Study on Comprehensive Adjustment Countermeasures of Weak Alkali ASP Flooding in Low Water Cut Period

Wenjing Liu
Daqing Oilfield Co., Ltd. No.3 Oil Production Plant Test Brigade 163000, China
57578521@qq.com

Abstract. The problems occurred in the production process of weak alkali ASP flooding industrial demonstration area in Class II oil layer of Block A are systematically analyzed, such as the injection pressure of some injection wells rising too fast, the low energy and low yield of some production wells after ASP flooding, and the water cut rising too fast. Aiming at the problem of time, the research work of comprehensive adjustment was carried out, and the effective ways to improve the test effect were summarized. Improve the injection-production relationship of well groups and reduce the plane and interlayer differences; Better development results have been achieved by improving the effectiveness of oil wells.

Keywords: Comprehensive adjustment; Stratification; Fracturing; Profile control; Development effect.

1. Introduction
During the development of Block, A, good effects of increasing oil production and precipitation have been achieved. However, due to the influence of geological factors and development factors, there is a big difference in the effectiveness among single wells. In order to prolong the low water, cut period of the block, it is necessary to deeply study the adjustment technology of strong alkali ASP driving mode, reduce the difference of well group effectiveness and maximize the economic benefit of ASP flooding.

2. Basic Overview of Demonstration Area
2.1. Basic profile
Block A is located in the pure oil area in the east of F Oilfield, and the production target layer is Sa II 10-16 oil layer, and local production of Sa II 10-16+Sa III oil layer. The mining area is 2.83km², the geological reserves are 266.12×10⁴t, the pore volume is 625.26×10⁴m³, and the well pattern with 125m well spacing and five-point method is adopted, with a total of 192 injection-production wells. Among them, there are 96 injection wells and 96 production wells, with an average thickness of 9.4m, an effective thickness of 7.1m and an effective permeability of 0.387μm².
2.2. Test progress
On August 13, 2012, Block A was put into blank water flooding, and pre-polymer flooding started on March 13, 2013. On July 16, 2013, the ternary main slug was injected, and on March 10, 2015, the ternary auxiliary slug was injected. On January 21, 2016, it entered the polymer protection slug stage, and on July 1, 2017, it was injected with subsequent water flooding. Accumulatively inject 0.951PV of chemical solution. Enhanced oil recovery by 23.5%.

3. Main Contradictions in the Development Process

3.1. In the ternary main slug stage, the injection pressure is unbalanced, which affects the oil recovery effect
After entering the ternary main slugging stage in July 2013, Block A still has high- and low-pressure wells with unbalanced pressure after continuously adjusting the dense viscosity of the scheme. After many program adjustments, the daily injection volume and injection viscosity of 13 of the 96 injection wells were all raised to be higher than that of the whole region, but the injection pressure was still lower than that of the whole region. At the same time, with the injection of chemical agents, the number of wells with injection difficulties increased. By the end of June 2014, 17 injection wells had been injected due to injection difficulties. The cumulative injection quantity affected by injection difficulties in the whole region is $7.56 \times 10^4$ m$^3$ (0.0121PV).

3.2. Unbalanced effect in low water cut period
After the water cut in Block A entered the low value period, the problem of uneven effect of production wells appeared. Judging from the degree of water cut reduction, there are 24 wells with water cut reduction of more than 20%, accounting for 25% of the total number of wells; However, there are 46 wells with water cut decreased by less than 10%, accounting for 47.9% of the total number of wells. There are great differences in the effectiveness of oil production wells.

| Grading of water cut | Number of wells | Proportion of wells (%) | Blank water drive | Low water cut period | Decrease of water cut (%) |
|----------------------|-----------------|-------------------------|-------------------|----------------------|--------------------------|
| ≤5                   | 29              | 30.2                    | 57                | 97.33                | 94.8                     |
| 5-10                 | 17              | 17.7                    | 37                | 97.57                | 90.02                    |
| 10-20                | 26              | 27.1                    | 67                | 97.2                 | 83.34                    |
| 20-30                | 13              | 13.5                    | 38                | 95.95                | 72.02                    |
| >30                  | 11              | 11.5                    | 30                | 97.22                | 55.88                    |
| Total                | 96              | 100                     | 53                | 97.21                | 85.79                    |

