Study on the relationship between well pattern and artificial fracture configuration in tight reservoir

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Abstract. In order to summarize the relationship between reasonably well pattern and artificial fracture in Fuyu reservoir which using the vertical well development, we determined the fracture network scale of overlay channel and a single channel sand body on the basis of the fracture network fracturing test and the downhole microseismic fracture monitoring data and annulus testing data. The reasonable fracture network sizes of different sand bodies were obtained by establishing a typical well fracture-matrix model and applying numerical simulation of the production of 16 different fracture networks in 5 years. Under the premise of established reasonable scale of the fracture network, it provides reference for the reasonably well pattern in the new area with similar reserves in geological conditions by the comparing of the 5-year oil production in 6 different well spacing.

Key words: fracture network; well pattern; reasonable allocation; artificial fracture.

1. Preface
In this study, the development layer system of the experimental area is Fuyu oil layer, which is mainly composed of narrow channel deposits, with poor reservoir physical properties and strong heterogeneity. Using the conventional fracturing development of 240m × 100m five point pattern and water injection, the problems of low single well productivity and rapid decline are exposed. In order to improve the overall development effect of the block, the fracture network fracturing test was carried out in 2013, and the single well production has been improved to a certain extent. However, it is necessary to study the reasonable size of fracture pattern and the suitable well pattern. The first part of this study is to summarize the best scale of fracture network suitable for superimposed channel and single channel sand body under the current well pattern conditions through the data of pressure monitoring, microseismic monitoring, fracturing operation parameters and the actual production effect. Secondly, through the establishment of fracture matrix model of typical wells and simulation of development effect under different well spacing, it is concluded that the development effect of 500m × 160m five point injection well network is the best under the condition of reasonable fracture network scale.
2. Study on the relationship between fracture network characteristics and sand body configuration

According to the orientation, length and width of fracture network of different sand body types determined by microseismic monitoring of fracture network fractured oil wells, corresponding to the actual amount of sand and fluid added in the fracturing process, the reasonable configuration relationship between fracture network and sand body is summarized. At the same time, according to the monitoring data and fracture network length and width interpreted by fracturing software, the relationship between fracture network length and width and water content of oil well is established, and the reasonable fracture network scale of different sand body types under current well network conditions is determined.

2.1. Relationship between main fracture characteristics of fracture network and sand body configuration

The direction of the maximum principal stress in the test area is nearly east-west, mainly 73° northeast. The main fracture direction is basically consistent with the main seepage direction and the main stress direction of the sand body. The length of main fracture is generally controlled near the adjacent oil wells on both sides, and the width of branch fracture is controlled within the allowable range of well pattern.

2.2. The largest fracture network scale of different sand body with current well pattern in the test area

Without considering the current production performance of oil and water wells, according to the fracturing process design, sand body range and the relationship in different sand body fracture length, fracture width, fluid addition and sand addition, the reasonable fracture network length and width of different sand bodies are determined under the current well pattern conditions in the test area, and the fracture network control reserves are calculated. The superimposed channel and single channel control reserves are higher (Table 1).

| Types of sandbodies          | fracture length (m) | fracture width (m) | effective thickness (m) | Porosity (%) | oil saturation (%) | Controlled reserves (×10⁴t) |
|------------------------------|--------------------|--------------------|-------------------------|--------------|------------------|-----------------------------|
| Superimposed channel         | 380-400            | 180-200            | 1.5-4.7                 | 13.8         | 59.5             | 0.77-2.80                   |
| Single channel               | 340-380            | 180-200            | 2.1-3.1                 | 13.0         | 55.0             | 0.81-1.55                   |
| Distributary intertidal zone | 300-360            | 110-180            | 1.2-1.5                 | 10.5         | 50.0             | 0.19-0.47                   |
| Lens                         | 260-300            | 90-120             | 0.9-3.0                 | 11.6         | 52.0             | 0.12-0.60                   |

2.3. Study on the reasonable size of seam net in experimental area

At present, 240m × 100m five point well pattern is used in the test area, and the degree of water drive control reaches 79.0%. Superimposed channel and single channel sandbodies account for 66.6% of the total reservoirs. Therefore, under the current well pattern conditions, the reasonable fracture network fracturing scale of superimposed channel and single channel sandbodies is mainly studied.

According to the data of length and width of fracture network monitored by microseismic method and the data of fluid production and water content obtained by annulus test before and after fracture network fracturing, the relationship between length and width of fracture network and water content is analyzed in two cases: superimposed channel sand body and single channel sand body (Fig. 1). It can be seen that the water content of the two types of sand bodies increases obviously with the increase of fracture network scale. Therefore, under the current well pattern, the reasonable scale of fracture pattern fracturing is controlled by the well spacing of the current well pattern. The reasonable fracture network size of superimposed channel and single channel sand body is 320m long and 100m wide.
In the first batch of wells a160-432 and a160-392, the main fracture layers are superimposed river channels. The main fracture length is 277-341m, the width is 33-102m, and the fracture network scale is reasonable. The effect of increasing oil and reducing water is obvious.

The three adjacent wells a160-352, a162-s352 and a164-352 in the superimposed channel area were also fractured with fracture network. The main fracture is 246-516m in length and 155-336m in width, resulting in the overlapping of the adjacent oil and water wells. Although the controlled reserves of single well are increased, the fracture length and width of most of the three wells are more than the reasonable fracture length and width, which leads to the communication between oil and water wells within the overlapping range of fracture network. To a certain extent, the water content of a162-s352 and a164-352 rises rapidly, and the oil production drops rapidly, which affects the stable production effect of fracture network fracturing wells.

