Network Fracturing Techniques Research and its Application in Sandy Conglomerate Reservoir

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Abstract. The permeability of sandy conglomerate reservoir in Erlian Basin is low, and its heterogeneity is very strong, and that its connectivity is bad. The shape of hydraulic fracture in sandy conglomerate reservoir is not regular, and a lot of complicated fracture will be forming in the process of fracturing operation. The effect will not be good when applying common fracturing techniques. Aiming at the pay sand characteristic in BA101x reservoir of Baolige Oilfield, we use some technological means to evaluate brittle index and analyze stress profile; we establish fracture design method which suits sandy conglomerate of research area and develop low damage fracturing fluid which has energy storage function. The research achievement is applied in BA77-30x well, using fluid 2201m³ and proppant 112m³. The SRV is about 111×10⁴ m³. The well produces 258 day and the cumulative production is about 2393t (4.8 times comparing with common fracturing techniques). It is observed that the effect of network fracturing techniques is better than common techniques.

1. Background
Sandy conglomerate reservoir distributes in Erlian Basin. Influenced by sedimentary environment, sandy conglomerate reservoir has the characteristic that its permeability is low and heterogeneity is very strong, and its connectivity is bad. According to preliminary study, the hydraulic fracture in sandy conglomerate reservoir is not simple symmetrical but complicated network. Obviously, it is not the same to sandstone reservoir. In the process of fracturing operation, the leak-off velocity is fast and the treating pressure fluctuates fiercely resulting in high risk of sand fracturing. The production effect is good in initial stage but the production decreases progressively. The stable production period is short, and daily average production is about 1t. Therefore, it is very necessary to study fracturing technology to improve the develop effect of sandy conglomerate reservoir.

2. The characteristic of sandy conglomerate reservoir
The permeability of Wuliyasitai Oilfield is about (0.1-5)×10⁻³μm² and the porosity is 5%-10%. This oilfield belongs to low permeability reservoir (Fig. 1). Through investigating a large amount of core
data, the gravel doesn’t distribute well-proportioned. According to rate-controlled mercury penetration data, distribution frequency of throat radius has obvious differences (Fig. 2, Fig. 3).

3. The feasibility analysis of Network fracturing

3.1 brittle index
Brittle index is the characterization of transient state before rock failure. The research fellow has already carried out a great amount of work in computing method of brittle index. And the relationship of brittle index and complicated network is also discussed.

Mineralogy method has already became classic model. Based on the whole rock analysis results, the mineral composition is confirmed. The main mineral includes clay mineral, quartz, calcite, feldspar, dolomite. Using the equation below to compute:

\[ \beta = \frac{C_{\text{quartz}}}{C_{\text{quartz}} + C_{\text{clay}} + C_{\text{carbonate}}} \]

in the equation, \( \beta \) — Brittle index, \%; \( C_{\text{quartz}} \) — quartz content, \%; \( C_{\text{clay}} \) — clay content, \%; \( C_{\text{carbonate}} \) — carbonate content, \%

Based on experimental data of Aershan Formation in BA101 reservoir (Tab. 1), the brittle index is about 69%. It is stated that the reservoir has brittle characteristic if the computing result is greater than 40%. Obviously, the brittle characteristic of Aershan Formation is very strong. The rock crushed easily and it is easier to form complicated network.

| Sample | Depth (m) | mineral composition and content(%) |
|--------|-----------|-----------------------------------|
|        |          | clay | quartz | Potash feldspar | plagioclase | calcite | dolomite | pyrite | analcime |
| 1      | 1940      | 10   | 47     | 6              | 26          | 11      |
| 2      | 1983      | 9    | 54     | 8              | 20          | 9       |

3.2 stress profile
It is very important that the hydraulic fracture shape is influenced by the difference value of maximum and minimum principal stress. The bigger the difference value is, the easier the main hydraulic fracture is formed. The smaller the difference value is, the easier the fracture network is formed. If the difference value is relative large, we can optimize perforating design and adjust fracturing parameter to improve net pressure. It is easier to form fracture network.
Collecting logging data, including SP, R, AC, COND, GR, DEN, CAL, we use software to curve the stress profile.