4. Classify and Determine Adjustment Measures
In order to facilitate the analysis of the reasons for the large difference in single well effectiveness, the oil production wells in the whole region are divided into four categories according to the water cut and recovery degree: Category I is water content $\leq$ 90%, recovery degree $>10\%$, 21 ports in total, category II is water content $>90\%$, recovery degree $>10\%$, 5 ports in total, category III is water content $\leq 90\%$, recovery rate $\leq 10\%$, 35 mouths in total, category IV contains water $>90\%$, and the recovery degree is $\leq 10\%$, 35 mouths in total. By analyzing the characteristics of four types of wells, a targeted single well tracking adjustment scheme is formulated, thus promoting the effectiveness of oil wells.
Class I oil production wells have large reservoir thickness and good communication, which is mainly channel-channel communication. Compared with the whole region, the development status of Class I production wells is 1.4m in effective thickness, 0.054 $\mu$ m$^2$ in permeability and 10.5% higher than that of the whole region. Due to the well-developed oil layer, the effective characteristics of Class I oil production wells are: early effective time, obvious effect of increasing oil production and reducing water cut. According to the analysis, although oil production increases and precipitation decreases, the liquid production capacity decreases greatly. The decrease of liquid production intensity is 37.0%, which is higher than the decrease of 26.1% in the whole region. And the average flowing pressure of this kind of well is lower than 0.4MPa in the whole area, which indicates that the formation energy of this kind of production well drops rapidly and there is a low-pressure well area, so fracturing measures should be taken in time to enlarge production parameters and increase oil production effect.

From the point of view of water absorption profile, there is a great difference between the layers of injection wells around this kind of wells. SII12 and SII13+14a are the main water absorption intervals, with a relative water absorption of 43.6%. For example, in the ternary main slugging stage of Well a1, only SII10+11b did not absorb water, and this interval developed into a channel sand body with an effective thickness of 3.1m, and there were medium and low water flooded horizons. To solve this problem, interlayer adjustment should be adopted to solve interlayer contradiction, so as to tap potential and use poor residual oil.
There are 5 production wells in Class II production wells, and the effective characteristic is that the water cut enters the low value period early, one month earlier than the whole region. However, the recovery rate of water cut in Class II oil production wells is too fast. After entering the period of low water cut, the water cut of this type of oil production wells rises rapidly, with the recovery rate of 4.12%, while the recovery rate of water cut in the whole area is only 2.52% under the influence of scaling.

After analysis, the production wells of Class II wells have strong liquid production capacity, but the recovery rate rises slowly. The daily liquid production is 31t higher than that of the whole region, but the recovery degree is always lower than that of the whole region. After injecting ternary main slug, the monthly recovery degree is 0.62%, which is lower than that of the whole region by 0.76%. The injection capacity of the surrounding injection wells is strong, the injection viscosity has been higher than that of the whole region by 19mPa·s, and the concentration of polymer recovery has suddenly increased, which is higher than that of the whole region by 111 mg/L. It shows that the water cut recovery rate cannot be controlled by increasing injection viscosity through scheme adjustment. According to static data, there are great differences in interlayer physical properties of this kind of wells. Compared with the whole area, the coefficient of variation is higher than that of the whole area by 0.21, and the permeability is extremely high by 2.55. It shows that the contradiction between layers of this kind of wells is the main cause of water cut recovery, and stratified injection can be adopted to control the water cut recovery of Class II production wells.
Tab.3 Static data sheet of type II injection well

| Classification | Number of wells | Effective(m) | Permeability(μm²) | Coefficient of variation | A kind of connected thickness ratio(%) | River connectivity ratio(%) | Permeability ratio (between units) |
|----------------|----------------|--------------|-------------------|--------------------------|----------------------------------------|---------------------------|-----------------------------------|
| Class II       | 5              | 5.1          | 0.361             | 0.6                      | 34.3                                   | 34.3                      | 6.7                               |
| The region     | 96             | 7.1          | 0.412             | 0.39                     | 47.3                                   | 41                        | 4.15                              |

