Effect Analysis of Cross-layer Fracturing in Horizontal Wells

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Abstract. This paper mainly analyzes the fracturing effect of horizontal wells in the development process of horizontal wells in low permeability A reservoir. On the basis of tracer monitoring, microseismic monitoring and production performance data, it is considered that fracturing breakthrough can be basically realized with the current fracturing scale of horizontal wells, but the actual breakthrough effect of communication layer depends on synchronous water injection to maintain formation energy. At the same time, the large-scale fracturing of horizontal wells can form a network fracture body in the formation, which is conducive to the production of oil layers near the well. Based on this conclusion, the next step is to formulate water injection policy for horizontal well development, so as to provide basis for future development research and water injection adjustment of horizontal wells in the same type of oilfield.

Keywords: Horizontal well, Low permeability, Fracturing through layers, Tracer monitoring, Microseismic monitoring.

1. Introduction

With the development of horizontal well production technology, horizontal wells are widely used in producing low permeability and thin interbedded reservoirs. In 2012, our factory set up a demonstration zone for joint development of horizontal wells and vertical wells in A oilfield, and achieved good results. At present, the application scope of horizontal wells is gradually expanding. When horizontal well technology is applied in new blocks such as Gu A, where the development of main layer is relatively inconspicuous, the importance of fracturing and cross-layer technology gradually increases. Whether or not to achieve fracturing through the formation and how much contribution to the productivity of fracturing communication formation has become a decisive factor for the successful exploitation of this kind of oilfield. However, in the dynamic production process of horizontal wells, it is difficult to determine the cross layer status of the main layer and the fracture communication layer through the dynamic analysis. Therefore, in developed horizontal well blocks, tracer monitoring, microseismic monitoring and other technologies are used to analyze the fracturing effect of horizontal wells.
2. Analysis of layer crossing effect

2.1. The orientation, length and distribution of cracks on the plane

1) Horizontal well: through microseismic monitoring of the fracture occurrence and development of three fracturing intervals in the hydraulic fracturing process of well B, the following understandings can be obtained:

Table 1. Well B fracturing monitoring effect

| Serial number | Horizon | Perforated interval (m) | Natural gamma (API) | Interlayer (m) | Rupture pressure (MPa) | Liquid dosage (m³) | Sand addition amount (m³) | Seam length (m) | Seam width (m) | Seam height (m) | Position | SRV (10⁴m³) | Remarks |
|---------------|---------|-------------------------|---------------------|---------------|------------------------|-------------------|---------------------------|----------------|--------------|---------------|----------|-------------|---------|
| 2             | P13     | 2310-2305               | 50                  | 62            | 54                     | 370               | 30                        | E160W, 170      | N95, S68     | NE85°         | 34       | 545.3       | Spread to paragraphs 1 and 3 |
| 3             | P13     | 2243-2240               | 105                 | 123           | 52                     | 240               | 15                        | E130, W170      | N62, S75     | NE85°         | 26       | 464.8       | Overlapping with paragraph 2 |
| 4             | P13     | 2117-2114               | 105                 | 51            | 51                     | 200               | 15                        | E160, W170      | N95, S68     | NE85°         | 17       | 202.2       | Smaller scale and more argillaceous |

Figure 1. Top view of fracturing microseismic event in Well B

Figure 2. Side view of fracturing microseismic event in Well B (N-S)
Figure 3. Density map of fractured microseismic events in Well B and affected geological body (SRV)

1. Directivity: the overall fracture orientation shows good consistency. After repeated verification for many times, it is confirmed that it is about 85° north by East, which is basically consistent with the east-west direction of the predicted principal stress direction.

2. Through layer effect of fracturing: P11, P13 and p14-2 layers are mainly developed in the well area, and the interval is about 8m and 6m. The monitoring joint height is 17-34m, which basically achieves the communication effect.

3. Distribution pattern of fractures: the average half length of three fractures is 160m, and the East and west sides are basically symmetrical. The average half fracture width is 77m. When the interval between perforating sections is less than 77m, the two fractures basically communicate and form a network fracture body with both interlayer and plane communication.

4. The volume of geological body (SRV) transformed in each section is not directly proportional to the amount of sand and liquid added, so it is impossible to accurately judge the scale of fracturing reform by the amount of sand and liquid.

2) Vertical well: real time monitoring of micro seismic fracturing fractures in well C shows that the fracture direction is vertical to the fault, the fracture length is about 200m, and the distribution of fractures on both sides is uneven, which is related to the physical properties of oil reservoirs near the well.

