# Analysis and Understanding of the Fracturing Effect of Small Fracture Network in P Reservoir

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**Abstract.** As the oil field enters the medium and high water cut stage, the difficulty of the measures to explore the potential is increasing, the geological conditions of new production wells are getting worse, it is more and more difficult to select wells and layers, and the effect of oil increase is gradually getting worse. In order to improve the effect of oil increase, it is necessary to refine the measures to explore the potential, expand the space of well and layer selection, and optimize the fracturing process. Therefore, we drew on the successful experience of small fracture network fracturing in T oilfield, selected six straight wells for fracturing of small fracture network in the P reservoir of the S oil field, expanded the oil discharge area, raised the seepage capacity of reservoir, and improved the development effect.

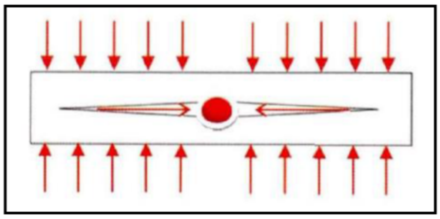
**Keywords:** Fracturing of small fracture network, conventional fracturing, oil increase intensity, input-output ratio.

## 1. Basic Situation

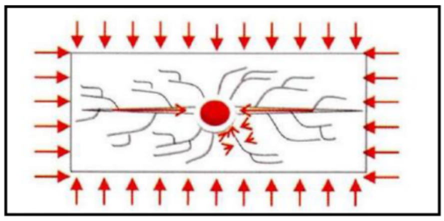
With the development of the oil field, the field has entered the medium and high water cut stage, the geological conditions of new production wells are getting worse and worse, it is more and more difficult to maintain stable production, so fracturing becomes one of the main measures to achieve production and efficiency increase of oil wells. However, as the number of measure wells increases year by year, the potential wells available for fracturing are getting less and less, and the well layer conditions are getting worse, so the effect of oil increase is also getting worse, therefore, it is necessary to refine the measures to explore the potential, expand the space of well and layer selection, optimize the fracturing process, and improve the effect of oil increase.

### 1.1 Fracturing mechanism of fracture network

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 the rock, it is prone to producing bifurcation fracture, and multiple bifurcation fracture will form the "fracture network" system. Among them, the main fracture as the backbone of the "fracture network" system, and the bifurcation fracture may return to the original fracture orientation after extending a certain length apart from the main fracture, finally form the longitudinal and horizontal "mesh seam" system with the main fracture as the backbone, this fracturing technique, which achieves the effect of "netted" fracture system, is called "fracture network fracturing" technology [1].



a. conventional fracturing



b. fracture network fracturing

**Fig.1** conventional fracturing

### 1.2 Comparison between fracture network fracturing and conventional fracturing

The fracture formed by conventional fracturing is single, the seepage area is small, which only expands the well control area; fracture network fracturing can form multiple fractures, expand the oil discharge area, reduce the reservoir seepage resistance, increase the seepage capacity, and improve the development effect.

Since fracture network fracturing requires the large well thickness, large construction scale, high field requirements and high construction costs, it has only been carried out in the Y oil layer, test cannot be carried out in the thin P oil layer. Therefore, by drawing on the advantages of conventional fracturing and fracture network fracturing, increase displacement, increase the construction scale, carry out small-scale fracture network fracturing, and improve development effect in well construction suitable for conventional fracturing.

Judging from the three fracturing ways, the fracturing fluid, sand addition and discharge volume of small fracture network fracturing are between conventional fracturing and fracture network fracturing, and single well fracturing is more expensive than conventional fracturing and can be carried out except in winter.