There are 35 Class III production wells, accounting for 36.5% of the total number of wells. The average level of oil layer development of this kind of wells is equivalent to that of the whole region, and the effective time is also consistent with that of the whole region, but the effect of increasing oil and reducing water is not obvious, the liquid production capacity is lower than that of the whole region, and the concentration of polymer production is lower than that of the whole region by 24mg/L, which indicates that there is no breakthrough in chemical agents. After analysis, there are wells with poor oil layer development and communication in Class III oil production wells, which affect the oil production effect. In view of this kind of wells, measures are taken to increase production rate and production ratio. From the distribution position of production wells, Class III production wells mainly exist in casing damage area, low injection pressure area and supplementary hole area. The rivers of injection wells around the area with low injection pressure are well developed, the injection pressure is low, the increase of injection pressure is small, and the injection viscosity is higher than that of the whole area. It shows that there are high permeability reservoirs in the wells in this area, so the implementation of profile control to alleviate the contradiction between layers is prominent. However, the injection pressure of the injection wells around the patching area and casing damage area is higher, the injection viscosity is lower than that of the whole area, and the injection intensity is only 6 m³/m. It shows that there are injection difficulties in injection wells in these two areas. For injection difficulties caused by poor oil layer development and poor communication in the patching area, injection enhancement measures are implemented, injection parameters are reasonably matched, and the plane injection-production relationship is coordinated. In view of casing damage area, the oil recovery efficiency is improved through scheme adjustment.

Tab.4 Table of injection conditions of injection wells around class III wells

| Distribution area          | Number of wells | Effective (m) | Permeability (μm²) | Proportion of first-class connected thickness of river channel (%) | Injection pressure (Mpa) | Daily injection quantity (m³) | Injection viscosity (mPa.s) | Injection intensity (m³/d) |
|----------------------------|----------------|--------------|-------------------|---------------------------------------------------------------|-------------------------|----------------------------|----------------------------|---------------------------|
| Casing damage area         | 11             | 5.5          | 0.338             | 37.2                                                          | 12.05                   | 33                        | 32                         | 6                         |
| Low pressure area          | 15             | 8.1          | 0.391             | 48.7                                                          | 10.92                   | 64                        | 52                         | 7.87                      |
| Supplementary hole area    | 16             | 7.5          | 0.353             | 36.3                                                          | 12.35                   | 48                        | 36                         | 6.4                       |
| The region                 | 96             | 7            | 0.359             | 43.7                                                          | 11.94                   | 51                        | 40                         | 7.29                      |

Class IV oil production wells are affected by oil layer development, and the effect is the worst. This kind of well has poor connectivity and strong heterogeneity. The mining concentration is low and lower than 81mg/L in the whole region.
According to the analysis, 14 of the 35 IV production wells are distributed in the casing damage area, and the surrounding wells have low injection intensity and low injection viscosity, which leads to poor effect of the production wells. For the wells in the casing damage area, the injection well scheme is adjusted to increase the volume and viscosity, strengthen the liquid supply capacity of the well group and improve the production degree of the production wells. In the remaining 21 non-casing damage wells, 13 wells have poor oil layer development and poor injection capacity of the surrounding injection wells, resulting in no effect. For this kind of wells, fracturing corresponding to oil and water wells is carried out to promote the effectiveness of oil wells. However, with well-developed oil layers, the injection ability around the production wells is strong, the interlayer contradiction is prominent, and there is a strong water absorption interval, which leads to a low production degree of the production wells. Therefore, layered injection is implemented to alleviate contradictions.