Figure 4. Comparison chart of facies and fracture monitoring of each layer in Well C

Table 2. Real-time monitoring and interpretation results of fractures in Well C

| Projects                        | 1821.9-1823.5m | 1810.7-1813.5m | 1798.5-1802.0m |
|---------------------------------|----------------|----------------|----------------|
| Seam length of east wing (m)    | 84.6           | 140.7          | 166.6          |
| West wing seam length (m)       | 116.9          | 74.3           | 39.9           |
| Fracture orientation (°)        | 37.3           | 48.7           | 50.1           |
| Affect the seam height (m)      | 2.8            | 2.9            | 2.5            |
| attitude                        | Vertical       |                |                |
2.2. Fracturing effect:
1) Vertical wells: Well A and Well B are tested by tracer diagnosis technology. Through testing and interpretation, the artificial fracture height and proppant distribution around the wells are given. The evaluation shows that well Gu A fractures PI3, and the fractures effectively communicate with five oil layers, namely PI2, PI3, PI4, PI4-2 and PI5. Well Gub fractured PI3, and the fractures effectively communicated with five oil layers, namely PI3, PI4, PI4-2, PI5 and PI6. After fracturing the reservoir PI1-1, the fractures effectively communicate with the two reservoirs PI1-1 and PI2. The seam width at the position with poor interlayer physical properties is only 0.3m.

2) Horizontal wells: During 2014-2015, tracer monitoring was carried out on 3 water injection wells A, B and C in Block A to study reservoir connectivity. The monitoring results show that: among the four horizontal wells around, 2 wells are fractured to communicate with each other, and the communication success rate is 50%. At the same time, compared with the main force layer, the communication layer has a longer breakthrough time, but the difference is small.

| Injection well number | Injection horizon | Interval | Consumption (g) | See the reagent | Well spacing (m) | Breakthrough time (days) | Breakthrough speed (m/days) | Equivalent permeability (Millidarcy) | Equivalent thickness (cm) | Pore throat radius (μm) | Sweep volume of well group (m3) |
|-----------------------|-------------------|----------|-----------------|----------------|-----------------|------------------------|------------------------------|-------------------------------|---------------------|-----------------|---------------------|
| A                     | Main layer        | PI1-2—PI3.2 | 3000            | A               | 300             | 18                     | 16.7                        | 3269.1                        | 57.5                | 10.5            | 106.0               |
|                       | Communication layer | PI4-1—PI4-2 | 3000            |                 | 300             | 22                     | 13.6                        | 2726.3                        | 42.9                | 9.6             | 443.5               |
| B                     | Communication layer | PI1-1—PI3.2 | 9000            | B               | 430             | 120                    | 3.6                         | 855.5                         | 105.2               | 5.2             | 1066.2              |
|                       | Main layer        | PI3-1—PI3.2 | 8000            | C               | 195             | 41                     | 4.8                         | 1070.0                        | 60.3                | 6.0             | 505.4               |
|                       | Main layer        | PI5        | 4000            | D               | 430             | 113                    | 3.8                         | 606.2                         | 134.2               | 4.7             | 900.4               |
| C                     | Main layer        | PI1-2—PI3  | 7500            | E               | 270             | 62                     | 4.4                         | 991.2                         | 81.0                | 5.8             | 713.1               |
|                       | Communication layer | PI4-2—PI5 | 7000            |                 |                 |                       |                             |                               |                     |                 |                     |

The channel between fractures was closed in the later stage: during the development of Block A, some perforation test wells were conducted by using the interlayer difference, which verified that the vertical wells fractured through the layers. At the same time, it was found that the channel between seams was closed in the later period.

For example, A is a test well. When it was put into production, it fractured the PI4 layer with poor physical properties, but did not penetrate the PI3 layer with good physical properties. At the initial stage of actual production, the liquid production is high and the water cut is low. It is analyzed that fracturing Communication layer PI3 is the main producing layer. Due to the delayed water injection of this well, the formation energy decreases rapidly and the production decreases rapidly. After 9 months of production, the water cut increases and the liquid production decreases. According to the analysis, the main production horizon in this stage is PI4, and the channel between fractures is gradually closed. After the water injection of this well in the later stage improves the formation energy, PI3 is not produced.

3. Conclusions
1. In block a with good physical properties, the fracture height can reach 17-34m, and in Block B with poor physical properties, the fracture height can reach 15-16m, which can achieve the effect of fracturing through layers.

2. Because the narrowest part of the channel is only 0.3mm, when the formation energy decreases rapidly, the channel will close later. In the development of fractured horizontal wells, if you want to give full play to the productivity of Communication layer, it is necessary to inject water into...
Communication layer synchronously, balance the formation energy between Main layer and Communication layer, and inhibit fracture closure.

3. The direction of fracture is the principal stress direction of stratum, which is nearly EW in the well area without large fault, and the wells around the fault are vertical to the fault direction. At the same time, the uneven distribution on both sides of fractures is related to the physical properties of reservoirs near the well.

4. The average half-fracture width of horizontal wells is 77m. At present, the interval between horizontal wells is basically 40-80m, and the fractures are basically communicated, which can form a network fracture body in the stratum.

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