Therefore, under the condition of existing well pattern, the length of fracture pattern is 320m and the width of fracture pattern is less than 100m, which can improve the production of single well and control the rapid increase of water content in fracture pattern fractured oil wells to a certain extent.

3. Study on reasonable well pattern in new development area
For the undeveloped block with similar geological conditions as the test area, oil wells are put into production by fracture network fracturing. On the premise of determining the reasonable fracturing scale, the reasonable well spacing design is carried out to maximize the advantages of fracture network.
fracturing, improve productivity, avoid the rapid rise of water content and improve the overall development effect of the block.

3.1. Determination of reasonable fracture network fracturing scale

Through software simulation, different fracture lengths correspond to different daily oil production, and the relationship between half fracture length and daily oil production is calculated (Fig. 2). When the half seam length is more than 100 m, the yield increases obviously with the increase of seam length; When the half seam length is more than 200m, the yield decreases with the increase of seam length. Therefore, from the point of view of fracturing technology, it is considered that the reasonable full fracture length of fracture network fracturing is about 400m.

Fig. 2 Comparison of different seam length and daily production

The reasonable fracture network fracturing scale of superimposed channel is determined as follows: Considering the reservoir properties of superimposed channel sandbodies, typical well fracture matrix model is adopted. The length of the seam net is 240m, 320m, 400m and 480m respectively, and the width of the seam net is 60m, 120m, 180m and 240m respectively. 16 different scale contrast schemes are combined for 5-year cumulative oil production prediction. Among them, the cumulative oil production of 480m long and 180m wide fracture network is the highest, but the cumulative oil production of 400m long and 180m wide fracture network is only 109t lower than that of 480m long and 180m wide fracture network (Fig. 3). Considering the fracture network size, oil increasing range, fracturing cost and other factors, the fracture network length of 400m and width of 180m is suitable for superimposed channel sand body.

Fig. 3 Cumulative oil production correlation of superimposed channel sandbodies with different fracture network length and width
The reasonable fracture network fracturing scale of single channel is determined as follows: Considering the reservoir properties of single channel sand body, the typical well fracture matrix model is also adopted. The length of the seam net is 240m, 320m, 400m and 480m respectively, and the width of the seam net is 60m, 120m, 180m and 240m respectively. 16 schemes with different sizes of fracture network are combined for 5-year cumulative oil production prediction. The four schemes with length and width of fracture network of 400-120m, 400-180m, 480-120m and 480-180m have good production effect (Fig. 4). The difference of cumulative oil production is less than 200t. Considering the fracture network size, oil increase range and fracturing cost, it is considered that the fracturing scale with length of fracture network of 400m and width of fracture network of 120m is more suitable for single channel sand body.

Fig. 4 Cumulative oil production correlation of single channel sand body with different fracture network length and width

3.2. Determination of reasonable well spacing

The water injection in the developed experimental area is not effective, so the five point injection pattern is used to enhance the water injection, which is beneficial to supplement the formation energy and establish an effective driving system. When the reservoir permeability is $1.35 \times 10^{-3} \mu m^2$, the starting pressure gradient is 0.07-0.08mpa/m, and the reasonable spacing of conventional fracturing is 100m. Considering that the reasonable length and width of fracture network required by superimposed channel sand body and single channel sand body are 400m and 180m and 400m and 120m respectively, the reasonable spacing of fracture network fracturing well network is 190m and 160m respectively. According to the relationship between recovery factor and well pattern density, the reasonable well spacing range of channel sand body is 462m-555m. Based on the calculation results, the well spacing range of numerical simulation scheme is 400m-600m.

The typical well fracture matrix model is selected, and the cumulative oil production of the schemes with well row spacing of 600m × 200m, 500m × 200m, 400m × 200m, 600m × 160m, 500m × 160m and 400m × 160m is compared by numerical simulation. The comparison shows that the cumulative oil production of the schemes with well row spacing of 500m × 160m is the highest (see Fig. 5). Therefore, under the condition of reasonable fracture network fracturing scale, the new development area adopts the 500m × 160m five point injection well network development, the fracture network and sand body, well network configuration degree is the highest, and the development effect is the best.
Figure 5. Cumulative oil production comparison of different well spacing in new fracture network fracturing

4. Field application

In the test area, 8 wells are selected, the oil well array is fractured with interval fracture network, and the alternate wells are shut in without production. Thus, the original well spacing of 240m × 100m is equivalent to increasing to 480m, which is close to the well pattern determined this time. According to the type of sand body, the fracturing scale is designed. The reasonable size of fracture network of superimposed channel sand body is 400m long and 180m wide; the reasonable size of fracture network of single channel sand body is 400m long and 120m wide. Compared with the previous 32 wells, the average effective thickness of single well fracturing is reduced by 2.1m, and the daily oil production of single well is increased by 1.2t at the initial stage of production, which has achieved good stimulation effect.

5. Conclusion

1) In the developed test area of tight oil, based on the monitoring results and production data of fracture network fracturing wells, combined with the fracturing operation, it is concluded that the reasonable fracture network scale of superimposed channel and single channel sand body under the current well network conditions is: the length of fracture network is 320m, and the width of fracture network is 100m.

2) In the new area with similar tight oil geological conditions, the reasonable size of fracture network of superimposed channel sand body is 400m long and 180m wide, and that of single channel sand body is 400m long and 120m wide. Under the condition of reasonable network size, through the numerical simulation of the five point injection well pattern of 500m * 160m, the degree of configuration of the sewn net and sand body and well pattern is the highest, and the development effect is the best.

3) As the fracture matrix model in this study is only established for typical wells in the experimental area, for new areas with similar geological conditions, the differences of reservoir conditions and their influence on this conclusion, as well as the adaptability need to be further studied.

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