Research on Profile Control Technology of Chengdao Oilfield

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Abstract. Chengdao Oilfield in Shengli was seriously submerged at the later stage of waterflood development, and its water content reached 85%. In view of the high water content of Chengdao Oilfield and the prominent contradictions with reservoirs, this paper studies the difficulties existing in offshore oilfield profile control and the profile control agent system for Chengdao Oilfield history. At the same time, the profile control effects of YG103 gel system, HST gel system, self-crosslinking gel system and DQG gel system used for profile control of Chengdao Oilfield were evaluated. According to the statistical data, the average production increment of YG103 jelly system per well group is 2137.8t, HST-1 jelly system per well group is 1924t, self-crosslinking jelly system per well group is 526t, DQG jelly system per well group is 182t. This paper analyzes the reasons why the profile control and production increasing effect of Chengdao Oilfield gradually becomes worse. Based on the research results, suggestions for improvement were put forward.

1. Introduction

Chengdao Oilfield is located in the extremely shallow sea area in the southern part of Bohai Bay. The regional structure is located at the southeastern end of chengbei low uplift at the intersection of Bozhong Sag and Jiyang Depression. Chengbei fault is adjacent to Chengbei sag in the southwest. It leans to the north in Bozhong Sag and Zhuangdong Sag [1]. The main Guantao group of Chengdao was put into conventional production in May 1995, and it was transferred to waterflood development in July 2000. In 2009, it entered the comprehensive adjustment phase of the old area. In 2017, the adjustm ent of the northern area of Chengdao was carried out based on the comprehensive adjustment. Due to the large formation deficit, good reservoir physical property and obvious heterogeneity in plane and longitudinal direction, the injected water mainly flows along the high permeability zone in Chengdao North area. The production effect of well is good after waterflood development, but some wells are closed due to high water cut due to seriously submerged. Due to the influence of offshore conditions and well conditions, the production well adopts a series of multi-layer combined production. As the result, production well can not realize the effective subdivision layer stratified water injection and aggravating the contradiction between layers. Therefore, the research on profile control technology suitable for Chengdao Oilfield injection well can alleviate inter-layer conflicts and improve the effect of oilfield waterflood development [2-4].

Because Chengdao Oilfield is located in shallow sea, it is impossible to simply borrow the profile control technology scheme of onshore oilfield. So there are certain difficulties in profile control construction of injection well in offshore oilfield of Shengli [5].
As Chengdao Oilfield in Shengli adopts the subsea pipeline gathering and transportation site construction mode of "satellite platform (single well or well group platform) - central platform - land gathering and transportation station". The well group platform only has oil production wellheads and transmission process. Power supply, distribution facilities, daily oil and water well moving pipe string operations require mobile construction work platforms to complete, which is costly. Therefore, for fixed pipe string profile control construction, selective gel plugging agent becomes the only choice for chemical profile control and water shutoff construction.

Because the oil production platform space of Chengdao Oilfield is very small, it is impossible to place other large construction equipment. Therefore, most of the chemical profile control construction relies on ship-borne equipment. Only a few oil production platforms can install small construction equipment. Glue preparation is simple, requires less equipment, less injection volume and short injection time, so it is suitable for profile control on offshore platforms.

The construction of offshore oilfields is severely restricted by weather conditions, sometimes causing ships to be unable to go out to sea for several days. Then resulting in insufficient supply of profile control agents and affecting the effect of profile control. The jelly-type profile control agent can be prepared on-site, usually within one to two hours and there is enough space on the platform to store related raw materials, thus ensuring the continuity of the profile control construction.

Offshore construction has high requirements for safety and environmental protection. There must be complete safety and environmental protection emergency measures during the construction process. The toxicity of chemical agents is required to be non-toxic and low-toxic, so as to avoid pollution to the marine environment due to leakage. Polymers and crosslinking agents can be selected from non-toxic chemicals.

2. Selection of profile control well
The selection of profile control well is mainly based on the pressure decision PI value calculated from the curve of the wellhead pressure of the water injection well. The stress index is defined as [1]:

\[
P_I = \frac{\int_0^t p(t) dt}{t}
\]

Where PI is pressure index (MPa), \( p(t) \) is the change function of wellhead pressure over time, \( t \) is test time (min).

It can be seen from formula (1) that the value of the pressure index PI is the area value enclosed by the wellhead pressure drop curve and the ordinate and abscissa within a certain period of time. The pressure index is related to the permeability of the oil layer. The permeability is good, there is a high-permeability layer, the wellhead pressure drops quickly, and the pressure index PI value is small. Conversely, the wellhead pressure drops slowly and the pressure index PI value is large.

