Application effect analysis of fracture net fracturing technology in a certain block

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Abstract. During the development of a certain block in Chaoyanggou Oilfield, there are many contradictions, such as high water injection pressure and fast rising speed, difficult to establish effective displacement of oil and water wells, poor oil well efficiency, difficult to establish effective displacement by conventional fracturing and water injection development, low single well output after fracturing and poor effect of measures. In view of these problems, we conducted fracture network fracturing test in a certain block to explore effective measures to improve single well production in low permeability reservoirs, in order to provide reference for future measures to tap potential and increase efficiency.

Keywords: Low permeability reservoirs; Seam net fracturing: A certain block; Measures to tap potential.

1. Basic overview of a certain block
A block is located on the southeast wing of Fanshen village anticline structure in Chaoyanggou terrace, and the target layer is Fuyu oil layer with top elevation of -800 ~ -950 m. There are 25 faults developed in the block, with a fault distance of 10 ~ 50m, which are mainly faults in the north-south direction, and the reservoirs are mainly sand bodies deposited by distributary channels and crevasse fans. Sand bodies are distributed in a strip shape and lenticular shape, with three main oil layers FI51, FI121 and FI11 developed, and 4.2 layers developed in a single well, with an effective thickness of 9.9m, which gradually becomes thinner from northwest to southeast.

Table 1. Geological parameter table of a block

| Development area (km²) | Geological reserves (10⁴t) | Porosity (%) | Permeability (mD) | Oil saturation(%) | Formation crude oil viscosity (mPa.s) | Saturation pressure (MPa) |
|------------------------|---------------------------|--------------|------------------|-------------------|-------------------------------------|--------------------------|
| 13.69                  | 549.68                    | 15.2         | 3.9-8.6          | 50.3              | 40.8                                | 4.8                      |

A certain block was put into development one after another in 2010, and the development mode of advanced water injection was adopted. There are 219 oil wells and 90 water wells in the whole region.
By December 2018, the cumulative oil production was $63.45 \times 10^4 \text{t}$, the cumulative water injection was $263.95 \times 10^4 \text{m}^3$, the cumulative injection-production ratio was 2.4, and the formation pressure was 6.92MPa.

2. Main problems in the development of a certain block

2.1. The reservoir physical property is poor, and the output decreases rapidly after putting into production

In a certain block, the porosity is 15.2%, the permeability is only 3.9-8.6mD, the viscosity of formation crude oil is as high as 40.8mPa.s, and the reservoir physical properties are poor. The block was put into development in 2010. At the initial stage of production, the average single well oil production was 3.5t/d. By December 2018, the average single well oil production had dropped to 1.0t/d, with a decline rate of 71.4%, and the output declined rapidly.

| Time          | Initial stage of production | December, 2014 | December, 2015 | December, 2016 | December, 2017 | December, 2018 |
|---------------|----------------------------|----------------|----------------|----------------|----------------|----------------|
| Average single well oil production(t/d) | 3.5 | 1.7 | 1.6 | 1.4 | 1.1 | 1.0 |

2.2. Poor water absorption, many well points and poor oil well performance

The water injection wells in a certain block have experienced poor water absorption since 2013. With the continuous development, the number of wells with poor water absorption has increased year by year. There are 90 wells in the block, and as of December 2018, the number of wells with poor water absorption has increased to 31. The oil wells around wells with poor water absorption suffer from poor efficiency, and the output declines rapidly.

| Time          | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---------------|------|------|------|------|------|------|
| Number of wells with poor water absorption | 5    | 9    | 15   | 20   | 30   | 31   |

For wells with poor water absorption, acidizing, turning to fracturing and other injection enhancement measures are taken in time according to the situation of single wells, but the results are not very good. In recent 3 years, 19 wells have been acidized and 2 wells have been injected by fracturing. The average effective period of 21 wells is only 128 days, and the average injection enhancement of a single well is only 1225m$^3$.

| Age | Action type | Number of wells | Average single well injection increase (m$^3$) |
|-----|-------------|----------------|-----------------------------------------------|
| 2016 | Acidulate   | 2              | 1728                                          |
| 2017 | Acidulate   | 11             | 1470                                          |
| 2018 | Acidulate   | 6              | 941                                           |
|     | Fracture    | 2              | 761                                           |
| Total |            | 21             | 1225                                          |

