Analysis of Reservoir Plugging in Later Development Stage of ASP Flooding in Block X

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Abstract. In the ASP flooding block X, there are some phenomena such as the abnormal law of agent concentration and the acceleration of water cut rise in some well groups. Analysis shows that it is mainly affected by the factors such as serious reservoir plugging and reservoir production situation decline. In this paper, injection wells in this block are divided into three categories: stimulation wells, non-stimulation wells and profile control wells and blocking condition and cause are analyzed. Based on this, the corresponding countermeasures are given for various wells. It can effectively improve the injection status of block X, so as to improve the development status of the block.

Key words: ASP flooding, reservoir plugging, stimulation measures.

1. Overview of block

1.1. General Situation
The target layer of X block is P11-3 oil layer, with 6 sedimentary units. The production layer series is complex, interlayer heterogeneity is strong, and interlayer contradiction is prominent. The oil-bearing area is 5.8km², and the five point method area well pattern is adopted. The injection production well spacing is 125m, 151 injection wells and 170 production wells. The ASP control degree is 79.7%, and the average effective permeability is 482×10⁻³μm².

1.2. Oil Displacement Scheme and Implementation
The displacement agent in block X is a strong alkali ternary composite system using alkyl benzene sulfonate surfactant, and the injection slug combination mode of "pre polymer slug + Ternary main slug + Ternary sub slug + subsequent polymer slug" is adopted. The slug design of oil displacement scheme is as follows: 0.06PV × 1300P + 0.35PV × [1.2%A + 0.3%S + 1900P] + 0.15PV × [1.0%A + 0.2%S + 1900P] + 0.2PV × 1700P. The total value of three-dimensional slug is 0.5PV, including 0.35 PV for main slug and 0.15 PV for secondary slug. Block X was fully put into operation in December 2014 and started injection in June 2016. At present, it has entered the ternary sub slug stage. By the end of August 2019, the average injection pressure is 13.14MPa, the daily injection rate is 5831m³, the cumulative injected chemical solution accounts for 0.684pv of underground pore volume; the daily liquid production is 5401t, the daily oil production is 484t, the comprehensive water cut is 91.04%, the stage recovery degree is
12.83%, the enhanced oil recovery rate is 9.57 percentage points, and the proportion of effective wells is 100%.

2. Current development contradiction

2.1. Injection Difficulties in some well areas are still serious
In the first half of the year, 31 injection wells were optimized for fracturing according to the comprehensive treatment plan and the development situation of the reservoir. The injection difficulty was improved to some extent. However, 28.5% of the injection wells were still in poor injection condition, including 21.2% of the injection wells with the injection pressure space less than 0.5MPa, and 7.3% of the injection wells were shut in.

2.2. The reservoirs put into use has not been improved
The use ratio of blank water flooding reservoir is 56.1%, the polymer slug stage increases to 78.3%, the main slug decreases to 65.4% in the early stage, and then decreases to 59.8% in the later stage. After entering the secondary slug, by reducing the molecular weight and optimizing the injection parameters, the use of the reservoir was improved. Compared with the later stage of the main slug, it increased by 9.38 percentage points to 69.2%, but 30% of the wells were still not improved.

2.3. During the peak period of scaling, the liquid production capacity continued to decline
At present, it has entered the peak period of scaling, and the number of wells with reduced liquid production capacity accounts for 71.18%. All the produced wells have scale, and the scale stuck wells are increasing, and the decline of liquid production index is large. Compared with the main slug stage, 36 wells have a decrease of more than 20%.

2.4. There was a significant difference in the dosage, and the synergistic effect of the three components decreased
Compared with the previous development blocks, the ASP flooding in block X has the characteristics of early agent tested, high concentration and low storage rate. Some well groups have high concentration of alkali and surfactant and high efficiency of injection and production.

2.5. The recovery rate of water cut in some well groups has been accelerated
Since 2019, the water cut in the whole region has risen by 2.89% in 7 months. Among them, affected by poor injection condition, single connectivity, poor profile, polymer breakthrough and scaling, water cut recovery rate of 48 wells exceeded 5%.