Since the wellhead pressure of water injection wells will reduce the curve pressure drop period mainly within 90 minutes after shut-in, the pressure drop value does not change much after 90 minutes, deliberately \( t=90\text{min} \) as a boundary, calculate the \( P_{I_{90}} \) value of each injection well and calculate the average value. When the \( P_{I_{90}} \) value of the water injection well is less than the average value, the profile adjustment is required, and the wells that are higher than the average value are not processed.

3. Dosage design of profile control agent
Complete the on-site injection work according to the design and construction requirements of the gel profile control scheme. The construction dosage of profile control agent is calculated according to the following formula (2) [1].

\[
W = \beta \times h \times \Delta P_I
\]

Where \( W \) is the amount of profile control agent (m³), \( \beta \) is Plug agent dosage coefficient (m³·m⁻¹·MPa⁻¹), \( h \) is thickness of oil layer (m), \( \Delta P_I \) is PI change value before and after profile control.
During the profile control construction process, the injection is generally divided into rounds to form a ring-type plug (Figure 1).

4. Selection and comparison of profile control agents

So far, four different types of gel profile control construction operations have been mainly carried out in Shengli Chengdao Offshore Oilfield. From 2004 to 2005, they were developed by China University of Petroleum (East China) and Shengli Oilfield Production Research Institute according to Shengli offshore conditions. The YG103 type gel system and HST type gel system. In 2012, the self-crosslinking system gel profile control was used to construct 7 wells in the 11N well area. In 2016, the temperature and salt resistance DQG was adopted for the 25G well area in the second zone. Jelly implemented an overall profile control operation. The four process formulas are compared in Table 1.

| Item                        | YG103 type gel | HST type gel | Self-crosslinking profile control agent | DQG gel |
|-----------------------------|----------------|--------------|-----------------------------------------|---------|
| Time of dissolution and curing (h) | 1.5            | 1            | About 1                                 | About 1 |
| Gel time(h)                 | 3~8            | 5~10         | 5~8                                     | 3~10    |
| Viscosity before injection(mPa·s) | 10             | 100          | 26.89                                   | 8.2     |
| Viscosity after gelation(mPa·s) | 350~1000      | 500~800      | 400~500                                 | About 2000 |
| Slug injection method       | Trial injection + 40% 8d jelly + 30% 5d jelly + replacement liquid | Leading slug + 44% weak strength + 39% medium strength + 17% high strength + replacement fluid | Pretreatment slug + main slug (self-crosslinking profile control agent) + sealing slug | Front slug + 1.5% gel + 1.5% polymer solution |
| Displacement radius(m)      | 3~5            | 3            | 5~10                                    | >5      |
| Formula composition         | Polymer main agent + crosslinking agent | Polymer main agent + stabilizer + crosslinking agent | Polymer main agent + crosslinking agent | Polymer main agent + crosslinking agent + additive |
| Crosslinking agent adding method | Add to the dosing tank before injection | Add to the pump suction port when injecting | Add to the pump suction port when injecting | Add to the pump suction port when injecting |
| Injection rate(m³/h)        | 10~12          | 5~6          | 3~5                                     | 5~15    |
| Dosage determination method  | β-ΔPI          | High permeability plugging radius | High permeability plugging radius | β-ΔPI |
| Relative liquid dosage      | Higher         | Lower        | Lower                                   | Higher  |
5. Profile control effect analysis
Shengli Chengdao Offshore Oilfield used the YG103 type gel system of China University of Petroleum (East China) and the HST type gel system \([6, 7]\) of Shengli Oilfield Oil Production Institute from 2004 to 2005 to complete the construction of 5 wells. In 2012, the self-crosslinking gel system completed the construction of 7 wells in the 11N well area. In 2016, the DQG gel was used to complete the construction of 8 wells in the 25G well area. The statistics are shown in Table 2.

Table 2. Profile control statistics of two gel systems

| Jelly system            | Wells number | Profile control wells          |
|------------------------|--------------|-------------------------------|
| YG103 type gel system  | 4            | CB11E-6, CB11F-1, CB25A-2, CB25A-3 |
| HST-1 type gel system  | 1            | CB251A-6                       |
| Self-crosslinking       | 7            | CB11NA-1, CB11NA-11, CB11NB-3, CB11NB-10, CB11NB-7, CB11NB-11, CB11NB-2 |
| system gel              |              |                               |
| DQG gel system          | 8            | CB25GB-2, CB25GB-6, CB25GB-8, CB25GC-5, CB25GB-4, GB25GB-10, GB25GC-8, CB25GC-9 |