2.3. Take timely measures to transform, but the transformation effect is not ideal

From 2016 to 2017, a total of 35 wells were taken, such as turning fracturing, hot gas acid plugging removal, hole repairing fracturing, water plugging fracturing and low-temperature self-generating gas, with an average effective period of 76 days, with an average oil increase of 142t per well. In 2017, 12
wells were turned to fracturing, with an average effective period of 91 days and an average oil increase of 231t per well, which did not achieve a good improvement effect.

### Table 5. Statistical table of oil well measures in a block

| Age   | Action type                      | Number of wells | Term of validity(d) | Cumulative oil increase (t) |
|-------|----------------------------------|-----------------|---------------------|-----------------------------|
| 2016  | Steering fracturing              | 4               | 83                  | 419                         |
|       | Water shutoff fracturing         | 3               | 16                  | 17                          |
|       | Hot gas acid plugging removal    | 8               | 96                  | 196                         |
| 2017  | Steering fracturing              | 12              | 91                  | 231                         |
|       | Hole-repairing fracturing        | 1               | 60                  | 14                          |
|       | Hot gas acid plugging removal    | 4               | 128                 | 79                          |
|       | Low temperature autogenous gas   | 3               | 57                  | 37                          |
|       | **Total**                        | **35**          | **76**              | **142**                     |

### 3. Carry out fracture test of seam net

In 2018, fracture network fracturing test was carried out in a certain block, which produced complex network fractures in the far well zone. At the same time, combined with the existing injection-production well network, the injection-production well spacing was shortened to establish effective displacement, and the single well productivity and recovery ratio were maximized. In 2018, 5 wells were fractured by fracture network, and 4 wells were fractured by fracture network in 2019.

#### 3.1. Principle of fracture net fracturing technology

In the process of hydraulic fracturing, when the net pressure of fracture extension is greater than the sum of the difference between two horizontal principal stresses and the tensile strength of rock, it is easy to produce bifurcation cracks, and multiple bifurcation cracks will form a "fracture network" system. Among them, the main fracture is taken as the backbone of the "net-fracture" system, and the bifurcated fracture may recover to the original fracture orientation after extending for a certain length from the main fracture, and finally form a vertical and horizontal "net-fracture" system with the main fracture as the main trunk. This fracturing technology to achieve the effect of the "net-fracture" system is called "net-fracture" technology.

Through fracture-net fracturing, the complex network fractures are cracked, and the displacement between wells is changed into the displacement between wells and fracture-net, thus shortening the injection-production distance and realizing effective displacement. At the same time, in order to reduce the influence of mutual interference between fractures after fracturing, fracturing is carried out every well. On the plane, the existing well pattern is used, combined with large-scale fracturing technology, to optimize the fracture scale to produce fracture pattern, expand the oil drainage area and reduce the injection-production well spacing; In the longitudinal direction, non-main oil layers are considered, fracturing intervals are optimized according to stress and lithologic shielding conditions, and thin interbeds with small interlayer thickness are compressed to maximize the production degree of various reservoirs.