3. Analysis of reservoir plugging
The analysis shows that the main reason for the abnormal law of agent discovery and the acceleration of water cut recovery speed is that the reservoir plugging is relatively serious, and the surfactant penetrates along the high seepage channel in the process of displacement, resulting in the low storage rate of the underground surfactant and the high surface concentration situation at the production end. At the same time, due to the decline of surfactant oil washing efficiency, the water cut of some well groups is increased. According to the dynamic and static characteristics of well groups, the measures and the actual development, the injection wells in the block are divided into three types: measure wells, non-measure wells and profile control wells. The plugging situation is analyzed, the dynamic characteristics of different types are defined, and the adjustment countermeasures are formulated individually to improve the injection status of the block.

3.1. Analysis of blockage of measure well
The results show that with the continuous injection of ternary slug, the plugging condition of reservoir is aggravated, the effect of measures is decreased, the injection volume of fracturing is gradually reduced,
and the effective period is shortened. Moreover, the effect of refracturing wells becomes worse, the injection pressure is still high after the measures, the recovery level of injection volume decreases, and the effective period of the measures is significantly reduced, so it is difficult to achieve good results by increasing sand volume fracturing (Table 1).

### Table 1. Effect of multiple fracturing measures

| Fracturing Times | Injection Pressure (Mpa) | Injection Volume (m³) | Effective Days |
|------------------|--------------------------|-----------------------|----------------|
|                  | Pre measures | Post measures | Decrease | Pre measures | Post measures | Decrease |             |
| 1st fracturing   | 13.9         | 9.5            | 4.4      | 20.7         | 33.0          | 12.3     | 261          |
| 2nd fracturing   | 14.1         | 11.7           | 2.4      | 18.3         | 31.0          | 12.8     | 120          |
| 3rd fracturing   | 14.1         | 12.1           | 2.0      | 9.0          | 25.8          | 16.8     | 50           |
| 4th fracturing   | 14.8         | 14.8           | /        | 4.0          | /             | /        | 0            |

In order to clarify reservoir plugging situation, single well group classification was carried out, and the effect of fracturing measures since 2018 was counted. According to the development status and measures effect, the measure wells were divided into five categories, with a total of 56 wells.

#### 3.1.1. Measure wells with poor reservoir quality.

**Type 1:** poor connectivity, continuous high pressure at the initial stage of production, rapid top pressure after polymer injection, poor injection production condition after multiple measures, short effective period of measures and ineffective measures. The dynamic characteristics of this type are: injection wells: the pressure is high since the injection, the injection capacity is poor, the matching injection concentration and the matching injection viscosity are low; the production wells: the liquid production capacity and the oil production level are poor, the water cut reduction is small, the submergence level is low, and the alkali concentration is high in the later stage. For this type, the next step is to carry out the corresponding fracturing of injection production wells every half a year to maintain the injection production capacity as far as possible.

**Type 2:** the development is relatively poor, and the injection concentration viscosity is high after polymer injection, which has certain effect after the measures, but the injection capacity and injection concentration viscosity are low, and the profile has not been improved. The dynamic characteristics of this type are: injection wells: the pressure is always high since the injection, the injection capacity is poor, the matching injection concentration and matching injection viscosity are low; the production wells: the liquid production capacity and oil production level are poor, the water cut reduction is small, the submergence level is low, and the alkali concentration is high in the later stage. For this type, the next step is to carry out a full well large sand volume fracturing every half a year to improve the injection difficulty.

**Type 3:** the development is relatively poor, but the effect of measures is good. The ternary system can ensure normal injection, and the profile production is good. The dynamic characteristics of this type are as follows: injection wells: the pressure is slightly higher than the whole area level, injection capacity is poor, the matching injection concentration and matching injection viscosity are low; the production wells: in the second half of 2018, the liquid production capacity is enhanced, the oil production level is higher, the water cut change and submergence level is close to the whole area, and the alkali surface concentration rises steadily. For this type, the next step is to optimize and adjust the injection production parameters to ensure the quality of injection system and the degree of reservoir production.

