Study on injection and production of oil and water wells in steam flooding test field of thin oil reservoir

Haiwei Yu
Third Oil Production Plant, Daqing Oilfield Co.Ltd, Daqing, Heilongjiang, China
email: yuhaiwei@petrochina.com.cn

Abstract: On the basis of dynamic changes of steam injection wells and extraction wells, the influencing factors of steam injection oil production in transition zone are analyzed and summarized. According to the dynamic relationship of oil-water wells, the feasibility of steam flooding in this zone is analyzed. According to the field conditions, the reasonable well spacing and injection parameters are optimized to provide reliable field data for the application of steam flooding in this zone.

1. The significance of the research
At present, steam injection oil recovery is widely used in heavy oil reservoirs, mainly by steam huff and puff and steam flooding. The technical level is relatively high, in which the recovery rate of steam flooding can reach 45%. The steam flooding test was conducted in some oilfield in 2006~2007. The average daily oil increase of 7t per day, decreased by 7.8% water content cut. Steam huff and puff test was conducted in a transitional zone of some oilfield in 2005~2008. The single well average daily oil increase was about 6t, and the water content decreased by 7.4%. These two tests are carried out in the thin oil development zone, and the field effect is good[1].

This test is to explore the possibility of steam flooding technology in thin oil reservoir by appropriately reducing injection production well spacing, then to improve the development effectiveness. If the test is successful, it has a good guiding significance for tapping the potential of oil reservoir in the development zone, and can provide technical reference for the application of steam flooding technology in the thin oil reservoirs.

2. Overview of the Development Zone
The development zone is located in a development zone of Daqing Oilfield, which is an anticlinal sandstone reservoir without fault development and gas cap. The original formation pressure is 11.63MPa, the saturation pressure is 10.52MPa, the original saturation pressure distinction is 1.11MPa, and the reservoir temperature is 43. The physical properties of crude oil are characterized by high viscosity, high density and high wax content[2].

The exploration data show that the sedimentary thickness of the development zone is relatively large, and the proportion of non washed thickness in the layer is still about 40%. By using numerical simulation method and dynamic analysis method, the recovery degree and water drive recoverable reserves of the test target layer are analyzed and calculated. It is calculationed that the recovery degree of the oil layer in the development zone is 23.9%, and the water drive recovery rate of the current well pattern is 31.8%.
3. General situation of oil and water well deployment in Development Zone

3.1. Well pattern deployment design
Combined with the development status of oil layers in the Development Zone, according to the principle of well pattern deployment, on the basis of considering the amplitude of EOR and economic evaluation, and considering the injection and production capacity of single well, oil production rate, convenience for later adjustment and other factors, nine sets of anti nine point zone well pattern layout schemes with different well spacing of 125m, 150m and 175m are designed[3].

| Programme | Injection production well spacing (m) | Deployment | Water drive control degree (%) |
|-----------|--------------------------------------|------------|--------------------------------|
| 1         | 125×225 Diamond                       | 40         | 9  | 49  | 87.2 | 12 | 99.1 |
| 2         | 125×175 Square shunt line             | 40         | 9  | 49  | 87.2 | 12 | 99.1 |
| 3         | 125×175 Square                        | 40         | 9  | 49  | 87.2 | 12 | 99.1 |
| 4         | (125-150) ×195 Rectangle              | 40         | 9  | 49  | 85.2 | 11.5 | 96.7 |
| 5         | 150×(200-250) Diamond                 | 40         | 9  | 49  | 83.3 | 11.1 | 94.4 |
| 6         | 150×212 Square shunt line             | 40         | 9  | 49  | 83.3 | 11.1 | 94.4 |
| 7         | 150×212 Square                        | 40         | 9  | 49  | 83.3 | 11.1 | 94.4 |
| 8         | 175×250 Square                        | 40         | 9  | 49  | 77.7 | 10.2 | 87.9 |
| 9         | Utilization of old wells Square       | 40         | 9  | 49  | 74.4 | 8.4 | 82.8 |

3.2. Injection production parameter design

3.2.1. Steam injection intensity
Steam injection intensity refers to the steam injection rate per unit volume of reservoir in the Development Zone well pattern, which reflects the speed of steam injection into the reservoir. Different reservoir properties have different optimal steam injection intensity. The optimal steam injection intensity of heavy oil reservoir is 1.5~1.8 t/(D·ha·m). The crude oil in the development zone has strong fluidity. On the basis of the situation of well pattern deployment reservoir, the steam injection intensity is about 1.2t/(D·ha·m), and the steam injection rate is 100~200t/d.

3.2.2. Steam dryness
When steam is injected into a steam injection well, the higher the dryness of steam, the greater the thermal energy injected into the reservoir. When the continuous heat supply in the reservoir is greater than the heat loss in the reservoir, the steam can carry the heat forward. The greater the dryness of the steam, the larger the advancing zone, the better the oil displacement effect. Therefore, high steam dryness should be maintained at steam injection wellhead. Through the data analysis of indoor simulation experiment, it is suggested that the steam dryness at the bottom of steam injection well in the development zone should not be less than 50%.
3.2.3. injection production ratio
In the process of oil well production, for the sake of maintaining stable formation pressure, the injection rate of injection well and the production rate of production well should be matched. The injection production ratio is about 1.0 in water flooding. With the same mass the steam have the larger volume than water, the formation pressure can be kept stable only when the production injection ratio approaches 1.1. Only when the injection production ratio is greater than 1.1, the formation pressure begins to reduce, and a certain pressure difference is formed between the injection well and the production well, the steam can move forward. According to the analysis, the injection production ratio of steam flooding should be about 1.2.