#### 3.2. Implementation of fracture test of seam net

Starting from 2018, oil wells with high output, rapid decline in output, poor water absorption of connected wells but high cumulative injection amount will be selected in a certain block for fracture network fracturing. In 2018, 5 wells will be fractured by fracture network, and in 2019, 4 wells will be fractured. According to the actual situation of single well and single layer, the plan of construction parameters should be made, so that "each well has a plan, and each layer has a parameter". The construction process should be carried out in strict accordance with the design parameters.
| Serial number | Oil well number | Thickness (m) | Production time | Design | Reality |
|---------------|----------------|---------------|-----------------|--------|---------|
|               |                | Effective | Link | Interval (number) | Malmstone (m) | Effective (m) | Sand addition amount (m³) | Sand adding strength (m³/m) | Liquid consumption (m³) | Sand addition amount (m³) | Sand adding strength (m³/m) | Liquid consumption (m³) |
| 1             | Well A         | 7.0         | 7.0   | 2013 07 | The first paragraph | F12 1 | 1.0 | 0.6 | 30 | 30 | 4000 | 30 | 30 |
|               |                |            |       |         | The second paragraph | F15 1 | 1.6 | 1.4 | 40 | 25 | 40 | 25 |
|               |                |            |       |         | The third paragraph | F21 | 2.6 | 2.2 | 40 | 15.4 | 40 | 15.4 |
|               |                |            |       |         | Fourth paragraph | F22 1 | 3.4 | 2.8 | 45 | 13.2 | 45 | 13.2 |
|               |                |            |       |         | Subtotal | 8.6 | 7.0 | 155 | 18 | 155 | 18 |
| 2             | Well B         | 8.2         | 8.2   | 2013 07 | The first paragraph | F21 | 8.0 | 6.6 | 50 | 6.3 | 3500 | 50 | 6.3 |
|               |                |            |       |         | The second paragraph | F22 1 | 2.0 | 1.6 | 50 | 25 | 40 | 20 |
|               |                |            |       |         | Subtotal | 10.0 | 8.2 | 100 | 10 | 90 | 9 |
| 3             | Well C         | 11.8        | 11.8  | 2011 10 | The first paragraph | F15 1 | 4.4 | 3.6 | 50 | 11.4 | 3500 | 50 | 11.4 |
|               |                |            |       |         | The second paragraph | F21 - F22 1 | 10.6 | 8.2 | 40 | 3.8 | 50 | 4.7 |
|               |                |            |       |         | Subtotal | 15.0 | 11.8 | 90 | 6 | 100 | 6.7 |
| 4             | Well D         | 18.4        | 15.0  | 2011 07 | The first paragraph | F15 1 | 5.0 | 3.6 | 45 | 9 | 5200 | 20 | 4 |
|               |                |            |       |         | The second paragraph | F16 2 | 3.2 | 3.0 | 40 | 12.5 | 19 | 5.9 |
|               |                |            |       |         | The third paragraph | F21 1 | 2.8 | 2.4 | 40 | 14.3 | 40 | 14.3 |
|               |                |            |       |         | Fourth paragraph | F22 1 | 4.0 | 3.2 | 45 | 11.3 | 79 | 5.3 |
|               |                |            |       |         | Subtotal | 15.0 | 12.2 | 170 | 11.3 | 79 | 5.3 |
| 5             | Well E         | 14.6        | 14.6  | 2013 10 | The first paragraph | F15 2 | 3.2 | 2.4 | 45 | 14.1 | 5400 | 45 | 14.1 |
|               |                |            |       |         | The second paragraph | F17 1 | 4.2 | 3.8 | 45 | 10.7 | 45 | 10.7 |
|               |                |            |       |         | The third paragraph | F21 | 5.2 | 4.2 | 45 | 8.7 | 45 | 8.7 |
|               |                |            |       |         | Fourth paragraph | F22 1 | 4.6 | 4.2 | 45 | 9.8 | 45 | 9.8 |
|               |                |            |       |         | Subtotal | 17.2 | 14.6 | 180 | 10.5 | 180 | 10.5 |
| Total         |                | 12.0        | 11.3  |         |            | 13.2 | 10.8 | 139.0 | 11.2 | 4520 | 120.8 | 9.9 |

In 2018, due to the pressure relief of Well D connected with Well F, the wellhead pressure was low, and the layer jumped during the construction, the designed fourth interval failed to be constructed according to the design. The total sand loading of wells was 91m³ less than planned, and the sand loading intensity was 6m³/m less than planned.
### Table 7. Statistical table of construction parameters of seam net fracturing in 2019

