Research on Optimized Penetration Ratio Fracturing Technology for Transition Zone

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Abstract. The geological reserves of the Sazhong transition zone are $10046 \times 10^4$ t, accounting for 12.5% of the Sazhong development zone. The effect of fracturing stimulation in this block is of great significance for the stable production of the Sazhong oilfield. The transition zone has the characteristics of low porosity, low permeability and low oil saturation. The crude oil has three high and one low characteristics: high viscosity, high wax content, high freezing point and low sulfur content. In the transition zone, due to poor physical properties of the oil layer, unbalanced formation pressure, high proportion of low-yield and low-efficiency wells, and energy replacement of thin oil layers, it is difficult to tap the potential of the production increase measures, and the effect of the measures is getting worse year by year. According to statistics, since the transition zone has 40 fractured oil wells since 2009, the fracturing process is general pressure and multi-crack, and the average pressure is 3 layers and 1 slit. The average average sand volume of single seam is 7.1m³, the average sand ratio is 25.7%, and the penetration ratio is only 14.1%. The average initial liquid increase after fracture is 20.4t, and the average initial daily oil increase is only 2.5t. Therefore, the study of transition zone fracturing technology can improve the overall development effect of the block, which is of great significance for the sustainable high yield and stable production of the Sazhong Oilfield.

Keyword: Transition zone, optimized penetration ratio, fracturing technology.

1. Introduction

The geological reserves of the Sazhong transition zone are $10046 \times 10^4$ t, accounting for 12.5% of the Sazhong development zone. The effect of fracturing stimulation in this block is of great significance for the stable production of the Sazhong oilfield. The transition zone has the characteristics of low porosity, low permeability and low oil saturation. The crude oil has three high and one low characteristics: high viscosity, high wax content, high freezing point and low sulfur content. In the transition zone, due to poor physical properties of the oil layer, unbalanced formation pressure, high proportion of low-yield and low-efficiency wells, and energy replacement of thin oil layers, it is difficult to tap the potential of the production increase measures, and the effect of the measures is getting worse year by year. According to statistics, since the transition zone has 40 fractured oil wells since 2009, the fracturing...
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2. The transition zone fracturing effect influencing factors and determine the engineering parameters

2.1. Establishment of fuzzy recognition mathematical model

The block diagram of the fracturing well selection layer using the fuzzy identification method is shown in Figure 1

![Figure 1](image1)

**Figure 1.** Principle of applying fuzzy identification theory to fracturing well selection.

2.2. Determination of the range of characteristic parameters of fracturing wells

Through the mathematical statistics and analysis of the effective period of the fracturing well layer, the range of ideal characteristic parameters of each development layer is discussed. According to the fuzzy recognition algorithm, the Euclidean closeness values of Sa, 1, and 2 were calculated. The Euclidean closeness range is determined to satisfy the post-press validity period of more than 20 months, and the Euclidean closeness value of each layer is preferred according to the standard.

3. Study on optimization of fracturing penetration ratio and conductivity of transition zone

The East and West transition zones are divided into 70%-80%, 80%-90%, and more than 90% water saturation regions. Combining the well pattern and the well spacing with the length ratio of the seam as the variable, the reasonable seam length ratio is determined by numerical simulation and considering factors such as initial oil increase, cumulative oil increase, recovery degree and water content.

In the case of water-containing 80-90%, the fracture conductivity is preferably $10 \mu m^2 cm$, $20 \mu m^2 cm$, $30 \mu m^2 cm$, $40 \mu m^2 cm$, $50 \mu m^2 cm$. Based on the optimum crack penetration ratio of the extraction degree, it can be seen from Fig. 2 and Fig. 3 that the optimum seam length ratio is about 30%; and the water content at this slit length ratio is the lowest.

![Figure 2](image2)

**Figure 2.** Optimizing the seam length ratio curve based on the degree of recovery.
Figure 3. Optimization of seam length ratio curve based on water content.

The slit is longer than 30% of the fracturing prediction curve in FIG. 2 Yield after pressing - in Figure.

4. Development of transition zone low damage fracturing fluid system

4.1. Transition zone fluid characteristics and crude oil properties
The Sazhong transition zone has the characteristics of porosity, low permeability and low oil saturation. The reservoir space of the reservoir is dominated by primary pore intergranular pores, with porosity of 24.4 % to 25.2 % and original oil saturation of 65.5 % to 68.2 %. Oily production is diverse, and thick oil layers are mostly oil-rich and oil-rich. The thin oil layers and outer layers are mainly oil-immersed and oil-spotted.