For example, stimulation interest interval of BA77-21x well is Aershan Formation. Depth is 2110-2131m, stress gradient is 0.016MPa/m, and the difference value is 5.3MPa. It is easier to form fracture network according the computing result (Fig. 4).

**Figure 4.** Stress profile of BA77-21x well.

### 4. hydraulic fracture propagation

Understanding the rule of hydraulic fracture propagation is significant because it can provide theoretical basis to specific measures. Use true triaxial equipment to test hydraulic fracture propagation. Based on the experimental result, we can observe fracture shape and study the rule of propagation in sandy conglomerate reservoir.

The sample size is 30cm×30cm×30cm; the stress difference value is 10MPa and 5MPa; the liquid viscosity is 120mPa·s and 2.5mPa·s; the displacement is 20mL/min and 50 mL/min.

The complicate fracture can be formed in the condition of smaller stress difference value or lower viscosity liquid. The amount of hydraulic fracture will increase while the rate increasing.

As shown, the Fig.5a is the appearance of sample through the test, and the experiment condition is that the stress difference value is 5MPa, the liquid viscosity is 2.5mPa·s, the displacement is 50 mL/min. We can observe that secondary fracture develop and fracture network is complicate. The treating pressure starts to increase gradually after the main fracture forming (Fig. 5b). We can split the sample and find that the penetration phenomenon, encircling phenomenon, fracture-ceasing phenomenon appears (Fig. 6).

**Figure 5.** The experiment of hydraulic fracture propagation in sandy conglomerate reservoir.

**Figure 6.** The photograph of sample.

According to the experiment of hydraulic fracture propagation and stress profile interpretation result, the stress difference value of BA101x reservoir is about 5MPa. The complicate fracture network will form in the condition of using lower viscosity liquid and large displacement.
5. Optimization of fracturing design

5.1 Design concept
Referring to network fracturing model of tight oil and gas reservoir and aiming at increasing SRV, we take some effective measures to break the reservoir and shorten migration tunnel. Taking advantage of the heterogeneity of sandy conglomerate reservoir and optimizing proppant injecting model, the complicate network fracturing will form by using lower viscosity liquid and large displacement.

![Figure 7. The photograph picture of target network fracture.](image)

5.2 Stimulation model
In the process of developing the sandy conglomerate reservoir, we usually use vertical well completion mode and the productive casing size is 5.5 inch. The thickness of sandy conglomerate in BA101x reservoir is about from 40 to 100 meter and pressure coefficient is relative low. Aiming at the characteristic of reservoir, we confirm the stimulation model that is about using case injecting, using a large amount of liquid, having storing energy function, injecting fracturing fluid accompany with variable displacement and different size ceramic proppant, closing well a certain time after fracturing.

5.3 Design optimization of injection procedure
The target is forming the best hydraulic network and high flow conductivity main fracture. There are two stage to carry out.

The first stage is that use low viscosity fluid to generate fracture network. Natural crack is connected by hydraulic fracture and those fractures propagate continuously. Shear action and slippage phenomenon of stratum is promoted. Then, complicated fracture network is formed.

The second stage is that use middle viscosity fluid to propagate main fracture continuously. The big size ceramic propppant is injected into reservoir accompany with fracture fluid. Finally, high flow conductivity main fracture is formed (Fig. 8).

![Figure 8. The design scheme of network fracturing of sandy conglomerate reservoir.](image)

5.4 Low damage fracturing fluid which has energy storage function
The fracturing fluid is carrier of generating fracture and sand-carrying. Also, it is key composition of fracturing operation. A large amount of fluid is injected into stratum. In the condition of ensuring operation successfully, the fracturing fluid system needs to optimize continuously and reduce
formation damage. A large amount of fracturing fluid is advantage because it can supply lots of energy to stratum. The favorable surfactant should be selected and its performance is good in order to make fracturing fluid have energy storage function and good oil displacement effect (Fig. 9).