**Table.1** Comparison table of fracturing construction parameters

| type | fracturing fluid ($m^3$) | sand increase ($m^3$) | displacement ($m^3$/min) | flowback quantity ($m^3$/d) | occupied area ($m^2$) | cost of single well (ten thousand yuan) | seasonal demand |
|---|---|---|---|---|---|---|---|
| conventional fracturing | 160 | 30 | 2.4 | 50 | 3000 | 45 | except for the rainy season |
| small fracture network fracturing | 1200 | single layer 20 | 6-8.0 | 25% | 8000 | 100 | except winter |
| fracture network fracturing | 3500-4000 | 50-120 | 8.0-12 | 25% | 10000 | 300-400 | best before freezing |

### 1.3 Test situation of T oilfield

In recent years, small-scale fracture network fracturing has been carried out in the P oil layer in the T oilfield, the average fracturing effective thickness is 4.3m per well, the oil increase of single well is 2.7t per day at the early stage, the oil increase intensity is 0.63t/d.m, the oil increase of single well of ten months reaches 466t, the input-output ratio is 1:3.1, its effect is significantly better than conventional fracture wells (the oil increase of single well reaches 1.5t at the early stage, the input-output ratio reaches 1:1.2.).

## 2. Fracturing Development of Small Fracture Network

Drawing on the experience of the T oilfield, the fracturing of small-scale fracture network has been carried out in the P oil layer in the S oilfield since 2019, which achieve better results.

### 2.1 Selection principles of small-scale fracture network fracturing

(1) The fluid recovery intensity is high at the early stage of production and the later stage of development decreases progressively

(2) The thickness of the transformed target layer is large; the plane development is stable and the oil-bearing property is good

(3) It is well connected with the surrounding water wells, and the cumulative injection-production ratio is high

(4) The effective thickness of the oil well development is thin, but the surrounding wells develop advantaged sand bodies, or there are horizontal wells around, and the oil well control area is large.

### 2.2 Fracturing test of small fracture network in P oil layer

In 2019, two vertical wells were selected to carry out fracturing tests of small fracture network in P oil layer, the designed half-fracture length is 200m. The early daily oil increase of well A reached 3.6t, the oil increase intensity was 1.20t/dm, the input-output ratio reached 1:1.4, and the oil increase of 15 months reached 727t, the fracturing effect was better than that of conventional fracturing well, (At the early stage, the daily oil increase of single well was 2.4t, the oil increase intensity was 1.09t/d.m, and the input-output ratio reached 1:1.2).Therefore, 4 wells were selected for implementing small fracture network fracturing in P oil layer in 2020.

### 2.3 Fracturing effect of small fracture network

The developed sandstone thickness of fracturing well of selected small fracture network was relatively large, the fracturing sandstone thickness of average single well was 7.0m, and the effective thickness was 2.5m.

The control area of well A was large. well B and C were repeatedly fractured, the reservoir of well D was well developed, oil increase fracturing, advantaged sand bodies were developed around well E and F. Small faults were developed around well F, there is production and without injection, and the cumulative injection-production ratio of the remaining wells was greater than 1.

During fracturing, the fracturing fluid used in single well of was 982$m^3$ on average, the sand increase was 37$m^3$, while the fracturing fluid of conventional fracturing wells was 157$m^3$, and the sand increase was 24$m^3$.

**Table.2** basic data of fracturing wells of small fracture network in 2019 and 2020

| year | well number | category | shot thickness (m) | | fracturing thickness (m) | | average permeability (mD) | recovery degree (%) | connected direction (a) | cumulative injection-production ratio | fracturing data ($m^3$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | sandstone | effective | sandstone | effective | | | | | fracturing fluid | sand increase |
| 2019 | A | large control area | 5.5 | 3.0 | 5.5 | 3.0 | / | 14.0 | 1 | 1.04 | 829 | 40 |
| | B | refracturing | 6.2 | 2.7 | 6.2 | 2.7 | 10.2 | 15.9 | 2 | 2.70 | 820 | 20 |
| 2020 | D | oil increase fracturing | 7.6 | 3.8 | 5.8 | 3.8 | 63.5 | 2.1 | 2 | 1.46 | 816 | 24 |
| | E | connected advantaged phase | 8.2 | 1.6 | 8.2 | 1.6 | 59.7 | 7.2 | 1 | 2.67 | 1264 | 68 |
| | C | refracturing | 7.4 | 1.7 | 7.4 | 1.7 | 11.3 | 26.2 | 1 | 1.47 | 921 | 24 |
| | F | connected advantaged phase | 9.0 | 2.1 | 9.0 | 2.1 | 19.9 | 6.3 | 0 | 0 | 1240 | 48 |