4.2. Preferred low residue fracturing fluid to optimize fracturing additives
The fracturing fluid is made of modified silicone fracturing fluid. The cross-linking ratio is 100:1 +0.05% demulsifier. The residue content, gel breaking performance and fluid loss performance can meet the requirements of the index. See Table 1.

| Table 1. Main performance table of modified silicone fracturing fluid. |
|---------------------------------------------------------------|
| Term project | It refers to the standard | Modified silicone fracturing fluid |
|---------------|----------------------------|-----------------------------------|
| Base viscosity mpas | ≥ 33 | Less than 25 |
| Gel cut 30min viscosity (mpas) | ≥ 150 | 137 |
| Breaking performance (mpas) | 24h viscosity is less than 10mpas | 1h viscosity 3.6mpas |
| Residue content (mg/l) | ≤ 400 | 134 |
| Flow behavior index | 0.2-0.7 | 0.51 |
| Breaking liquid surface tension (mN/m) | ≤ 30 | 27.9 |

Was added 1.5% of the pre-foamed high flowback agent, 2.5% PB-1 reducing agent to improve the rheology of the formation fluid, the pressure of each slit opening slits to 1M. 3 / min displacement flowback foaming agent was added 1 250 kg , then into the pre-liquid, while adding 25 kg of potassium persulfate breaker , the remaining 100 kg of potassium persulfate from the sanding to the end of the sand at the end of the wedge addition , from the last step of sanding to add sodium sulfite 10kg to add The sand ends.
After the end of the fracturing construction, the technology of rapid breaking and forced returning was adopted. After the fracturing, the well was shut down for 40 minutes, and the 10 mm nozzle was used to control the discharge. The average fracturing fluid return rate reached 65%.

5. Transition zone fracturing field test and effect analysis
Due to the poor connectivity of the sandstone body and the lack of connectivity of the reservoir, the oil-water well is difficult to establish effective driving and the conventional water injection development is difficult. Therefore, the large-scale fracturing transformation changes the seepage mode in the reservoir, as shown in Figure 4. Shown.

Through the large-scale fracturing transformation, the crack propagation range is expanded, and the formation fluid radial seepage into the wellbore is changed into linear seepage into the crack, reducing the seepage distance and resistance. Apply the maximum reach and design penetration ratio to achieve a reasonable match between sanding scale and sand body.

5.1. Exploring the 50% penetration ratio fracture test of super large sand
Three wells with a spacing of 150m were selected for comparison test. The designed crack penetration ratio was 50%. The data of the fracturing interval are shown in Table 4.

In terms of long-term effects, the Dong 71-19 well with low sand ratio construction is more stable. After 23 months, the daily oil production is 8.84t, the daily production liquid is 203t, and the cumulative oil increase is 4446t.
5.2. Explore 30-40% penetration ratio fracture test
Three wells with different well spacings were selected for comparative tests. The designed crack penetration ratios were 30-40%, respectively, and the optimized penetration ratio fracturing tests under different well spacings were explored. The initial effect is shown in the table.

5.2.1. Test well fracturing analysis

| Hashtag        | Pump diameter | Before pressing | After pressing | Difference value |
|----------------|----------------|----------------|----------------|------------------|
|                |                | Production fluid t/d | Oil production t/d | Watery % | Production fluid t/d | Oil production t/d | Watery % |
| Medium 82-76   | ∅57mm          | 15             | 0.41           | 97.3       | 65.5             | 5.6           | 91.5       | 50.5     | 5.2     | -5.8 |
| East 41-15     | ∅57mm          | 2              | 0.1            | 97.5       | 82.9             | 7.5           | 91         | 80.9     | 7.4     | -6.5 |
| West 42-10     | ∅44mm          | 9.2            | 0.8            | 91.5       | 22.8             | 1.9           | 91.8       | 13.6     | 1.1     | 0.3  |
| average        |                | 8.7            | 0.4            | 95.4       | 57.1             | 5.0           | 91.4       | 48.3     | 4.6     | -4.0 |

The well is 6.4m in diameter and 2.4m effective. It has the same single layer sanding 60m 3 as the East 71-19, but the sand ratio is 25% (17% in the East 71-19 well), and the penetration ratio is 10% lower. The effect is quite good. From the long-term effect, its high-yield period is shorter than 18 months, and the cumulative oil-increasing effect is poor. Therefore, for wells with poor oil layer conditions, low sand ratio control and high penetration ratio construction fracturing effect are good.