![Figure 9. Performance test of surfactant.](image)

Low damage fracturing fluid which has energy storage function is optimized by experiment. Making fracture network needs low viscosity liquid which is call slickwater and shaping high flow conductivity main fracture needs the crosslinked fracturing fluid. The liquid formula is as follows:

(1) slickwater liquid formula:
- $0.1\%-0.2\%$ gelling agent + $0.4\%-0.6\%$ cleanup additive + $0.1\%-0.3\%$ demulsifier + $0.4\%-0.6\%$ clay stabilizer + $0.02\%-0.1\%$ bactericide;

(2) crosslinked fracturing fluid:
- $0.3\%$ gelling agent + $0.4\%-0.6\%$ cleanup additive + $0.1\%-0.3\%$ demulsifier + $1\%$ potassium chloride + $0.5\%$ clay stabilizer + $0.05\%-0.1\%$ bactericide;

In comparison with common fracturing fluid, fracturing fluid which has energy storage function has good wetting effect and good oil displacement effect. At the same time, the residue of fracture liquid we develop is low and it has low damage to the formation (Tab. 2). The fracturing effect can be promoted at a certain extent.

![Table 2. The performance test of Low damage fracturing fluid which has energy storage function.](image)

6 Field application

The reservoir thickness of BA77-30x well is about 41.2m. The perforating depth is 2105-2125m and thickness is 20m. According to of logging interpretation this well, the target stratum of stimulation is in the bottom of the sand body. Some effective measures should be taken to prevent the hydraulic fracture extend to top (Fig. 10). The pressure factor of this well is 0.78 and it shows that the energy is low.

![Figure 10. The logging interpretation of BA77-30x well.](image)

There are two wells which are BA77-25x well and BA77-32x well around BA77-30x well. And well spacing is about 380-400m. Therefore, the length of fracturing network is 300-320m and the height is 40-45m.

There are four sets of design schemes being made and the scheme C is selected (Tab. 3). The simulation result of scheme C is shown as Fig. 11.
Table 3. Four different design schemes.

|                  | Scheme A | Scheme B | Scheme C | Scheme D |
|------------------|----------|----------|----------|----------|
| Proppant(40/70 mesh), m³ | 10       | 15       | 20       | 20       |
| Proppant(30/50 mesh), m³ | 20       | 35       | 40       | 40       |
| Proppant(20/40 mesh), m³ | 40       | 50       | 50       | 60       |
| Slickwater, m³    | 1340     | 1738     | 1768     | 2005     |
| Base fluid, m³    | 310      | 367      | 506      | 425      |
| Total liquid mount, m³ | 1650     | 2105     | 2274     | 2430     |
| Half of long axis, m | 110.51   | 140.68   | 167.32   | 170.54   |
| Half of short axis, m | 31.56    | 40.31    | 43.57    | 48.23    |
| Height, m         | 43.8     | 44.3     | 45.6     | 47.2     |
| Width, mm         | 3.58     | 4.13     | 4.46     | 4.81     |
| Treating pressure, MPa | 21.7     | 22.5     | 23.2     | 25.7     |

(a) vertical view of the fracture network  
(b) width profile

Figure 11. The simulation result of scheme C.

In the process of fracturing operation, the biggest rate is 12.4 m³/min; the treating pressure is 21-23MPa; the volume of injecting fluid is 2201 m³; the volume of proppant using is about 112 m³. And the SRV is 111×10⁴ m³ by monitoring (Fig.12 and Fig. 13).

Figure 12. Fracturing curve of BA77-30x well.  
(a) vertical view  
(b) side view

Figure 13. The fracturing monitoring result.

The well is closed 7 days after fracturing. And the well is in flowing production at early stage of development. Effective production time is about 258 days until 28 Feb, 2018 and the cumulative producing oil volume is 2393 t. BA77-25x well, which is the adjoining well of BA77-30x, uses common frac technology to stimulate and its cumulative producing oil volume is 499 t (producing time is 258 days). It is observed that the effect of network fracturing techniques is better than common techniques.

7 Conclusion and Suggestion
(1) In the condition of smaller stress difference value, complicate fracture network is easier to be formed by using lower viscosity liquid; The amount of hydraulic fracture will increase while the rate increasing.
(2) The amount of hydraulic fracture will be formed by using fracture network technology and SRV is very large, but the most important fact is that it is obviously that the production is better than using common fracturing technology.
(3) It provides an effective method to stimulate sandy conglomerate reservoir and the technology has significance at a certain degree.
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