| Serial number | Oil well number | Thickness (m) | Productive time | Interval (number) | Design | Reality |
|---------------|-----------------|---------------|------------------|-------------------|--------|---------|
|               |                 |               |                  | Malmstone (m)     | Efficve (m) | Sand additive amount (m³/m) | Sand adding strength (m³/m) | Liquid consumption (m³) | Sand adding strength (m³/m) | Liquid consumption (m³) |
| 1             | Wel 1G          | 9.2           | 2013 07          | The first paragraph | F2 21 | 3.0 | 2.8 | 50 | 30.0 | 50 | 16.7 | 3700 | 2954 |
|               |                 | 6.6           |                  | The second paragraph | F2 1 | 4.0 | 3.8 | 55 | 25.0 | 55 | 13.8 |
|               |                 | 6.6           |                  | The third paragraph | F1 22 | 1.0 | 0.8 | 50 | 15.4 | 203 | 13.1 |
|               |                 |               |                  | Subtotal           |       | 8.0 | 7.4 | 155 | 13.2 | 105 | 13.1 |
| 2             | Wel 1H          | 9.2           | 2013 07          | The first paragraph | F2 21 | 5.4 | 4.6 | 60 | 18.0 | 60 | 11.1 | 4000 | 3917 |
|               |                 | 9.2           |                  | The second paragraph | F2 1 | 3.0 | 2.8 | 50 | 6.3 | 50 | 16.7 |
|               |                 | 9.2           |                  | The third paragraph | F1 21 | 3.2 | 2.8 | 50 | 25.0 | 50 | 15.6 |
|               |                 |               |                  | Subtotal           |       | 11.6 | 10.2 | 160 | 10.0 | 160 | 13.8 |
| 3             | Wel 1I          | 12.0          | 2013 12          | The first paragraph | F2 21 | 5.0 | 4.0 | 50 | 11.4 | 60 | 12.0 | 4000 | 4071 |
|               |                 | 10.2          |                  | The second paragraph | F2 1 | 4.4 | 3.2 | 50 | 3.8 | 50 | 11.4 |
|               |                 | 10.2          |                  | The third paragraph | F1 21 | 2.2 | 2.0 | 60 | 6.0 | 50 | 22.7 |
|               |                 |               |                  | Subtotal           |       | 11.6 | 9.2 | 160 | 9.0 | 160 | 13.8 |
| 4             | Wel 1J          | 13.6          | 2013 12          | The first paragraph | FI 22 | 4.6 | 3.8 | 60 | 12.5 | 60 | 13.0 | 5000 | 5023 |
|               |                 | 9.8           |                  | The second paragraph | FI 21 | 3.2 | 2.6 | 50 | 14.3 | 50 | 15.6 |
|               |                 | 9.8           |                  | The third paragraph | FI 1 | 4.2 | 3.0 | 50 | 11.3 | 50 | 11.9 |
|               |                 |               |                  | Fourth paragraph   | FI5 21 | 2.6 | 2.2 | 50 | 11.3 | 50 | 19.2 |
|               |                 |               |                  | Subtotal           |       | 14.6 | 11.6 | 210 | 14.1 | 210 | 14.4 |
| Total         |                 | 11.0          |                  |                   |       | 11.5 | 9.6 | 171 | 11.6 | 4175 | 159 | 13.8 | 3991 |
In 2019, due to the failure of fracturing the third interval designed for Well G, the sand addition of the total well was 50m³ less than planned, and the fracturing fluid consumption was 746m³ less than planned.

3.3. Fracture effect of seam net

In September, 2018, five wells were fractured by fracture network in a certain block. The average daily oil production of each well was 1.0t before the measures and 6.5t at the initial stage after the measures. As of September 31, 2019, the average daily oil production of each well was 0.9t, the average single well was valid for 326 days, and the average cumulative oil increase of each well was 654t, of which the daily oil production of Well A was 2.4t and the cumulative oil increase was 1384t.

