Optimization of large-scale fracturing technology and improvement of development effect of hard-to-recover reservoirs

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Abstract. At present, the development of unconventional and low-permeability oil and gas reservoirs has become a hot spot of energy development at home and abroad. The typical feature of this kind of oil and gas reservoirs is that the reservoir permeability is very low, and certain transformation measures need to be taken before they can be put into operation. The reservoir volume transformation technology is one of the important technologies for the effective development of unconventional oil and gas reservoirs. In recent years, in order to improve the development effect of ultra-low permeability reservoir, Hailar complex fault block oilfield has carried out field application tests of volume transformation technology in different types of reservoirs year by year. By increasing the amount of fracturing fluid and fracturing sand, increasing the fracturing sweep volume and improving the reservoir seepage conditions, the effective production of the reservoir is realized. However, from the perspective of fracturing effects of different reservoirs, there will be great differences in fracturing effects under the same fracturing method. It shows that the effect of large-scale fracturing development of oil and gas reservoir is related not only to the fracturing mode, but also to the geological characteristics of the fracturing horizon. The in-depth study of the factors affecting the fracturing effect has important guiding significance for the development of low-permeability reservoirs.

1. Introduction
After 20 years of development, Hailar oilfield has few advantageous reservoirs that can be developed by water injection, most of which are typical ultra-low permeability reservoirs. This part of low permeability reservoirs has the characteristics of "high recoverable reserves, scattered distribution and low oil production rate", and the oil production rate is generally less than 0.5%. The use of new infill wells has little effect and poor economic benefits. The remaining exploitation intervals basically belong to low permeability reservoirs or low efficiency reservoirs with high shale content, which is very difficult to exploit. Reservoir reconstruction has gradually become one of the main tasks of oil and gas exploitation.

Based on the comparative analysis of large-scale fracturing wells over the years from the aspects of reservoir buried depth, reservoir characteristics, sedimentary characteristics, fracturing thickness and production data before and after fracturing, this paper summarizes the factors affecting the difference of large-scale fracturing application effect of different types of reservoirs, which enriches the fracturing
development theory of low-permeability oil and gas reservoirs, It provides reference and guidance for subsequent fracturing well selection and fracturing development of similar reservoirs in Hailar.

2. Application effect classification evaluation

2.1. Reservoir distribution of fractured wells.
In order to improve the development effect of ultra-low permeability reservoir, Hailar oilfield has carried out field application tests of large-scale fracturing technology in different types of reservoirs since 2014, and achieved good development effect. It has been applied to 11 fault blocks of 4 oilfields, such as sudert, bell, Wuerxun, Hu and noren. At present, it has become an important and effective means for volume transformation of Hailar reservoir.

2.2. Classification and evaluation of field application effect.
Based on the statistics of actual production data after fracturing of large-scale fracturing wells, this classified evaluation analyzes the production data of 49 fracturing wells (string fracturing and scrapped wells are not included), and selects three oil increase indexes: average daily oil increase, current daily oil increase, difference between current and post fracturing daily oil (to measure whether it is in the production increase period) as the evaluation index to measure the effect of oil wells after fracturing, The classification and evaluation criteria of three indexes of oil increase in large-scale mold fracturing wells are established.

The fracturing effect of 49 wells was evaluated, including 28 wells with good effect, accounting for 57% of the total number of wells, 9 wells with medium standard, accounting for 18% of the total number of wells, and 12 wells with poor standard, accounting for 25% of the total number of wells.

According to the statistical classification evaluation results, after large-scale fracturing measures in Hailar oilfield, the success rate of oil well oil increase is about 75%.

3. Comparative analysis of application effects of different types of reservoirs.

3.1. Influence of structural location and reservoir buried depth on fracturing effect.
According to the evaluation results of 49 oil wells, the wells with good fracturing effect are mostly distributed in the high part of the structure, and it is particularly important to select the wells with structural advantages for fracturing. For example, among the 13 wells fractured in B28 Xing'anling fault block, 9 wells in the high part are high-yield wells, and the other 4 medium evaluation wells are distributed in the edge or low part of the structure, In addition, the scale of 3 wells in the high part of B14-50 well block B14 is significantly better than that of 3 wells in the relatively low part. The reason for the difference is that the oil and gas accumulation is concentrated in the favorable part of the structure, the reservoir is developed, the reservoir in the low part is thin and controlled by faults and oil-water interface, and it is easy to have high water cut or poor water injection effect after fracturing, thus affecting the fracturing effect.

Large scale fracturing technology has been applied in four Hailar oilfields. The depth of the measure horizon ranges from 1179.4m to 2744.7m. The shallowest layer is huhoren, with an average of 1197.3m, followed by sudert, with an average of 1732.6m, and the deepest measure horizon is Wuerxun and Beier oilfields, with 2228.6m and 2384.0m respectively.

