Re-Fracturing Technology Research and Application for Low Permeability Reservoirs in Huabei Oilfield

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Abstract. The research on the mechanism of repeated fracturing fractures shows that the pressure drop caused by the initial fracturing fractures and the production activities of the oil layer in the repeated fracturing wells leads to changes in the stress field near the well, which causes the fractures to re-fract during the repeated fracturing process. Combining with the low permeability characteristics of Tongxi fault block reservoir in North China Oilfield, optimization of repeated fracturing parameters and selection of fracturing materials were carried out, and the principle of well selection and layer selection was put forward. The repeated fracturing technology was successfully implemented in the Tong47-43x well and achieved a good oil-increasing effect, which provided important technical measures for the next development of the Tongxi fault block reservoir.

1. Introduction
Hydraulic fracturing technology is an important measure to increase and stabilize production of low-permeability reservoirs, and it has been widely used in oil fields. For low-permeability reservoirs, the formation energy decreases with the continuous production of underground crude oil, causing the gradual closure of support fractures or proppant rupture and embedding, particle migration, and formation pollution caused during production operations, which caused the previous fracturing. The crack gradually failed. In order to improve the effect of reservoir development, it is necessary to carry out repeated fracturing. In recent years, many authors at home and abroad have done a lot of work in the research of repeated fracturing theory, technological improvement and mineral deposit application. Studies believe that after repeated fracturing of oil and gas wells, new fractures formed around the wellbore and initial fractures, more natural fractures that communicate with each other, and areas where the initial fractures were not used form a new fracture drainage system, which improves the fluid flow channels in the reservoir. The Tongxi fault block is located in the northwestern part of the Wanzhuang structure. It is a fault block trap cut by multiple faults. The main fault runs in the NE-SW direction. The structural high points are distributed along the upper fault edge of the fault, and the trap range is large. The strata encountered in the fault block from top to bottom are the Quaternary Pleistocene Plain Formation, the Upper Tertiary Pliocene Minghuazhen Formation, the Lower Tertiary Oligocene Shahejie Formation, Sha 1, Sha 2, Sha 3 upper section, Sha 3 middle section and Sha 3 lower section. The main oil-producing interval is the middle part of Shahejie Formation, and the lower Es33 and Es34-1 are the main oil intervals. The lithology is mainly detrital feldspar sandstone, with an
extremely fine-grained structure, and some fine-grained and extremely fine sandy fine-grained structures. The average porosity of the reservoir rock is 20.0%, the average permeability is 7.18 mD, and the reservoir is a medium porosity and low permeability reservoir. In order to further improve the development effect of the Tongxi fault block reservoir, through repeated fracturing mechanism research and implementation in the block, the oil increase effect is significant, which provides a new idea for the next development of this area.

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2. Mechanism Research

According to the theoretical principles of rock mechanics and hydraulic fracturing mechanics, hydraulic fracturing fractures are generated along the direction perpendicular to the minimum principal stress. In re-fracturing wells, due to the stress field distribution of the initial supporting fractures and natural fractures, and the change in pore pressure caused by production activities, the stress changes near the wellbore, resulting in an induced stress field, which is in the two horizontal principal stress directions. All additional induced stress. This stress field distribution determines the initiation and extension of new fractures in repeated fracturing [4]. The maximum induced stress is equal to the net pressure on the proppant after the fracture is closed [5], the stress is perpendicular to the initial supporting fracture, and the minimum induced stress is parallel to the initial supporting fracture. Near the wellbore, new fractures will begin to crack at the weakest point of stress. If the two horizontal principal stresses are equal to the elliptical area around the wellbore and the initial fracture, the sum of the original minimum horizontal principal stress and the maximum induced stress is greater than the sum of the original maximum horizontal principal stress and the minimum induced stress, then during repeated fracturing. The secondary cracks will be reoriented, and the orientation of the crack initiation will be perpendicular to the orientation of the primary crack. That is, the condition for new cracks is that the sum of the maximum induced stress and the minimum horizontal principal stress of the original stress field is greater than the minimum induced stress and the maximum horizontal principal stress of the original stress field.
As the fracture continues to extend away from the wellbore, the influence of the induced stress field gradually decreases. Outside the two elliptical regions with equal horizontal principal stresses, it rotates towards the initial fracture direction. However, due to the inertial effect of crack growth, the crack will still extend a certain distance along the redirection direction, and finally the crack will extend along the initial crack direction.