### Table 8. Statistical table of fracture effect of seam net in 2018

| Serial number | Oil well number | Before measures | Initial stage after measures | Now | Current oil increase (t/d) | Cumulative oil increase (t) | Term of validity (d) |
|---------------|----------------|----------------|-----------------------------|-----|--------------------------|----------------------------|---------------------|
|               | Liquid production (t/d) | Produce oil (t/d) | Containing water (%) | Liquid production (t/d) | Produce oil (t/d) | Containing water (%) | Liquid production (t/d) | Produce oil (t/d) | Containing water (%) | Liquid production (t/d) | Produce oil (t/d) | Containing water (%) | Liquid production (t/d) | Produce oil (t/d) | Containing water (%) |
| 1             | Well A          | 1.7            | 0.8                        | 51.0 | 19.8 | 6.1   | 69.2 | 8.2 | 3.2   | 61.0 | 2.4 | 1384 | 383 |
| 2             | Well B          | 1.4            | 1.2                        | 16.0 | 18.1 | 8.6   | 52.6 | 7.6 | 2.3   | 70.0 | 1.1 | 827  | 375 |
| 3             | Well C          | 1.1            | 1.0                        | 12.0 | 9.1  | 6.6   | 27.5 | 2.7 | 2.1   | 22.0 | 1.1 | 626  | 357 |
| 4             | Well D          | 1.1            | 0.9                        | 16.0 | 7.8  | 5.4   | 30.2 | 1.2 | 0.9   | 20.0 | 0.0 | 188  | 355 |
| 5             | Well E          | 1.5            | 0.9                        | 40.0 | 10.3 | 5.8   | 43.5 | 0.0 | 243   | 162  |    |      |     |
|               | A total of 5 wells | 6.8            | 4.8                        | 29.4 | 65.1 | 32.5  | 50.1 | 19.7 | 8.5   | 56.9 | 4.6 | 3268 | 1632 |
|               | Average         | 1.4            | 1.0                        | 29.4 | 13.0 | 6.5   | 50.1 | 4.9 | 2.1   | 56.9 | 0.9 | 654  | 326 |

3.3.1. The effect of fracture net fracturing is better than that of conventional steering fracturing. Compared with conventional steering fracturing in a block, because the scale of fracture-net fracturing is larger than that of conventional fracturing, the sand adding strength is increased from 3.9m³/m to 9.9 m³/m. After fracturing, the daily oil production of a single well is higher than that of conventional fracturing, and the high production time is longer and the fracturing effect is better.

### Table 9. Comparison table of conventional fracturing and fracture network fracturing parameters in a block

| Action type       | Number of wells | Effective thickness (m) | Porosity (%) | Permeability (mD) | Oil saturation (%) | Crude oil viscosity (mpa•s) | Water cut before fracturing (%) | Recovery degree before fracturing (%) | Fracturing fluid consumption (m³) | Sand addition amount (m³) | Sand adding strength (m³/m) |
|-------------------|-----------------|-------------------------|--------------|-------------------|-------------------|---------------------------|----------------------------------|-------------------------------------|-------------------------------|-----------------------------|-----------------------------|
| Conventional frackting | 20              | 11.0                    | 15.2         | 4.8               | 50.3              | 10.3                      | 26.9                             | 12.80                               | 260                          | 48                          | 3.9                        |
| Fracture net fracturing | 5               | 12.6                    | 15.8         | 5.9               | 52.9              | 10.4                      | 26.2                             | 12.85                               | 4446                         | 129                         | 9.9                        |

The average daily oil production of 20 steering fracturing wells is 0.9t before the measures, 3.8t at the initial stage after the steering fracturing, 1.0t before the measures of 5 fracture-net fracturing wells, and 6.5t at the initial stage after the fracture-net fracturing, which is obviously higher than that after the steering fracturing. After 12 months of measures, the average daily oil production of conventional
fracturing wells is 1.2t, and that of fracture network fracturing wells is 1.8t. The effect of fracture net
fracturing is better than that of conventional steering fracturing.

Figure 1. Comparison table of daily oil production between conventional fracturing and fracture-net
fracturing in a block

3.3.2. The water injection situation of water injection wells in fracture network fracturing well area has
been improved obviously. Ten wells are connected with five fracture-net fracturing wells. The average
oil pressure before fracture-net fracturing is 14.8MPa, with daily injection of 13m³. After fracturing, the
initial oil pressure is 13.3MPa, with daily injection of 18m³. At present, the oil pressure is 14.5MPa,
with daily injection of 15m³.

