Study on the method of improving fracturing effect by waterflooding in extra high water cut stage

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Abstract. After the oil field enters the stage of "double ultra-high" development, the development potential turns to the reservoir with worse development, and it is more difficult to identify the remaining oil. In order to meet the requirements of potential tapping under the new situation and achieve accurate potential tapping, the conventional fracturing technology has been continuously developed and improved by strengthening the analysis of remaining oil, optimizing the scheme design and other methods, effectively making up for the decline of production of old wells. At the same time, on the basis of conventional fracturing technology, aiming at the characteristics of reservoir and well pattern, the new high-efficiency fracturing technology represented by fracture controlled sand body fracturing and three types of reservoir pressure flooding is explored, which realizes the breakthrough of low production well productivity in poor reservoir and expands the fracturing technology.

1. Introduction

As an effective means of reservoir transformation and production, fracturing is the most direct and effective way to make up the production gap. During the 11th Five Year Plan period, the annual increase of fracturing oil has accounted for about 46% of the increase of measure oil. Since the 12th Five Year Plan period, the proportion has exceeded 60% and reached 73% at the highest. It can be seen that the increase of fracturing oil is a powerful supplement to the decrease of unprotected production and has become a water drive An important part of stable production. With the deepening of development, the overall increase of water cut and the improvement of the degree of tapping potential, the distribution of remaining oil is becoming more and more scattered, increasing the difficulty of tapping potential[1]; at the same time, after the third production object is expanded to the second class oil layer, the remaining thickness of water drive is small and scattered after matching with plugging; in recent years, the potential of water drive densification is decreasing year by year, in order to maintain the stability of production, oil and water are increased by stable fracturing in the extra high water cut period It has become an important topic to expand fracturing objects.
2. Methods to improve the effect of conventional fracturing

2.1. Strengthen the application of static and dynamic data
In view of the fact that it is difficult to recognize the remaining oil, we should comprehensively use a variety of geological data such as multi-disciplinary, dynamic and static combination to improve the understanding accuracy of the remaining oil [2]. In dynamic data, "five clearness" should be achieved, i.e. clear dynamic production data, clear adjustment and change in the whole process, clear previous measures, clear reservoir production status and well bore basic conditions; in static analysis, "five applications" should be achieved, i.e. application of fine reservoir description, application of small layer basic data, application of interlayer connectivity status, application of profile test data and application of water flooded data Explain the results. Through the analysis and application of dynamic and static data, not only the accuracy of well selection and layer selection is improved, but also the basis for the scheme design including well adjustment, fine stratification and parameter optimization is provided.

2.2. Improvement of well and layer selection standard
Based on the analysis of historical fracturing data and big data, the relationship between the time and intensity of pre fracturing culture and the effect of increasing oil production was established.

| Item                      | Conventional standard | Added standard |
|---------------------------|-----------------------|---------------|
|                           | Strength of liquid production (t/d.m) | Number of connected wells (No.) | Total pressure difference (MPa) | Water cut (%) | Effective thickness of measures (m) | submergence depth (m) | Water well pressure (MPa) | Time of measures training (Month) | Intensity of measures training (m³/d.m) |
| Original standard         | ≤6                    | ≥2            | ≥1.5          | ≤ average | ≥5          | ≤Field  |                     |                          |                              |
| New standard              | ≤6                    | ≥2            | ≥1.5          | ≤93       | ≥6          | ≤300     | ≤1.5                | ≥2                      | April 8th                     |

2.3. Optimization design of strengthening scheme
One is to further optimize fine stratification. For the remaining oil accumulation layer, the proportion of single well fracturing 5-SECTION and above wells in the total number of wells increased from 47.2% to 56.0%, and the number of single section small layers decreased from 3.26 to 2.98 at present. Through fine stratification, the pertinence of measures is improved.

The other is to optimize the combination application of technology. According to the development status and development status of different oil layers, the fracturing scheme is designed by using multiple combination of technology types in a single well, with the proportion reaching 83.7%, which improves the degree of reservoir reconstruction in the section.

Thirdly, the process parameters are optimized, the relationship curve between sand addition and oil increase is calculated, the scale of sand body fracturing is further classified, the transformation from general sand addition to sand distribution and sand addition is realized, and the range of potential exploration is improved. At present, the amount of sand added to single joint is 11.78 cubic meters, which is 5 cubic meters more than that of general sand adding; the penetration ratio reaches 19.7%, which is 2.9 percentage points higher.

Through the continuous optimization and improvement of the above work, the increase of oil in the initial stage of fracturing in the past five years has remained above 4.5t, ensuring the contribution of annual increase of oil to production.
3. Application and popularization potential of new fracturing technology

The potential targets of water drive measures have been transferred to three types of reservoirs. Although conventional fracturing has made great progress, it faces the problems of three types of reservoirs, such as many small layers, thin layers, small thickness of separation layer, unbalanced vertical production, limited increase in oil production. In order to further expand the fracturing space, new fracturing technology has been applied.