5. Tracking Adjustment Effect

According to the adjustment principle formulated by the effective characteristics of classified wells, corresponding measures are taken for oil and water wells to maximize the remaining oil potential. According to injection wells, timely individualized scheme adjustment can improve test results. The injection wells around Class I production wells are mainly concentrated and speeded up, so as to ensure adequate and good injection and realize balanced adjustment of profiles. Class II oil production wells have high concentration of production agent due to water cut recovery, and the injection scheme of surrounding injection wells is mainly to reduce the speed and increase the concentration, so as to control the water cut recovery speed. Injection wells around Class III production wells should appropriately increase injection in the direction of high oil saturation, and control injection in the direction of low oil saturation, so as to realize balanced effect of oil wells. Individualized design of injection wells around Class IV production wells can improve injection pressure, increase production degree and promote the efficiency of production wells. According to this principle, a total of 176 wells are adjusted. After adjustment, injection fracturing tends to be balanced in the demonstration area, and the effective thickness utilization ratio is as high as 91.7%.

In order to improve the injection capacity, fracturing was carried out for 26 injection wells with injection difficulties around Class I, III and IV. After fracturing, the injection pressure decreased by 2.25MPa, and the daily injection increased by 1640m$^3$/d, which ensured the liquid supply capacity of the production well.

Particle depth profile control was carried out to solve the problem of low pressure in injection wells around Class III production wells, which promoted balanced effect and relieved contradictions in layers. A total of 10 wells were profile controlled. After profile control, the injection pressure increased by 1.42MPa, which was 0.14m$^3$/d.m.MPa lower than the intake index. The 19 oil production wells in the surrounding area increased liquid production by 132t, oil production by 24.4t and water cut by 3.78%.

To consolidate the oil production effect of Class I oil production wells, control the water cut recovery rate of Class II oil production wells, and promote the effectiveness of Class III and IV oil production wells, 34 injection wells were injected separately. After relieving interlayer contradiction and stratification, the permeability range decreased from 3.6 to 1.6, the injection pressure increased from 11.25MPa to 11.87MPa, and the proportion of suction thickness of medium and low permeability layers...
increased. 65 oil production wells in the surrounding area are affected, with daily liquid drop of 3t, daily oil increase of 0.8t and water cut down of 2.56%.

The measures taken by oil production wells are mainly fracturing measures, raising fluid and releasing production, and prolonging the low water cut period. In view of the fact that the water cut of Class III and IV oil production wells is in the declining stage, the river channel edge is mainly fractured to promote the effect. A total of 8 wells have been fractured, with an average daily liquid increase of 11t, daily oil increase of 5.1t and water cut decrease of 8.18%. In view of the main fractured river channel parts where the water cut of Class I and III oil production wells is in stable stage, 15 wells have been fractured cumulatively, with an average daily liquid production of 28t, daily oil production of 10t and water cut down by 4.63%. After fracturing, the production parameters were enlarged to promote the effect, and the parameters were increased by 13 wells in total. The average daily liquid production and oil production of a single well increased by 4t and 1.5t respectively, and the water cut decreased by 1.84%.

Through the above comprehensive adjustment, the injection pressure in Block A tends to be balanced, with the injection pressure mainly concentrated above 12.0MPa, and the effective thickness utilization ratio in the ternary main slug stage is 10.4% higher than that in the blank water drive. All production wells have achieved results, with 62 production wells with the maximum water cut falling more than 20%, accounting for 64.6% of the total number of wells. The lowest water cut of oil production wells is reduced to 80.81%, which is 16.35% lower than that of blank water flooding, and the low water cut period lasts for 21 months.

6. Summary

(1) In the low water cut period of weak alkali ASP flooding, the water cut and recovery degree are adopted for classification treatment, and the development contradiction of wells and layers in various regions is clarified, which can effectively guide the adjustment of the scheme.

(2) Timely tracking and adjustment is the necessary guarantee to improve the development effect of ASP flooding. The fracturing effect of producing wells in different areas of the demonstration area by stages is remarkable, and the fracturing effect can be further improved by increasing sand addition.

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