Table 10. Statistical table of changes of connected water wells in fracture network fracturing wells

| Oil well number | Connected well | Injection allocation (m³) | Oil pressure (MPa) | Daily injection (m³) | Oil pressure (MPa) | Daily injection (m³) | Oil pressure (MPa) | Daily injection (m³) |
|----------------|----------------|--------------------------|--------------------|---------------------|--------------------|---------------------|--------------------|---------------------|
|                | Well A         |                          |                    |                     |                    |                     |                    |                     |
|                | Well A         | 1 Well K                 | 15                 | 13.7                | 15                 | 12.5                | 15                 | 13.7                |
|                | Well B         | 2 Well K                 | 15                 | 13.7                | 15                 | 12.5                | 15                 | 13.7                |
|                | Well C         | 3 Well L                 | 15                 | 15.3                | 9                  | 13.2                | 12                 | 15.3                |
|                |                | 4 Well M                 | 35                 | 14.9                | 35                 | 13.6                | 33                 | 14.3                |
|                |                | 5 Well N                 | 20                 | 15.1                | 7                  | 11.9                | 20                 | 15.3                |
|                | Well D         | 6 Well Q                 | 15                 | 15.1                | 8                  | 10.6                | 15                 | 15.3                |
|                |                | 7 Well P                 | 25                 | 13.8                | 25                 | 13.7                | 25                 | 13.3                |
|                |                | 8 Well Q                 | 15                 | 15.2                | 7                  | 14.8                | 15                 | 15.5                |
|                |                | 9 Well R                 | 15                 | 15.4                | 7                  | 14.8                | 15                 | 13.3                |
|                |                | 10 Well S                | 20                 | 15.4                | 5                  | 15.3                | 16                 | 15.5                |
|                | Total: 10 wells|                        | 190                | 14.8                | 13                 | 13.3                | 18                 | 14.5                |
|                | Average        |                          | 19                 | 14.8                | 13                 | 13.3                | 18                 | 14.5                |

Comparing the water absorption profile data of 5 wells, the water absorption layers and thickness of
the whole well have increased, in which the percentage of water absorption layers has increased from
58.3% to 66.7%, and the percentage of water absorption thickness has increased from 58.8% to 64.0%.

3.3.3. The water injection situation of connected wells has a certain influence on the fracturing effect
of fracture network. Compared with the water injection situation of 5 fracturing wells connected to water
injection wells in a block, among them, well E is connected to 3 water injection wells, all of which are
under-injected wells before fracturing, and the cumulative injection-production ratio is only 2.41, which
is lower than the average level of the block. The output of this well drops rapidly within one month after
fracturing, and the effect of increasing production does not reach the expectation.
Table 11. Comparison table of water injection status and oil increase status of fracture network fracturing wells in a block

| Serial number | Oil well number | Thickness (m) | Connected injection well | Initial daily oil increase (t) | Cumulative injection-production ratio | Cumulative water injection(×10⁴m³) | Cumulative oil increase(t) | Cumulative oil increase(t) |
|---------------|----------------|--------------|--------------------------|-------------------------------|--------------------------------------|----------------------------------|----------------------------|--------------------------|
| 1             | Well A         | 7.0          | 7.0                      | 2                             | 3.41                                 | 3.4                              | 5.3                       | 651                      |
| 2             | Well B         | 8.2          | 8.2                      | 3                             | 3.34                                 | 3.16                             | 7.4                       | 467                      |
| 3             | Well C         | 18.4         | 15.0                     | 2                             | 5.21                                 | 2.89                              | 5.6                       | 280                      |
| 4             | Well D         | 14.6         | 14.6                     | 3                             | 2.44                                 | 2.41                              | 4.5                       | 173                      |
| 5             | Well E         | 15.0         | 11.8                     | 2                             | 4.1                                  | 3.32                              | 4.9                       | 147                      |

Figure 2. Oil production curve of single well after fracture of well D and 4 wells in the same block

4. Summary
First, the fracture network fracturing technology provides a technical means for the effective use of difficult-to-produce reservoirs and achieves good results.

Second, the effective time of fracture-net fracturing measures is long, the cumulative oil increase is much, and the effect is obviously better than that of common steering fracturing.

Third, fracture-net fracturing can improve the water injection status of water injection wells in well areas.

Fourth, the water injection situation of connected wells has a certain influence on the fracture net fracturing effect. Before fracture net fracturing, the injection increase measures should be implemented for wells

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