#### 3.1.2. Well developed measure wells.

**Type 1:** The connectivity is close to the level of the whole area. The ternary system is normal in the early and middle stages, and the plugging condition of oil layer is aggravated in the later stage. Although fracturing is carried out for many times, the effect is not ideal, and the injection production capacity is poor at present. The dynamic characteristics of this type are as follows: injection wells: pressure slightly higher than the whole area level, injection capacity is poor,
late injection concentration and injection viscosity are low; production wells: in the second half of 2018, the liquid production capacity becomes poor, the oil production level in the later stage is low, the water cut reduction is lower than the whole area level, the submergence level is close to the whole area, and alkali surface concentration suddenly appears in the later stage. For this type, the next step is to implement injection increase measures every half a year according to the situation of single well, focusing on layer selection fracturing to improve profile production. Taking X1 well group as an example, since 2018, the refracturing effect of well X1 is poor, the pressure drop is small, the production is not significantly improved, and the effective period is short. (Fig.1)

Type 2: well developed connectivity, high concentration and viscosity in the first and middle stage of the ternary system, and stable injection capacity, but the reservoir were blocked to a certain extent in the second half of the year 2018. By optimizing parameters and measures to increase injection, the injection condition was improved, and the injection production capacity remained stable at present. Compared with the whole area, the dynamic characteristics of this type are as follows: injection wells: the pressure is slightly higher than the whole area, the injection capacity is low, the injection concentration in the later stage decreases greatly, and the later injection viscosity decreases; the production wells: the liquid production capacity remains stable, the oil production level is higher, the water cut change and submergence level is close to the whole area, and the alkali and surfactant concentration increases steadily. For this type, the next step is to optimize the parameter, and take timely injection increase measures to ensure stable injection. Taking well group X2 as an example, the fracturing effect of the well in 2018 is good, the decline rate is small, the production is not significantly improved, and the effective period is short.

3.2. Analyses on blocking condition of non-measure wells
According to the whole process injection status of single well group and the current top pressure situation, the wells without measures are divided into four categories, and the plugging degree of each classification well group is determined.

3.2.1. The pressure space is less than 1MPa and no measures are taken. Type 1: well with high pressure by the end of the front plug. This type has high pressure in the initial stage of production, the pressure rises rapidly after the injection of front slug, the pressure level is high, and the reservoir plugging time is long. The dynamic characteristics of this type are as follows: injection wells: high pressure in the front stage, stable injection capacity, injection concentration and viscosity close to the whole area; production wells: stable liquid production capacity, high oil production level, good efficiency condition, submergence level lower than the whole area level, steady increase of alkali surface concentration, and polymer concentration of produced fluid is lower than that of the whole area. (Fig.2)
For this type, the next step is to control profile inversion and improve reservoir production by fracturing thin and poor layers. Taking X3 well group as an example, the blank water drive and the end plug pressure of the front stage are relatively high, and the reservoir production is high in the early ASP period, but the reservoir production decreases in the middle and late stage, and the reservoir is blocked, which is improved after molecular weight replacement in 2019.

Type 2: Wells with large pressure rise after the injection of 25 million molecular weight main slug. This type is well developed and connected. The pressure level is low at the initial stage of production, and the pressure rise is small after the injection of pre slug. After the injection of ternary main slug, the pressure rises rapidly and increases greatly. Before the replacement of 19 million molecular weight, the reservoir has been blocked, leading to the difficulty of top pressure injection and the decline of production degree. The dynamic characteristics of this type are as follows: at the injection end, the pressure rises rapidly, the injection capacity is strong, the injection concentration in the initial ternary phase and the injection viscosity in the initial ternary phase are higher than the average in the whole area; at the production end, the liquid production capacity remains stable, the oil production level is lower than the whole area, the water cut decreases slowly, the submergence level is close to the whole area level, and the alkali surface concentration suddenly rises in the later stage. Polymer concentration is lower than that of the whole area. For this type, the next step is to select the layer for fracturing to improve the reservoir production.