It can be seen from the fracturing effect of small fracture network that the early average daily oil increase of the single well is 3.5t, the fluid increase intensity is 2.43t/d.m at the early stage, and the oil increase intensity is 1.39t/d.m.

**Table.3** Effect of fracturing wells measure of small fracture network in 2019 and 2020

| year | well number | before measures | | | after measures | | | daily oil increase at the early stage (t) | production increase intensity (t/d.m) | | cumulative oil increase (t) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | liquid production (t/d) | oil production (t/d)) | moisture content (%) | liquid production (t/d)) | liquid production (t/d) | moisture content (%) | | fluid increase | oil increase | |
| 2019 | A | 1.7 | 1.5 | 13.0 | 5.8 | 5.1 | 12.0 | 3.6 | 1.37 | 1.20 | 727 |
| | B | 1.4 | 0.9 | 37.0 | 6.1 | 3.3 | 46.5 | 2.4 | 1.74 | 0.89 | 346 |
| 2020 | D | 2.5 | 1.9 | 23.0 | 6.8 | 5.6 | 18.0 | 3.7 | 1.13 | 0.97 | 425 |
| | E | 1.5 | 1.0 | 36.9 | 10.4 | 4.0 | 61.9 | 3.0 | 5.56 | 1.88 | 192 |
| | C | 0.5 | 0.3 | 32.0 | 4.8 | 3.9 | 18.0 | 3.6 | 2.53 | 2.12 | 322 |
| | F | 2.4 | 1.8 | 27.0 | 12.6 | 6.3 | 49.9 | 4.5 | 4.86 | 2.14 | 476 |

## 2.4 Comparison of effects between small fracture network fracturing and conventional fracturing

### *2.4.1 Comparison of refracturing wells*

According to statistics, 11 wells in the Z oilfield have been routinely repeatedly fractured, compare with the small fracture network repeated fracturing well C: the effective thickness of well C is 1.7m, and the fluid production intensity is only 0.29t/d.m. During fracturing, the fracturing fluid was 921m$^3$, and the sand increase was 24m$^3$; while conventional fracturing, the average single well fracturing fluid was 125m$^3$ and the sand increase was 22m$^3$.

The fluid increase intensity (2.53t/d.m) of well C is 1.85 times that of conventional fracturing, and the oil increase intensity (2.12t/d.m) is 2.90 times that of conventional fracturing. After fracturing four months, the cumulative oil increase per unit thickness is 188t/m, it is 2.58 times that of conventional refracturing wells. The oil increase in 4 months was 322t, due to the short statistical time, the production output proportion is only 1:0.70, it is worse than conventional fracturing (1:1.0).

**Table.4** Effect comparison of small fracture network fracturing and repeated fracturing

| category | well number | fracture thickness | | before measures | | | after measures | | | production increase intensity (t/d.m) | | cumulative oil increase per unit thickness in the same time (t/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | sandstone (m) | effective (m) | fluid production (t/d) | oil production (t/d) | moisture content (%) | fluid production (t/d) | oil production (t/d) | moisture content (%) | fluid increase | oil increase | |
| repeated fracturing | 9 | 4.7 | 3.0 | 1.4 | 0.9 | 39.1 | 5.5 | 3.1 | 43.1 | 1.37 | 0.73 | 73 |
| small fracture network fracturing | 1 | 7.4 | 1.7 | 0.5 | 0.3 | 32.0 | 4.8 | 3.9 | 18.0 | 2.53 | 2.12 | 188 |

### *2.4.2 Comparison of primary fracturing wells*

The small fracture network fracturing wells and primary fracturing wells are compared (medium and low water cut) in 2020: the fracturing fluid of small fracture network fracturing single well is 1107m$^3$, sand increase is 47m$^3$; the fracturing fluid of primary fracturing single well 168m$^3$, and sand increase is 25m$^3$.

