Refracturing well selection method for ultra-low permeability reservoir based on multi-parameter coupling

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Abstract: At present, with the continuous increase in the development of ultra-low permeability reservoirs, fractures are prone to closure during the initial fracturing operation, which will affect the fracture conductivity to a certain extent, and the oil well production shows a gradual decline trend, and the water content of the target oil well is gradually increased. Therefore, in order to ensure a better recovery rate of ultra-low depth oil reservoir, it is necessary to use re-fracturing reconstruction technology for some low-production oil Wells, so as to gradually improve the conductivity of fractured fractures near the target oil well and restore the actual productivity of a single well, which is conducive to realizing the stable production of ultra-low permeability oil reservoir.

Key words: Multi-parameter coupling; Ultra-low permeability reservoir; refracturing.

1. Introduction

Compared with long-track reservoirs that have been developed over a period of time, low-pressure, permeable, low-abundance reservoirs have the characteristics of poorer formlessness, tighter lithology, finer pore throat, and slower natural fracture development. Therefore, in the production of such reservoirs, the oil recovery efficiency is slow and the production per well is low, so to ensure its stable production and achieve efficient development is the focus of research scholars and relevant personnel. According to the investigation and research, in order to ensure that the ultra-low permeability reservoir has a good productivity, in addition to the necessary energy supplement during exploitation, it is also necessary to carry out fracturing reform in the preparation or early stage of production to effectively improve the nearby geological seepage capacity.

2. Research background of refracturing well selection in ultra-low permeability reservoir based on multi-parameter coupling

In practice, for some short-term production is relatively considerable, but in the use of re-fracturing transformation technology, with better productivity of a single well, it can also take effective measures to transform it, so as to ensure better well productivity, improve the recovery rate of all Wells in the target reservoir in the middle and late period, and achieve the goal of efficient exploitation of ultra-low permeability reservoir.

Refracturing is a highly effective tool used to increase oil field productivity. With the development of exploration technology and oilfield development, traditional primary fracturing technology has been unable to meet the needs of oilfield development. The core idea of refracturing is to re-inject fracturing fluid into a well that has already been fractured once. This technology can leverage existing wellbore structures and infrastructure to maximize field productivity. Compared to drilling new holes, refracturing not only saves costs, but also reduces the environmental impact.

The key of refracturing technology is to select the right borehole for secondary fracturing. By analyzing raw fracturing data and field geology, engineers can determine which Wells are suitable for refracturing. In general, Wells that have produced more and have higher residual reservoir potential are the best candidates for refracturing [1].

The advantage of refracturing is that it can effectively improve wellbore productivity. By injecting fracturing fluid again, the original fracture can be reopened and the effective permeability of the reservoir can be increased. In addition, refracturing can control the direction of fracture propagation to better utilize reservoir characteristics. Selecting the right borehole for refracturing requires accurate geological and engineering data and requires detailed analysis and evaluation. Re-fracturing operations require the original fracturing fluid to be removed first, which incurs additional time and cost.

3. Key points of influencing parameters of optimum refracturing

When using refracturing technology for ultra-low depth reservoir characteristics, in order to ensure a high success rate of refracturing, the operator should accurately understand the production dynamics, ground stress changes, formation earth pressure changes, reservoir rock and fluid characteristics, reservoir utilization degree, and production dynamics. Based on the successful cases of refracturing in the past and the actual situation of the current reservoir, the following factors affect the refracturing effect at each stage of the well development:

(1) Fracturing construction: mainly includes the density of the refracturing technology, the quality of the proppant and the length of the fracturing fracture;

(2) Pressure parameters: mainly include bottom hole and formation pressure and formation principal stress;

(3) Reservoir: mainly includes target layer porosity, actual reservoir thickness, saturation and permeability, etc.

(4) Production dynamic parameters: mainly include the water production, past oil production, production time, cumulative production and decline rate of oil Wells that have been transformed.