3.1. Analysis on the popularization potential of fracture sand control technology

3.1.1. Technical thinking of fracture sand control body. In view of the characteristics of transition zone and the poor effect of conventional fracturing, this technology is explored and applied. Due to the "three highs" of fluid and poor reservoir development, the injection production well spacing in the transitional zone is more than 170m, so it is difficult to establish displacement relationship, and the proportion of low efficiency wells reaches 45.7%. After conventional fracturing, the daily oil increase is only 2.5t at the initial stage, and the stable oil increase is only 0.92t, with poor effect. There are two main reasons for analysis: poor development of sand body in geology and small control range of fracture in technology [3]. In order to improve the fracturing effect, the penetration ratio is designed according to the development scale of sand body, and the sand body is controlled by fractures, so that the seepage pattern in the far well zone changes from radial flow to linear flow, and the seepage range is increased. In 2011-2016, 10 wells were tested for sand control fracturing, with an initial daily oil increase of 4.4 tons, 1.9 tons higher than that of conventional fracturing; the average effective period was 1472 days, and the input-output ratio was 1:2.74 (50 US dollars / barrel). The fracturing benefit of single well with low oil price was obvious.

3.1.2. Analysis on the popularization potential of fracture sand control technology. The development scale of sand body in transition zone is small, the corresponding rate of perforation is low, the control degree of water drive and the proportion of multi-directional connection are 80.00% and 31.11% respectively, which are 6.90% and 14.95% lower than that of pure oil area, respectively. The control ability of well pattern to sand body is lower than that of pure oil area, so it is difficult to establish effective displacement. Therefore, it is necessary to design reasonable fracture length according to the distribution scale of sand body to control sand body in order to improve the potential tapping effect. This transition zone area has the conditions for promotion.

3.2. Analysis on the promotion potential of three types of reservoir pressure drive technology

3.2.1. Technical thinking of pressure flooding in three types of oil layers. The object of waterflooding is three kinds of oil layers. From the development point of view, the two and three types of oil layers are seriously poor in plane and vertical[4], the sand body development and physical properties are poor, the relative permeability curve shows that the co permeability area is small [5], the recovery degree of the three types of oil layers is only 31.9%, a large number of remaining oil needs to be further explored. In view of its development problems, three types of oil layer reverse pressure drive field tests were carried out, in which a large number of oil displacement agents were injected at the same time of fracturing long fractures at the production end, and at the same time of improving the seepage situation, energy was supplemented and oil washing capacity was improved [5], so as to realize the effective potential tapping of the remaining oil in three types of oil layers.

Since 2018, 30 wells have been tested in the field, with daily oil increase of 9.4T in the initial stage of a single well, 2.5 times of the conventional fracturing effect, and an accumulated oil increase of 31000 tons in the stage. The test results show that the reverse pressure drive effect of the three types of oil layers is significant, which is an effective measure to improve the potential tapping effect of the three types of oil layers.
3.2.2. *Potential analysis of reverse pressure flooding in three types of reservoirs.* According to the analysis of test well effect, the target of reverse pressure flooding in three types of oil layers is low efficiency wells with poor production due to lack of energy, which can improve the injection production relationship. However, due to the small scale of sand body development or large well spacing, the well pattern cannot control the sand body, and it can also be the wells with imperfect injection production due to fault shelter or sand body pinch out [6].

According to the comprehensive analysis of sand body and well pattern, the transitional zone has the conditions for popularization. In addition, from the perspective of well pattern and sand body combination relationship, injection production relationship in the three production areas is half of pure three types and half of two or three types. Two or three types of oil layers are distributed in horizontal and vertical interaction, and sandstone connected thickness accounts for 47% (Table 2), which is very suitable for pressure flooding to carry out measures to tap potential.

| Layer segment   | Injection(III classes)-Produce(III classes) | Injection(III classes)-Produce(II/III classes) |
|-----------------|---------------------------------------------|-----------------------------------------------|
|                 | wells (%) | layers (%) | Sandstone thickness (%) | Effective thickness (%) | wells (%) | layers (%) | Sandstone thickness (%) | Effective thickness (%) |
| saertu oil layers | 58.5      | 58.1       | 55.5                      | 51.5                   | 41.5      | 42.0       | 44.5                      | 48.5                   |
| putaohua oil layers | 51.1      | 51.2       | 49.5                      | 41.3                   | 48.9      | 48.8       | 50.5                      | 58.7                   |
| average         | 55.8      | 55.2       | 53                        | 48.4                   | 44.2      | 44.8       | 47.0                      | 51.6                   |

4. **Conclusion**

1. The determination of fractured well layers in the period of ultra-high water cut should be based on the comprehensive analysis of dynamic and static data.
2. In heterogeneous reservoir, based on the knowledge of remaining oil, it is beneficial to increase the fracture length to improve the effect of measures.
3. The method of large-scale potential tapping by pressure flooding is feasible for the remaining oil with poor well pattern control or incomplete injection production.

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