The oil increase of the small fracture network fracturing well is 3.7t at the early stage, it is higher than that of primary fracturing (2.7t); the early fluid increase intensity (3.12t/dm) is 1.87 times that of primary fracturing, and oil increase intensity (1.48t/dm) at the early stage is 1.31 times that of primary fracturing, and the cumulative oil increase per unit thickness (126t/m) in the same time is 1.88 times that of primary fracturing. The oil increase of single well is 364t in 4 months, due to the short statistical time, the production output ratio was only 1:0.68, which was worse than primary fracturing (1:0.76).

**Table.5** Effect comparison of small fracture network fracturing and primary fracturing

| category | well number | fracture thickness | | before measures | | | after measures | | | production increase intensity (t/d.m) | | cumulative oil increase per unit thickness in the same time (t/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | sandstone (m) | effective (m) | fluid production (t/d)) | oil production (t/d) | moisture content (%) | fluid production (t/d) | oil production (t/d) | moisture content (%) | fluid increase | oil increase | |
| primary fracturing | 27 | 7.0 | 2.4 | 1.5 | 1.2 | 21.0 | 5.5 | 3.9 | 29.4 | 1.67 | 1.13 | 67 |
| small fracture network fracturing | 3 | 7.7 | 2.5 | 2.1 | 1.6 | 26.6 | 9.9 | 5.3 | 46.6 | 3.12 | 1.48 | 126 |

## 2.5 Comparison of the fracturing effect of small fracture network in the past two years

The design half-fracture length of small fracture network fracturing wells in 2019 and 2020 are both 200m, but the effective fracturing thickness of fracturing wells in 2020 is smaller than that in 2019, but the fracturing scale of is larger than that in 2019-single well fracturing used 1060m$^3$ of fracturing fluid and 41m$^3$ of sand increase in 2020, single well use 825m$^3$ of fracturing fluid and 30m$^3$ of sand increase in 2019.

The fracturing effect of small fracture network in 2020 is better than that in 2019. In 2020, the fluid increase intensity of single well is 3.04t/d.m at the early stage, and the oil increase intensity is 1.61t/d.m. In 2019, the initial fluid increase intensity of single well is 1.52t/d.m at the early stage, and the oil increase intensity is 1.03t/d.m.

**Table.6** Comparison condition of fracture network fracturing wells in 2020 and 2019

| year | fracturing thickness (m) | | fracturing data ($m^3$) | | oil increase at the early stage (t/d)) | production increase intensity (t/d.m)) | |
|---|---|---|---|---|---|---|---|
| | sandstone | effective | fracturing fluid | sand increase | | fluid increase | oil increase |
| 2019 | 5.9 | 2.9 | 825 | 30 | 3.0 | 1.52 | 1.03 |
| 2020 | 7.6 | 2.3 | 1060 | 41 | 3.7 | 3.04 | 1.61 |

## 3. Conclusion

(1) The construction scale and cost of small fracture network fracturing in P oil layer are between conventional fracturing and fracture network fracturing.
(2) The scale of small fracture network fracturing is larger than that of conventional fracturing. Compared to first conventional fracturing wells, the oil increase intensity of small fracture network fracturing wells at the early stage is 1.31 times that of conventional fracturing. Compared to conventional re-fracturing wells, the oil increase intensity of small fracture network fracturing wells at the early stage is 2.90 times that of conventional fracturing.
(3) For the same small fracture network fracturing well, the increase of fracturing scale will make the oil increase effect become better. The fracturing scale increased in 2020, and the oil increase intensity of single well at the early stage was 1.56 times that of 2019.

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