5.1. Analysis of the effect of profile control from 2004 to 2005
Based on the data analysis of 4 water injection wells using YG103 gel, the water injection pressure increased to varying degrees after profile control, and the increase range was between 0.4 and 1.3 MPa. Indicating that the high permeability layer was effectively suppressed after profile control, then the start-up pressure rises. The water injection indicator curves after profile control are parallel, indicating that the water injection capacity is not greatly affected. The wellhead pressure drop curve is significantly slower and the average PI value rises from 0.09 to 0.66. It is means that the high permeability bands and large channels are blocked, and the pressure conduction coefficient near the well is reduced. The water injection pressure of well CB251A-6 using HST-1 gel was increased by 1.4MPa, and the water absorption indicator curve was obviously slowed down.

From the perspective of well-end production, YG103 gel construction has achieved obvious results. The oil-producing capacity has increased from 27.7t to 34t, it is means daily production increase 6.3t. The cumulative oil increase of 4 well groups is 8551.1t, and the average oil increase of each well group is 2137.8 t. HST-1 jelly construction well has a cumulative increase of 1924t at the oil well end. Practice has proved that the profile control effect of the two gel systems is better. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

5.2. Analysis of the effect of profile control in 2012
Before and after the injection of the self-crosslinking gel system in the 11N well area, the average water injection start pressure of the 7 injection wells increased from 2.5MPa to 6.4MPa, an increase of 3.9MPa. The water absorption index dropped from 7.14 to 2.86, a decrease of 60%. The pressure drop curve changed significantly slowly and the water injection indicator curve moves upward, indicating that the effect at the well end is obvious.

From the perspective of well-end production, the 7 well groups in the 11N well block have increased oil production by 3682t. The average of single well group has increased oil by 526t, which has a certain oil increase effect. The input-output ratio is 1:2.7, which has a good oil increase effect.

5.3. Analysis of the effect of profile control in 2016
From the analysis of the water injection well, the start-up pressure of the 8 oil wells in the 25G well area all increased after the injection of the DQG gel system. The start-up pressure of the water injection
before the profile control was 1.4 MPa, and after the profile control it increased to 5.8 MPa, an increase of 4.4 MPa (Figure 2). PI90 value after profile control increases from 1.7 MPa before profile control to 5.4 MPa after profile control, and increases by 3.7 MPa (Figure 3).

By comparing the wellhead pressure changes, it can be found that the wellhead pressure drop curve becomes significantly slower after profile control (Figure 4).

Different from the pressure variation trend, the indication curve of water injection after profile control moves up significantly (Figure 5).
Through the analysis of production data, it can be found that the profile control has a certain effect on the injection well. But from the perspective of production well, the effect of profile control in the 25G well block is not obvious. After profile control in 8 well groups, the cumulative net oil increase is 681t, and the oil increase is decreasing by 1456t. Based on the 2016 crude oil price of 1991.46 yuan/t, the net oil increase The input-to-output ratios of declining and increasing oil were 1:0.23 and 1:0.49 respectively, indicating that this profile control not only failed to achieve economic benefits, but also caused a large loss.

6. Conclusion
It can be known from this paper
(1) For the profile control construction of Chengdao Oilfield in Shengli, the chemical gel profile control system is the only option. Currently YG103 type jelly, HST-1 type jelly, self-crosslinking jelly system and DQG type jelly have been applied in Chengdao Oilfield.
(2) The YG103 type jelly developed by China University of Petroleum (East China) and the HST-1 type jelly developed by Shengli Oilfield Oil Production Institute have an average oil increase of 2137.8t and 1924t respectively. The oil increase effect is better. The average single well oil increase of the joint system jelly is 526t and the input-output ratio is 1:2.7, which has a certain oil increase effect. The DQG type jelly system has an average single well oil increase of 182t and the oil increase effect is poor.
(3) Through comparative analysis, all four profile control agents use seawater-based emulsion polymer as the main agent of profile control agent. The main reason for the large difference in profile control effect is that in recent years, the Chengdao Oilfield has adopted strong injection and strong production. With the development measures, the heterogeneity of the formation is more serious. Therefore, the longer the time of strong injection and strong production, the worse the effect of profile control. Offshore oil fields should choose "early profile control".
(4) Since the emulsion polymer jelly has poor stability and is easy to break, the seawater-based emulsion polymer jelly is no longer suitable for profile control in Chengdao Oilfield. It should be used for more stable and stronger gel strength the solid particle polymer with larger and larger molecular weight is used as the main agent of the profile control agent.

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