Re-fracturing mode research for horizontal well in Chang 7 Tight Reservoir of Ordos Basin

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Abstract. Re-fracturing is one of the main methods to increase single well production and stable production time for horizontal wells in tight reservoir. The optimization of re-fracturing method is very important for improving the development efficiency of horizontal wells after the treating of re-fracturing. Taking Chang 7 tight Reservoir in Ordos Basin as an example, a model for predicting the productivity of horizontal wells after re-fracturing is established by numerical simulation, and the effect of horizontal well development under different fracturing modes is studied. The results show that the best perforation method for Chang 7 tight oil reservoir is to increase the new perforation position and only fracturing the new perforation section according to the fracturing cost and stimulation effect.

1. Introduction
Tight oil Reservoir has good resource prospects and has been found in Ordos, Junggar, Songliao, Bohai Bay and Sichuan basins [1-3]. It is one of the most important areas for future oil exploration in China [4]. Influenced by sedimentation, diagenesis, tectonism and densification in different stages, the pore throat of the tight reservoir is small, and its physical properties are extremely poor [5]. The permeability of overburden matrix is mostly lower than 0.1mD, and the porosity is mostly lower than 10%. There is no natural industrial productivity in single well, and horizontal well and fracturing technology are needed to form relatively high yield [6].

Influenced by the proppant placement effect and fracturing volume during the fracturing process, many tight oil wells are not well developed after a single fracturing process. In addition, in the fractured oil wells, pressure drop and particle plugging may lead to the closure and failure of the original fracture. In view of the above problems, the key to ensure stable production and increase production of tight reservoirs is to adopt re-fracturing technology for low production wells [7-8]. As early as the 1950s and 1960s, a large number of practices have been carried out for the re-fracturing technology. At present, scholars have carried out a lot of research work on the seepage mechanism, fracture morphology and single well productivity prediction under the condition of re-fracturing [9-15]. These researches are all carried out under single fracturing mode, but there are few systematic studies on stimulation effect produced by different fracturing modes during re-fracturing in tight reservoirs.

In view of this, the author takes Chang 7 tight reservoir low production well as an example, establishes the prediction model of repeated fracturing productivity by using numerical simulation method, and makes a comprehensive study on different repeated fracturing operation modes.
2. Different construction methods of re-fracturing

Current horizontal well fracturing technology is mainly divided into three types according to the construction method:

(1) Secondary fracturing at the original perforation site without increasing the number of perforations. This method mainly increases the half-length of the fracture and the conductivity through newly injected fracturing fluids and proppants to achieve the goal of increasing production (both fracture length and conductivity are major factors affecting productivity of fractured horizontal wells), as shown in Figure 1.

(2) Increasing the number of perforations and perforating in the new position, but only fracturing in the new perforated section, this method can save material costs, mainly by increasing the fracture density, increasing the volume of reservoir reconstruction, to achieve stimulation effect, but the disadvantage is that it is difficult to achieve, as shown in Figure 2;

(3) In the new position perforation, both the new perforation section and the old perforation section are fractured, and the stimulation effect is close to that of the second method, but the construction process has its advantages and disadvantages, as shown in Figure 3.

Figure 1. Re-fracturing at original perforation positions.

Figure 2. Re-fracturing at new perforation positions.
3. Establishment of re-fracturing productivity prediction model

Aiming at the low production wells in Chang 7 tight reservoir, the commercial software eclipse was used to establish the model of re-fracturing horizontal well, evaluate the development effect of different technology, and optimize the fracturing method to guide the next improvement measures in the field. The main idea of this well production prediction model is: (1) Selecting the existing fractured horizontal wells in tight reservoirs and establishing the primary fracturing productivity model (the basic parameters of the model are shown in Table 1, the reservoir parameters are mainly derived from the results of comprehensive geological evaluation, and the fracturing parameters are based on the actual fracturing operation.) to simulate the production performance from the beginning of primary fracturing to before re-fracturing; (2) A restart file is generated at the time node of re-fracturing, and the initial oil saturation field and pressure field of the prediction model are obtained, as shown in Figure 4-5. Further work is carried out to optimize the re-fracturing method.

Table 1. Basic parameters of model.

| Parameters                        | Value            | Parameters            | Value |
|-----------------------------------|------------------|-----------------------|-------|
| Reservoir size, m                 | 2000×1000×20     | Initial water saturation, % | 30    |
| Grid number                       | 80×50×1          | Formation oil viscosity, mPa·s | 1.5   |
| Formation pressure, MPa           | 16.2             | Number of fractured sections | 12    |
| Reservoir top depth, m            | 1840             | Fracturing interval, m  | 100   |
| Average porosity, %               | 10.5             | Half length of fracture, m | 230   |
| Average permeability, 10⁻³μm²     | 0.19             | Fracture conductivity, μm⁻²·cm | 10    |

Figure 3. Re-fracturing at both original and new perforation positions.

Figure 4. Initial oil saturation field of re-fracturing horizontal well model.
Figure 5. Initial pressure field of re-fracturing horizontal well model.