According to the evaluation results, there are 3 wells in Huhe noren oilfield, which are classified as good standard wells and poor wells account for 0%; A total of 22 wells are implemented in Xing'anling reservoir in sudelte, including 12 good wells, 6 medium wells and 4 poor wells, accounting for 18.2% of the total implemented wells; According to this calculation, the poor wells account for 30% of the total number of wells in Wuerxun oilfield; Poor wells in Beier oilfield account for 35.7% of the total implemented wells. It can be seen that the buried depth of measure horizon has a certain impact on the effect of large measures. The deeper the depth, the worse the overall fracturing effect.
According to the previous research results, the above laws are related to diagenesis. The physical properties of the reservoir in the south section of Beier Sag change with the buried depth, and the buried depth has an obvious control over the physical properties of the reservoir. At 1500m, the primary pores of the reservoir are dominant, and the physical properties are the best. At 2200-2300m, the compaction is strong, and the physical properties are poor. At 2500m, the secondary pores are relatively developed, and the physical properties of the reservoir are slightly better.

3.2. Reservoir thickness.
According to the statistics of 49 large-scale mold fracturing wells implemented during 2014-2020, B28 Xing'anling oil layer is intensively developed with large single-layer thickness. In the initial stage, the method of temporary well staggered fracturing and well separated same layer fracturing has achieved good production effect, which is inseparable from the thick reservoir in the block as a whole. The remaining potential layer is about 1 time, and the measure layer only accounts for 54% of all potential layers. Beizhong reservoir is poor sand mud interbedding. Wudong reservoir has large development span and thinner thickness, and the fracturing effect is relatively poor. Therefore, the extremely thick effective reservoir with low permeability is more suitable for volume fracturing.

3.3. Oil bearing property of reservoir.
Logging data can also directly guide the optimization of large-scale fracturing horizon. The better the oil content of the reservoir, the better the oil increase effect. Compare two wells x46-37 and x45-35. Among them, well x45-35 mainly displays oil spots, with fluorescence level of 11.3, and its oil content is significantly better than that of well x46-37. After the water content is stable after fracturing, the daily oil increase is 3.2T, and the daily oil increase of well x46-37 is 1.4T, and the oil increase effect is significantly better than that of well x46-37. Therefore, when the reservoir is poorly developed, the dominant interval can be selected for centralized fracturing with reference to logging.

3.4. Sedimentary facies and sand body development scale.
According to the classification results and the comparison of sedimentary facies research results, the thickness of underwater distributary channel with good fracturing effect accounts for 85.3% of the whole well thickness, the underwater distributary channel with width greater than 300 accounts for 75.5% of the whole well thickness, the underwater distributary channel with thickness greater than 2m accounts for 69.5% of the whole well thickness, and the effect of poor wells is 53%. Combined with the above factors, When a single well is drilled and meets a well with a thickness of more than 300m underwater distributary channel $\geq$ 5.0m, the fracturing effect is good. Therefore, the dominant facies zone and scale are beneficial to the fracturing effect. In addition, pay attention to the phase change area in well selection, and try to avoid the dominant phase change within the fracturing volume.

3.5. Fracturing sand strength.
The main purpose of well fracturing is to transform the reservoir, improve the seepage capacity of the reservoir and improve the productivity of development wells. Therefore, with the increase of sand addition and support joint length, the cumulative oil increase increases. However, when the fracture support fracture length reaches a certain value, the increase range decreases sharply, and the net investment income decreases. Therefore, there is an optimal sand addition for any development well, which mainly depends on the geological conditions of the oil well.

The theoretical research shows that the sand addition amount of the oil well is related to many factors, such as the buried depth of the fracturing block, the distance between the oil well and the edge water, bottom water, effective permeability, well spacing, reservoir pressure, effective thickness, reservoir span, the quality of caprock interlayer, well pad conditions, equipment capacity and so on. Due to many parameters involved, it is difficult to determine the accurate optimal sand addition strength, but a certain reasonable value range of a certain reservoir can be obtained through statistical analysis of the post fracturing effect.
According to the statistics of cumulative oil increase and sand increase of 28 wells in B28 Xinganling reservoir, B14 Xinganling reservoir and xx1 south section I reservoir, the sand increase of 2 wells in B14 Xinganling is too high, and the post fracturing production effect is not ideal. The sand increase of 2 wells in Beizhong N1 is too low, resulting in low cumulative production increase. The overall sand increase of B28 Xinganling is reasonable and ideal. According to the production relationship diagram, the design of large-scale fracturing single well is reasonable, and the sand addition amount should be controlled at 100m$^3$ to 180m$^3$. The sand adding strength shall be 6.0m$^3$/m to 10.0m$^3$/m.

4. Conclusion

4.1. The classification and evaluation standard of three indicators of oil increase in large-scale mold fracturing wells has the characteristics of intuition, convenient application and strong operability. It can accurately classify the effect of large-scale mold fracturing wells and has good application effect. According to the classified evaluation, after large-scale fracturing measures for oil wells in low permeability reservoirs, the success rate of oil production increase is about 75%.

4.2. Oil well structure location, measure horizon depth, reservoir development degree and plane heterogeneity of sedimentary facies all have a direct impact on fracturing effect. Therefore, well and layer selection should be considered as important factors. Through the comparative analysis of oil increase production, sand addition amount and sand addition intensity after fracturing in a block, the reasonable sand addition amount and sand addition intensity range of each reservoir can be estimated, so as to guide the geological design of large-scale mold fracturing wells in the corresponding block and improve the fracturing success rate.

4.3. Shorten fracturing fluid discharge cycle. After large-scale mold fracturing, the liquid shall be drained and put into operation as soon as possible to avoid secondary closure and plugging of fractures and reduce the impact on fracturing effect.

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