3. Principles of well selection and layer selection
Whether the oil well can achieve the designed oil increase effect after repeated fracturing measures, well selection and layer selection are crucial. In general, the selection of wells and layers for repeated fracturing follows the following basic principles: ¹Fractured intervals have sufficient remaining recoverable reserves and formation energy. The remaining recoverable reserves are the material basis for fracturing stimulation, and formation energy is conducive to prolongation. Effective period of oil increase. ²The initial fracturing of oil wells is small, the sanding strength is not enough, and effective supporting fractures cannot be formed. The fractured interval has not been effectively reformed, and the conductivity of supporting fractures is low, which causes the production of oil wells to decline. After the initial fracturing of the oil well was successful, during the production process, the oil layer was polluted due to the operation or well washing, which caused the permeability of the oil layer near the wellbore to decrease, causing the production of the oil well to decrease. ¾ The effective support range of the previous fracturing of the oil well is not enough, or the proppant placement is unreasonable, or the proppant is severely broken, the permeability is low, and the output of the oil well decreases rapidly. There is no channeling outside the pipe in the interval of ½ repeated fracturing well, and the cementing quality is good.

4. Feasibility and application effect analysis
Well Tong 47-43x underwent a fracturing operation on November 8, 2005. The construction section Es33 (2254.0~2258.0 m) has a total thickness of 13.8 m. Among them, 4.4 m logging interpretation results and logging analysis are poor reservoirs; 9.4 m logging interpretation and logging analysis are reservoirs. The logging interpretation and logging analysis results are shown in Table 1.

| Horizons | Number | Section (m) | Interpretation Thickness (m) | Formation Resistivity (Ω m) | Oil Saturation (%) | Porosity (%) | Acoustic Time (μs·m) | Permeability (mD) | Interpretation Result |
|----------|--------|-------------|-----------------------------|-----------------------------|-------------------|-------------|----------------------|-----------------|------------------|
| Es³      | 13     | 2254.0-2258.4 | 4.4                        | 7.8                         | 7                 | 18.1        | 276.7                | 18.63           | poor reservoirs   |
|          | 14     | 2259.2-2265.0 | 5.8                        | 8.9                         | 41.6              | 19.9        | 286.1                | 31.71           | reservoirs        |
|          | 15     | 2266.0-2269.6 | 3.6                        | 9.4                         | 45.6              | 20.6        | 289.5                | 45.52           | reservoirs        |

The amount of fracturing fluid used in this construction is 240.0 m³, and 0.45~0.9 mm ceramsite 32 m³ is added. The initial fracturing operation curve of this well is shown in Figure 1. Through the analysis of fracturing operation, it is believed that the well is suitable for repeated fracturing, and its favorable conditions are: The physical properties of the reservoir show better, and it has a certain increase in production potential. The strength of the initial fracturing is limited, and the length of the fracture obtained by the analysis and fitting of the construction pressure is about 50 m. From the previous construction curve, there is still room for improvement in construction pressure, which reduces the risk of repeated fracturing pressure rise. Log interpretation results show that the lower part of the pay zone is a dense layer above 10m, so the lower barrier is good; the upper part of the pay zone is thinner, but the interpretation interval is poor. Through analysis, it can be known that the implementation of repeated fracturing technology in this well is feasible.

Repeated fracturing operations were carried out on Well Tong 47-43x, on September 30, 2006. The total liquid volume of this well is 269.18 m³, the actual sand is 37.58 m³, the average sand ratio is 27.17%, and the repeated fracturing construction curve is shown in Figure 2. The actual fracturing construction data of Well Tong 47-43x is simulated and analyzed. The simulation results are: dynamic fracture half-length 138.7 m, dynamic fracture height 43 m, fracture top depth 2240 m, fracture bottom...
depth 2283 m, fracture support half-length 116.7 m, The height of the supporting joint is 25.5 m, the maximum crack width is 19.2 mm, and the average crack width is 9.4 mm. The simulation results show that the support fracture height of the well after fracturing is 25.5 m and the length of the support fracture is 138.7 m, which indicates that the well has been renovated. After the well pressure of Tong47-43x, the discharge was performed from September 30th to October 12th, and the production curve was shown in Figure 3. The daily oil production of the Tong47-43x well was 8.5 tons. Until mid-November, the daily oil production of this well was stable at 6 tons, and the oil increase effect was obvious.

5. Conclusion and understanding

(1) The stress field distribution of the first supporting fractures and natural fractures, as well as the changes in pore pressure caused by production activities, lead to changes in stress near the wellbore. The combined effect of these stresses determines whether the re-fracturing fractures can be redirected.

(2) During repeated fracturing, the initiation and extension of fractures are affected by many factors. The selection of wells and layers for repeated fracturing is very important. The remaining recoverable reserves and formation energy are the prerequisites for repeated fracturing to achieve oil enhancement effects. In the formations with good physical properties and weak heterogeneity, it is more conducive to improving the oil increase effect.

(3) The repeated fracturing technology was used in the Tong47-43x well, and the 5mm nozzle was self-injected after fracturing. The daily oil production was 8.5 t, which achieved a significant oil increase effect, indicating that the repeated fracturing technology has the potential to increase oil in the Tongxi area.

(4) Due to the complex reasons that cause the decline in oil and gas well production, in the future development process, repeated fracturing technology should be combined with the overall development plan of the oil field in order to achieve a better oil increase effect.

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