoothly in the mining side. With the chemical injection, the pressure difference between injection and production gradually
increases, indicating that under 125m well spacing conditions, an effective driving pressure system is established in the weak base ASP flooding of Class II reservoirs.

### 3.5. Section exploitation features

The ASP flooding expands the swept volume and at the same time, improve the oil displacement efficiency. First, the inhalation condition of the reservoir is improved in the ASP flooding stage. From the blank water flooding to main alkali - surfactant - polymer slug, the inhalation thickness gradually increase and the highest proportion of suction can being 92%. Compared with the blank water flooding, in the main ASP slug, the inhalation thickness proportion can be increased by 6 percent or more and in the auxiliary ASP slug, the profile is reversed slightly. Second, the produced heavy components of crude oil increase and the residual oil has been used. The total hydrocarbon content curve shifts to the right after the injection of chemical agents, and the high carbon content in the crude oil increases which indicates that the heavy components in the crude oil are increased, the residual oil has been used and the oil displacement efficiency is improved (Fig.4).

![Fig.3 Injection and production pressure difference of Block B](image)

![Fig.4 Total hydrocarbon content analysis of Block B](image)

### 3.6. Emulsion features

Laboratory study shows that emulsification contributes to enhanced oil recovery. With the enhancement of the emulsifying ability, the crude oil is easily dispersed into small oil droplets, which can be produced by forming continuously flowing oil-rich belt, making the oil displacement efficiency improved. In addition, when the crude oil forms an oil-in-water emulsion, the viscosity reduces greatly which further improves the flow ratio of the displacement liquid and the crude oil. Meanwhile, the different particle size of the droplet in the migration of porous media has a local profile control effect, thereby expanding the macro and micro sweep efficiency.

Field experiments show that: the petroleum sulfonate weak base ASP flooding has a good emulsion ability. The water content of emulsified serious wells can fall 25.39% more than other wells and recovery percent can increase 15.8% more than other wells.

### 3.7. Scale features

The weak base ASP flooding scaling is weaker than strong alkali ASP flooding. After two months(0.04PV) weak base ASP injection, static mixer of injection end begins to scale. The scale component is mainly calcium carbonate. Taking two cleaning methods, online and offline, the scaling phenomenon has been alleviated. The cleaning cycle of various parts is about one to two months.

After ten months(0.23PV) weak base ASP injection, produced end begins to scale. The scale component is mainly calcium carbonate scale. Through the combination of chemical scale prevention and chemical scale removing, the pump detection period in whole process is close to 500 days.
4. Conclusion
A. The weak base ASP flooding has a strong injection-production capability and a high water cut amplitude reduction. The effect of oil increasing and water content decreasing is remarkable, and the enhanced oil recovery is more than 20%.

B. The ASP flooding expands the swept volume and at the same time, improve the oil displacement efficiency. The chromatographic separation is not serious and has little effect on the performance of the oil flooding system.

C. The emulsification of the weak base ASP flooding can improve the oil displacement efficiency and expand the volume. Emulsification serious wells have a high water cut amplitude reduction and a high recovery percent.

D. Compared with strong alkali ASP flooding, the injection-production capability of the weak base ASP flooding is stronger and the scaling degree is weaker. The weak base ASP flooding is more suitable for industrial promotion.

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