5.2.2. East 41-15 test effect. The well is 7.8m open and 4.7m effective, with an initial daily oil increase of 6.2t. It has been producing smoothly for 9 months and currently produces 7.42t of oil per day. It can be seen that the development thickness of the reservoir sand body is the premise of ensuring the effect of the measures; the single-plate single-pressure small layer is more conducive to improving the fracturing effect of the test well; the sand body is well developed, and the single layer 20m 3 can also be obtained under the single-card single-pressure condition. Good test results.

| Hashtag        | Layer number | Well spacing m | Liquid volume m³ | Displacement m³/min | Sand ratio % | Sand volume m³ | Seam length m | Penetration ratio % |
|----------------|--------------|----------------|------------------|--------------------|--------------|----------------|----------------|--------------------|
|                | Sa II1       | 150            | 94               | 3                  | 25           | 18             | 43.7           | 30                 |
| East 41-15     | Sa II4 ~ 5+6 | 150            | 94               | 3                  | 25           | 18             | 43.7           | 30                 |
|                | Sa III3-4    | 150            | 104              | 3                  | 25           | 20             | 46.1           | 30                 |
|                | Sa III7      | 150            | 94               | 3                  | 25           | 18             | 43.7           | 30                 |
| Subtotal       |              | 386            | 25               | 76                 |

5.3. Analysis of the effect of fracturing measures
In the transition zone, 6 wells were tested, with an average shot of 9.2m for sandstone and 2.8m for launching. The average daily oil increase was 5.02 tons. Compared with the conventional conventional fracturing, the oil increased by 2.6t. The oil-increasing strength is higher than that of conventional fracturing wells. High 1.8t/dm. It is 1471t higher than the conventional fracturing well and the effective period is extended by 11.8 months.
Table 4. Large-scale fracturing wells in the transition zone.

| Hashtag | Before pressing | After pressing | Difference value | Cumulative oil increase | Validity period m |
|---------|----------------|---------------|------------------|------------------------|------------------|
|         | Production fluid t/d | Oil production t/d | Moisture % | Production fluid t/d | Oil production t/d | Watery % | Production fluid t/d | Oil production t/d | Watery % |                       |
| Medium 82-76 East | 15 | 0.41 | 97.3 | 65.5 | 5.6 | 91.5 | 50.5 | 5.2 | -5.8 | 1339 twenty three |
| East 71-19 East 52 oblique 16 East 71- Oblique 24 | 6.5 | 0.26 | 96 | 84.9 | 5.8 | 93.1 | 78.4 | 5.5 | -2.9 | 4446 |
| East 41-15 | 2.4 | 0.02 | 99 | 94.4 | 6 | 93.7 | 92 | 6.0 | -5.3 | 1911 |
| West 42-10 | 8.3 | 0.95 | 93.3 | 75.8 | 6.0 | 92.1 | 67.5 | 5.0 | -1.2 | 1771 |
| average | 8.3 | 0.95 | 93.3 | 75.8 | 6.0 | 92.1 | 67.5 | 5.0 | -1.2 | 1771 |

Figure 6. Increased liquid

6. Analysis of economic benefits

6.1. Input
In the transition zone, the single layer of the fracturing oil well increased the sand volume by 41.5m³, and the six wells increased the input by 2.863 million yuan, the average single well was 940,000 yuan, which was 560,000 yuan more than the conventional fracturing fee of 380,000 yuan in the transition zone. A total of 3.36 million yuan.

6.2. Economic benefits
At present, the average effective period is 15.8 months, the average single well oil increase is 1771t, which is 1471t higher than that of conventional fracturing wells, the average oil increase is 0.8826×10⁴t, the crude oil price is 5003.44 yuan, and the production operation cost is calculated as 1135.98 yuan. Can be realized: economic benefits of oil increase = 8826×(5003.44-1135.98) = 34.135 million yuan, the current input-output ratio of 1:10.2.

7. Conclusion and understanding
(1) The transition zone fracturing should comprehensively consider and quantify the parameters of the fracturing interval and determine the fracturing timing based on the Euclidean closeness value.
(2) Large-scale fracturing can improve the production capacity of low-yield wells in the transition zone. The low-sand ratio control and high-penetration ratio construction fracturing effect is better. It is better not to rebuild the single well in the Sa-I oil layer. The oil layer is combined and modified.

(3) The transition zone uses low-residue modified silicone fracturing fluid to add high-efficiency foaming backflow agent and viscosity reducer, which can improve the effect of the measures and prolong the effective period of the measures.

(4) Through the comparative analysis of the effects of the measures, the optimized penetration of the transition zone is better than that of the fracturing, and the economic benefits are obvious, which has broad application prospects.

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