(5) Fluid physical properties: mainly includes the density and viscosity of crude oil, volume coefficient and other physical properties;

(6) Wellbore characteristics: The diameter of the wellbore, the depth of the wellbore, the integrity of the wellbore wall and other factors will have an impact on the effect of refracturing. Larger wellbore diameters can provide greater fracturing fluid volume and increase fracture length and area. A deeper well depth can increase the propagation distance of fractures. Complete well walls prevent fracturing fluid leakage and improve fracturing efficiency. Therefore, it is necessary to fully consider the characteristics of the wellbore when selecting the parameters affecting refracturing to ensure the smooth operation of fracturing.

(7) Fracturing fluid characteristics: fracturing fluid viscosity, density, chemical composition and other parameters will have an impact on the fracturing effect. The lower viscosity can improve the flow of liquid in the wellbore and increase the length and area of fractures. The proper density can control the pressure of fracturing fluid and the expansion of fracture. Appropriate chemical composition can increase the adhesion ability of fracturing fluid and improve fracture stability [2].

Based on the static and dynamic characteristics of low permeability reservoir, the re-fracturing technology is reasonably applied to screen out the main factors affecting the re-fracturing effect in a timely and accurate manner, and combine with other data to provide relevant personnel with relevant data support for well selection [3].

Firstly, from the analysis of reservoir characteristics of low permeability reservoir, the oil saturation and the thickness of the oil layer affect the production of the oil well in the bottom deep reservoir. Therefore, in order to achieve effective productivity, for unsaturated or low-permeability reservoirs, it is necessary to take appropriate replenishment measures before production.

Second, from the perspective of reservoir pressure analysis, because low permeability reservoir because of its own characteristics, so the geological conditions, natural energy is slightly insufficient compared with other types of reservoirs, need to supplement energy later.

Third, without analysis from the perspective of dynamic production reservoir, Wells with low water content, high initial production and rapid decline may not have fully released their production capacity, so it is more likely to achieve the purpose of increasing production by using fracturing reconstruction technology. This type of oil well is the first choice to apply refracturing reconstruction technology.

Based on this, for the oil well group that has been injected and produced, the operator should consider its static indicators, such as remaining oil saturation and oil reservoir thickness. At the same time, it is also necessary to consider dynamic indicators, such as decline rate and initial production, and comprehensively analyze the dynamic and static characteristics of the target oil well, so as to have a strong rationality, effectiveness and unity in the practical application of refracturing well selection technology.

4. Analysis of key points of refracturing well selection technology for ultra-low permeability reservoir

Taking an ultra-low permeability reservoir as an example, the relationship between the decline rate, thickness and the effect of the first fracturing is compared and analyzed. It can be seen that when there is only a single factor, the correlation with the application of this technology to improve productivity is low. As shown in Figure 1 and Figure 2, it is the curve analysis diagram of the relationship between decline rate, reservoir thickness and daily oil production of target oil well in the previous three months.

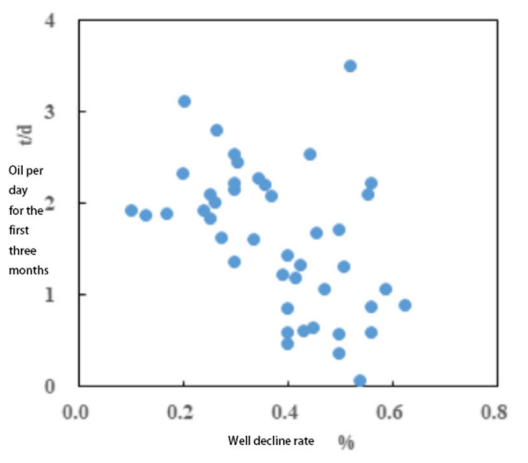

Figure 1. The relationship between decline rate and oil production in the first three months of the target well