Type 3: Large pressure rise well after replacement of 19 million molecular weight. Such wells are well developed and connected, and the pressure level of the front slug and the main slug with 25 million molecular weight are effectively controlled. Replacing the molecular weight to 19 million to improve concentration and guarantee viscosity. The pressure continues to rise, and the pressure level is relatively high. The dynamic characteristics of this type are as follows: injection end: after changing molecular weight, the pressure continues to rise, the injection capacity is strong, and the later injection concentration is higher than the whole area average; the production end: the liquid production capacity remains stable, the oil production level is high, the water cut drop is large, the submergence level is close to the whole area level, and the alkali and surfactant concentration rises steadily. Polymer concentration is close to the level of the whole region. For this type, the next step is to optimize the injection parameters to improve the production capacity. Taking well group X5 as an example, the pressure level of the front slug and the main slug is well controlled. After the replacement of 19 million molecular weight, concentration of secondary slug remains high, and the pressure rises. Parameter matching and profile production are good now.

3.2.2. Non-measure wells with pressure space larger than 1MPa. This type has a strong injection capacity and no stimulation measures have been implemented. The pressure space is still large now and the adjustment potential is sufficient. However, the remaining oil in thin and poor layers is difficult to
tap. The dynamic characteristics of this type are as follows: injection end: after changing the molecular weight, the pressure decreases, the injection capacity is strong, the injection concentration and viscosity are higher than the average of the whole area; the production capacity is stable. The oil production level, water content, submergence level and polymer concentration are similar to the whole area. Alkali and surfactant concentration rises steadily. For this type, the next step is to optimize injection parameters, cooperate with layer selection fracturing, stop high permeability, and control inefficient and ineffective circulation.

3.3. Analysis of plugging condition of profile control wells
There are 32 profile control wells in X block. In order to improve reservoir production, profile control should be carried out in the early stage of ASP, while high concentration and high intensity injection should be maintained. The top pressure appeared in the second half of 2018. After the concentration reduction, the current pressure is close to the level of the whole area, but the injection status is worse. The dynamic characteristics of this type are: injection wells: after profile control, the pressure rise speed is faster, the injection capacity is stronger, the injection concentration and viscosity is higher than the average of the whole area; the production wells, the liquid production capacity is stable, the oil production level is lower than the whole area, the water cut drop rate is slow, the submergence level is close to the whole area level, the concentration of surfactant and alkali rises suddenly in the later stage. For the top pressure wells in profile control, injection parameters should be optimized and plugging removal should be coordinated to improve the injection capacity.

4. Comprehensive potential tapping countermeasures
On the basis of defining the degree of reservoir plugging of well group, treatment countermeasures for injection difficult wells are formulated: focusing on the improvement of production through fracturing in thin and poor layers, supplemented by large sand volume fracturing in poor development wells, and timely extension of main slug. In 2020, 29 injection wells will be fractured according to the countermeasures, and 106 well times will be adjusted. The injection and production capacity of the block will be effectively restored. The apparent water absorption index and liquid production will remain stable throughout the year, pressure will drop by 0.3 MPa, producing performance of oil layers will be increased by 3.3%, and the water cut recovery rate will be controlled at 0.1% per month.

5. Conclusions
(1) The reason for the current development contradiction in block X is the plugging of oil layer, the surfactant pushed forward through high seepage channel, and high concentration surfactant is found in liquid produced. Due to the decline of surfactant oil washing efficiency, the water cut of some well groups is accelerated.
(2) The injection wells in the block are divided into three types: measure wells, non-measure wells and profile control wells, and plugging situation and dynamic characteristics are analyzed. Targeted treatment countermeasures are formulated, which can effectively improve the injection status and development effect.

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