4. Optimization of re-fracturing perforation method for Chang 7 tight oil horizontal well

4.1. Comparison of original perforation and new perforation re-fracturing method

Keeping the other parameters of the model unchanged, the original perforation position is fractured twice, and a new perforation section is added at the central position between the original adjacent fracturing sections. Two simulation schemes are developed for the original perforation stage and the new perforation stage. They are the 6 and 12 segments of the re-fracturing, the half-length of the re-fracturing fracture is 470 m, and the conductivity is 20 D.cm. Simulating the production for 5 years with the bottom hole flowing pressure of 4.2 MPa, the simulation results are shown in Figures 6-8.

Figure 6. Oil rate under different simulation conditions.

Figure 7. Oil production under different simulation conditions.
As can be seen from Figure 6, the production of horizontal wells increases both at new and old perforations. At the initial stage after fracturing, the daily oil production of fracturing only in the new perforation section is obviously increased under the same secondary fracturing series, which is about 0.8-1.6 times higher than that of without re-fracturing, and the daily oil production of fracturing at the old perforation is also increased to a certain extent, which is about 13.5-27% higher than that of without re-fracturing. Under the same perforation method, the higher the fracturing series, the higher the initial daily oil production. At the same time, the daily output is decreasing rapidly. After a year and a half, the curves almost coincide.

Figure 7 shows that: (1) under the same fracturing series, the oil increment effect of new perforation fracturing is better than that of old perforation fracturing. The cumulative production increment of 12 stage old perforation fracturing and 6 stage new perforation fracturing is more than 2700 tons, and the cumulative oil increment of 12 stage new perforations is 2.8% higher than that of 12 stage old perforations. (2) Under the same perforation mode, the cumulative oil production increases with the increase of fracturing series, and the cumulative oil increment increases by 2.6% in the 12 stage new perforation fracturing compared with the 6 stage new perforation fracturing.

Figure 8 shows that the initial oil increment effect is the best after repeated fracturing in Chang 7 tight reservoir, and the cumulative oil increment decreases year by year with the prolongation of production time. At the same time, there is a phenomenon that the cumulative oil increment in the 16 stage old perforation is higher than that in the 8 stage new perforation within two years after re-fracturing.

The third years were flat, and third years later the situation reversed, but the difference between them was very small.

4.2. New perforation + old perforation position re-fracturing method

Compare the method of re-fracturing both the new perforation section and the old perforation section with the method of only re-fracturing the new fracturing section. Keeping other formation and fracture parameters unchanged, two schemes of new perforation fracturing 6 + old perforation fracturing 6, new perforation fracturing 12 + old perforation fracturing 6 are simulated. The half-length of the re-fracturing fracture is 470 m, and the conductivity is 20 D.cm.

Simulating the production for 5 years with the bottom hole flowing pressure of 4.2 MPa, the simulation results are shown in Figure 9.
Figure 9. Cumulative oil production under different simulation conditions.

Table 2. Cumulative oil production under different simulation conditions.

| Simulation condition | 6 stages of old with 6 stages of new perforation point | 12 stages of re-fracturing at new perforation point | 6 stages of old with 12 stages of new perforation point |
|----------------------|-------------------------------------------------------|---------------------------------------------------|--------------------------------------------------------|
| Increased oil production, m$^3$ | 3128.2 | 3394.9 | 3526.5 |
| Cumulative increase in crude oil, % | 12.9 | 14.0 | 14.5 |

It can be found from Figure 9 and Table 2 that the same 12-stage re-fracturing, the production of well which fracturing only in the new perforation is higher than that fracturing both in the new perforation and the old perforation. Under the condition of same number of new perforation segments, the effect of increasing the number of re-fracturing sections at the old perforation is very small. Therefore, for Chang 7 tight oil reservoir, from the point of view of fracturing cost and stimulation effect, adding new perforation location, and fracturing only new perforation interval is the best re-fracturing method.

5. Conclusions
(1) In view of the unsatisfactory stimulation effect of tight reservoir after primary fracturing, the feasibility analysis of repeated fracturing in Chang 7 horizontal well was carried out. By establishing the productivity prediction model of horizontal well with repeated fracturing, the optimization of repeated fracturing technology in tight reservoir was studied by numerical simulation.

(2) Re-fracturing in tight reservoirs has three modes: 1) without increasing the number of perforations, only secondary fracturing at the original perforation; 2) increasing the number of perforations and only fracturing the new perforated interval; 3) increasing the number of perforations and fracturing the new perforated interval and the old perforated interval.

(3) The above 3 ways of re-fracturing all can enhance the single well production capacity of tight reservoirs. When the fracturing series is the same, the second fracturing method has the most remarkable stimulation effect, while the first fracturing method has the worst stimulation effect.

(4) When the perforation method is the same, with the increase of fracturing stage, the effect of oil production will be improved correspondingly. The effect of increasing oil is the best in the early stage of repeated fracturing. With the extension of mining time, the cumulative oil production rate decreases year by year.
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