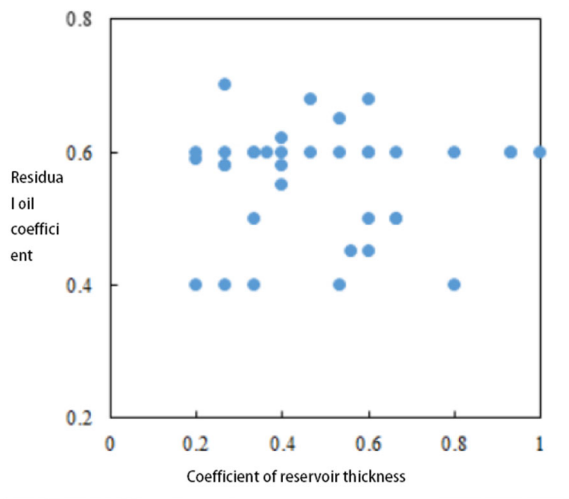

Figure 2. Curve analysis diagram of the relationship between reservoir thickness and daily oil in the first three months of the target well

Through in-depth analysis and research on Figure 2, it is found that the output of the target oil well is mainly affected by factors such as saturation and reservoir thickness. The better the geological condition of the oil well, the higher the saturation of the oil well, the higher the production will be. The better the reservoir thickness factor, the higher the target well production will be.

From the perspective of reservoir pressure analysis, it is found that the geological conditions and natural energy of most ultra-low deep reservoirs are slightly insufficient compared with other types of reservoirs, so most of them belong to the low-production refracturing effect and their correlation is relatively poor. Therefore, the staff should analyze the factors affecting the re-fracturing effect from an objective perspective, and build a scientific and reasonable fracturing well selection coefficient and well selection model [4].

5. The well selection coefficient of refracturing was constructed

5.1 Coefficient of reservoir thickness

According to Figure 3, the higher the thickness of the oil layer in the low permeability reservoir, the stable production capacity of the target oil well will be gradually improved; otherwise, the stable production capacity of the target oil well will be affected, indicating that the oil layer thickness has a good positive correlation with the stable production capacity. In the same batch of repeated pressure demonstration, the ratio of single well oil layer thickness to maximum oil layer thickness can generally be used to reflect the geological potential of applying refracturing to improve the productivity of the target reservoir. As shown in the formula, the target oil layer thickness coefficient can be calculated:

$$\mathrm{H_S}\frac{H_i}{H_{max}} \qquad (1)$$

In formula (1), the oil layer thickness of a single well and the theoretical production of a well are represented by H_i and H_{max} respectively.

5.2 Residual oil coefficient

Through multiple fracturing operations in oil and gas Wells, increase fracture length and area, and improve oil and gas recovery. Residual oil factor is very important to fracturing performance during refracturing operations. After the target oil well has been exploited for a period of time, it is necessary to consider the degree of reservoir utilization, and select the oil well with relatively rich remaining oil for refracturing operations to ensure a higher fracturing productivity. Table (2) below

$$\mathrm{R_s} = \frac{\overline{B_0}}{2\varphi h\,(1-S_W)} max_n \left(\frac{1}{n}\sum_{i=1}^{n}\frac{0_{pi}\,(t)}{r_i^2}\right) \qquad (2)$$

In formula (2), the output of adjacent well and the distance from the measured well are represented by 0_{pi} and r_i respectively, while the output of adjacent well is represented by n.

In the study, it was found that efficient production in adjacent Wells can lead to over-exploitation of well groups, low residual oil coefficient, and insufficient fluid production during refracturing operations, affecting refracturing production. However, when the remaining oil coefficient is large, it reflects from the side that the reservoir production degree in the area of the study well is relatively low, and the oil is relatively rich, so it will obtain better refracturing effect.

5.3 Well decline factor

Oil Wells in ultra-low permeability reservoirs with good fracturing potential generally have the characteristics of faster reduction of water injection, larger radius of liquid supply, more repetitive formation energy supply and slower production decline efficiency. Based on this, the production decline coefficient can be redefined as the initial production decline of an oil well under the initial fracturing fracture, expressed as D, which also has dimensionless characteristics [5].