3.2.4. ending method
When the oil steam ratio is close to 0.15, the end of steam flooding can be decided according to the field test[4].

4. Site conditions of steam flooding test

4.1. Injection condition
After steam injection for 8 months, the boiler outlet steam temperature is 315 °C, the dryness is 72%, and the cumulative steam injection is 82×10⁴t, which is equivalent to 0.32PV of underground pore volume. The average injection pressure of 9 steam injection wells is 9.8MPa, and the daily steam injection is 1156t.

4.1.1. the steam injection pressure increases gradually
The average steam injection pressure is 7.7MPa in the early stage, and gradually rises to 9.5MPa in the later stage, the pressure distinction is about 1.8MPa. In addition to the influence of steam injection equipment, the steam injection pressure of the development zone increases slightly with the steam injection time, which is basically consistent with the steam flooding law of heavy oil reservoir[5].

4.1.2. the accumulated effective steam injection volume per unit thickness of steam injection well is more than 1500t
The statistics of the effective cumulative steam injection and the effective cumulative steam injection per unit thickness of 9 steam injection wells show that the effective cumulative steam injection per unit thickness of steam injection wells is more than 1500t/m.

4.1.3. the steam absorption condition is slightly improved, and the steam absorption of reservoir accounts for 90.5%
The comparison of the steam injection wells shows that the number of steam absorption layers, the proportion of sandstone and effective thickness in the later stage of the test are 2.6%, 3.7% and 5.1% higher than those in the earlier stage respectively, and the steam absorption capacity of the main steam absorption layers accounts for 90.5% of the whole well.

4.2. production condition
After the operation of steam flooding, the average daily fluid production is 1451t, the daily oil production is 75t, the comprehensive water cut is 95.7%, the cumulative fluid production is 250×10⁴t, the cumulative oil production is 30×10⁴t, the production degree is 4.8%, and the formation pressure is 7.4MPa.

4.2.1. production wells show the characteristics of three rises and one stability”
The main performance of "three rises and one stability" is "liquid production rise, oil production rise, water cut rise and temperature stability". When the steam injection reach 0.04pv in the Development Zone, the average output of single well increases from 21t to 38t, by 17t, by 83%; the daily oil production
of single well increases from 1.1t to 2.0T, by 0.9t, by 81%; the water cut enters a stable period when the steam injection reaches 0.05PV.

4.2.2. gradual recovery of formation pressure
Before the test the formation pressure is 4.6MPa, and gradually rises to 7.8MPa with steam injection.

4.2.3. the oil temperature rise of the production wells
In the early stage of the test, the average oil return temperature of the production wells was 33, and in the late stage of the test, the average temperature of the production wells rose to 43, and the temperature of five production wells exceeded 50.

4.2.4. decrease of chloride ion and salinity concentration in produced liquid
The analysis of ion concentration change of produced fluid shows that the chloride ion concentration is 529mg/L, the total salinity is 4329mg/L in the late stage of the test, which is 364mg/L and 649mg/L lower than that in the early stage of the test, respectively, and the pH value is slightly lower, which is 0.3 lower than that in the early stage of the test, from 8.0 to 7.7.

4.2.5. The physical properties of light crude oil increased slightly
The total analysis of crude oil shows that slight changes in physical properties of the crude oil, but the proportion of C11-C19 in hydrocarbon components increases by 7.5%[6].

4.2.6. the oil reservoir around the steam injection well is well developed
The analysis of the production wells shows that each oil layer is relatively balanced in the early stage of the test, and the production ratio of the effective thickness of the oil layer is 90.8%. In the late stage of the test, the production ratio of the effective thickness is reduced to 87.1%. The reasons for the decline of effective thickness production ratio are analyzed as follows: first, the interference between layer of production wells in depressurization stage is small, and the reservoir production is good; second, the steam absorption profile of some steam injection wells is uneven, lead to the production decrease of the oil wells.

5. Conclusions of the study

5.1. The test result show that it is feasible to adopt steam flooding technology in the Development Zone, which can improve the development level of thin oil reservoir. According to the test results, compared with water flooding, the increase of oil production can by more than 10%[7].

5.2. The indoor physical simulation experiment indicate that steam flooding is mainly affected by the structure of oil reservoir, oil saturation, injected steam temperature, injected pressure and injected steam speed. Ensure the development effect of the steam flooding, we should pay attention to the injected steam temperature, pressure and injected steam speed.

5.3. The effect of steam flooding is greatly affected by the dryness of injected steam. The higher the wellhead steam dryness of steam injection wells, the higher the steam dryness reaching the reservoir, and the better the steam displacement effect.

5.4. The water saturation of formation and accumulated steam injection increase simultaneously. When the water saturation of the formation reaches about 60%, the water content of the production will increase, and the oil displacement effect of steam flooding will gradually decrease.

5.5. According to the production status of the oil reservoir and the production wells capacity, it is shown that the quality of steam injection can be improved and the test effect of steam flooding can be guaranteed by adopting the 125×175m square anti nine point zone well pattern.
5.6. The production wells around the steam injection wells with good steam absorption have better oil production, and the production wells around the steam injection wells with uneven steam absorption have different oil production.

5.7. In the process of steam injection, wellhead elevation and bottom hole packer failure may occur in different degrees. According to the field test, it is suggested that nitrogen injection in annulus and vacuum insulated tubing can be used to protect tubing and casing during the completion of drilling[8].

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