5.4 Well yield

When analyzing the output of the target oil well, the theoretical productivity expression is calculated mainly by comparing the analytical expression of the average production of the first month, as shown in formula (3), and the production coefficient of the oil well is

calculated: $$\mathrm{F_s} = \frac{Q_{field}}{Q_{theory}} \qquad (3)$$

In formula (3), the actual production of oil well is represented by Q_{field}. The theoretical production of oil well is expressed by Q_{theory}.

According to formula (3), a dimensionless quantity representation with a value between 0-1 is obtained, which can effectively represent the actual production level of the oil well. In practice, if the value is larger, it indicates that the actual output of the well is higher; otherwise, the actual output is smaller. The formula is the ideal formula, ignoring the influence of other factors such as bottom hole pollution.

6. Analysis of refracturing drilling effect in low permeability reservoir

6.1 Effect

Chang 7 ultra-low permeability reservoir in block A adopts the above refracturing transformation technology. 57 refracturing Wells will be developed by this method in 2021, and 40 re-fracturing Wells will be implemented by the end of the year. In-depth analysis and research are carried out on the reconstructed Wells, and the analysis from the perspective of production increase shows that the annual oil increase in block A is 7951 tons, with an average oil increase of 42t. It is estimated that the yield increase efficiency can reach 94.52%, and the A zone has obtained a good effect of improving quality and efficiency. By the end of the year, from the perspective of single well production, it is found that the oil layer thickness and remaining oil coefficient of well A are 0.91 and 0.58 respectively, and the actual oil production coefficient of well is 0.88, which belongs to the great potential. The target well was re-fractured in July 2012 and has accumulated 384.5t of oil production by the end of December.

According to the analysis of the overall refracturing effect of block A, the refracturing reconstruction technology involved in this project has high stability, safety and reliability, and provides corresponding data support for continuous optimization and improvement of refracturing implementation.

6.2 Result analysis

1. In order to achieve the purpose of improving the quality and efficiency of target Wells in low permeability reservoirs, the key lies in well selection. In the research and design stage, if only one or a few factors are considered, the design cannot be analyzed from multiple angles and in an all-round way. The refracturing technology mainly consists of development dynamics, reservoir properties, fluid formlessness, wellbore characteristics and other factors.
2. For unsaturated and low-pressure reservoirs, when using refracturing technology, it is necessary to ensure that the reservoir energy is sufficient in the preparation stage, so as not to affect the subsequent work and fracturing effect.
3. Based on the dimensionless coefficient method, factors such as reservoir thickness, remaining oil and well production are mainly considered. At the same time, the reservoir engineering dynamics can be analyzed by using the data statistical method, so that the main factors affecting the refracturing effect can be fully considered. The method has good accuracy, reproducibility and consistency, and can also be applied to the well selection of low permeability reservoirs in other areas.

7. Conclusion

In summary, the refracturing well selection method based on multi-parameter coupling has important application value in the development and production of ultra-low permeability reservoir. By considering the influence of many parameters, such as reservoir thickness, residual oil coefficient and production through the reservoir, the best refracturing well selection scheme can be obtained to improve the development efficiency and production capacity of the oilfield. It provides technical support and decision basis for the effective development and production of ultra-low permeability reservoir.

References

1. HE Dongxu. Research and application of imbibition fluid for refracturing in low permeability tight reservoir [J]. Petroleum & Gas Chemical Industry, 2019,52(02):99-103.
2. ZHANG Yongchun. Horizontal well refracturing technology in tight low permeability reservoir in Jinghe Oilfield [J]. Fault-block Oil & Gas Field, 2019,28(05):711-715.
3. MENG Xiangcan. Refracturing stimulation technology of Block A of Daqing Zijing Oilfield [J]. Oil and Gas Well Testing,20,29(05):44-49.
4. Su Liangyin, Chang Du, Qi Yin et al. Research and application of old well volume fracturing technology in ultra-low permeability reservoir [J]. Drilling & Production Technology,2020,43(02):75-77.
5. LI Jing. Research on refracturing technology of medium and low permeability reservoir in Bamianghe Oilfield [J]. Journal of Jianghan Petroleum Workers University,20,33(02):41-43.