

Optimization of Horizontal Well Fracturing Schemes Under Different Reservoir Barrier Conditions In Tight Conglomerate Reservoirs

Elyar Ahmad¹, Xiuhua Zheng^{1,*}

School of Engineering and Technology, China University of Geosciences (Beijing), Beijing 100083, P.R. China.

Corresponding author (Xiuhua Zheng) Email: xiuhuazh@cugb.edu.cn

Keywords: hydraulic fracturing, fracture height control, parameter optimization, Mfrac

ABSTRACT

In recent years, due to the increasing shortage of oil resources, tight oil reservoirs have become an important part of my country's oil resource production. Hydraulic fracturing technology is one of the most important measures to increase production in the exploitation of unconventional oil and gas reservoirs. In hydraulic fracturing construction, the extension and propagation behavior of fractures in the formation has an important influence on the effect of hydraulic fracturing stimulation. In a layered formation, the propagation behavior of hydraulic fractures is affected by factors such as geological factors, interlayer interface properties, rock mechanical properties, hydraulic fracturing construction parameters, and other factors, and the law of fracture propagation is very complicated. In the actual hydraulic fracturing construction, in addition to the above influencing factors, the conditions of the reservoir barrier will also have a greater impact on the propagation and propagation of fractures.

This study uses the fracturing software Mfrac Suite to analyze the impact of tight sandstone petrophysical properties on fracturing. Given the geological characteristics of the tight conglomerate in Mahu, Xinjiang, the fracturing software Mfrac Suite was used to optimize the fracturing construction parameters. Specific to the field application, after small-scale fracturing is performed in the tight Conglomerate reservoir to obtain the stratum and rock mechanics parameters, the fracturing horizontal well design is completed. Use the oil test data to analyze the fracturing effect, combined with the results of small-scale fracturing tests, have a more detailed understanding of the complex process of hydraulic fracturing, and finally realize the optimization of hydraulic fracturing construction parameters and fracture parameters. This research summarizes the high fracture control technology of low displacement, variable displacement, and the use of low viscosity fracturing fluids, and the optimization of fracturing parameters. The research results have a certain guiding significance for the optimization design of similar reservoir fracturing.

1. INTRODUCTION

Hydraulic fracturing technology is one of the most important stimulation measures for the exploitation of unconventional oil and gas reservoirs. In hydraulic fracturing construction, the extension and propagation behavior of fractures in the formation has an important influence on the stimulation effect of hydraulic fracturing. Tight conglomerate reservoirs have the characteristics of low porosity and low permeability, and the expansion and extension behavior of hydraulic fractures is affected by geological factors, interlayer interface properties, rock mechanical properties, hydraulic fracturing construction parameters, and other factors. The reservoir barrier will also have a greater impact on the extension of the fracture.^[1,2]

The Mahu tight sandy conglomerate reservoir in the Junggar Basin, Xinjiang is rich in resources. The Mahu sag is a large hydrocarbon-rich sag with multi-layered reservoirs. Several tight conglomerates have been proved in the Permian Wuerhe Formation and Triassic Baikouquan Formation. The oil reservoir block has become the world's largest conglomerate oil reservoir. A total of 185 horizontal wells have been put into production in the Mahu tight conglomerate reservoir with the development method of "horizontal well + subdivision cutting volume fracturing". There are many problems such as complex reservoir conditions, low degree of fracture development, and difficulty in effective reservoir stimulation. After years of exploration and practice, Mahu horizontal wells have formed a fracturing technology based on subdivision and cutting, and achieved remarkable results, fully verifying the large Feasibility of application of large-scale subdivision-cut volume fracturing technology in horizontal wells in the Mahu conglomerate reservoir.^[1,3]

The practice of hydraulic fracturing in the Mahu conglomerate reservoir shows that most of the artificial fractures are mainly double-winged fractures, and the artificial fracture network cannot guarantee the full utilization of reserves. In the development process, the main technical problems such as rapid production decline after fracturing and low recovery degree are faced. How to further improve the effectiveness of the volume fracturing process under the existing geological conditions is the main goal of continuously improving the post-fracturing effect.^[3]

Mahu tight conglomerate reservoirs are generally buried deeper than 3000 m, have poor physical properties, strong heterogeneity, high formation pressure coefficient, lack of natural fractures, a large difference between horizontal and two phases of stress, and large differences in reservoir and barrier distribution characteristics. The great diversity of reservoirs brings great challenges to the volume fracturing of horizontal wells. Combined with the characteristics of tight conglomerate reservoirs in Mahu and the difficulty of reservoir stimulation, through the integrated research platform of geology and engineering, different lengths of horizontal sections, different well spacings, different fracturing stimulation techniques, different fracturing scales and methods have been carried out in the Mahu area. Various horizontal well volume fracturing tests such as construction parameters have been carried out, and the horizontal well volume fracturing technology has been continuously improved in practice, the production potential of horizontal wells has been tapped, and the comprehensive benefits of horizontal well volume fracturing have been improved.^[4,5]

No large-scale fracturing horizontal wells have been put into production in the Mahu X well area. To effectively develop low-porosity and ultra-low permeability oil reservoirs and increase the production scale of refractory reserves in the Upper Wuerhe Formation and Baikouquan Formation, The Wuerhe Formation Oil Reservoir has carried out horizontal well research tests, using large-scale, close-cut volume fracturing technology to test the effects of different well spacings and lengths of horizontal sections on productivity, and to determine the single-well productivity of horizontal wells. In areas with thick sand bodies, good continuity, and continuous and stable oil layers, test horizontal wells should be deployed in favorable positions to further implement the development effect of this type of oil layer.^[6]

Through the research of this study, referring to the research method of integration of geology and engineering, the fracturing stimulation effect of each well is analyzed in detail, the main controlling factors affecting the fracturing stimulation effect are clarified, and the horizontal wells in this area and similar reservoir conditions are sub-clustered. The fracturing optimization design puts forward targeted suggestions, and continuously adjusts and improves the fracturing engineering technical scheme.^[7]

The thickness of the oil layer changes rapidly in the horizontal and vertical directions. With reference to the accurate 3D model, it is necessary to analyze whether it is necessary to fracture and how to frack the wells with a low oil encounter rate, to fully tap the production potential.^[8]

2. SIMULATION PROCEDURE

The production layer can be divided into a thin layer and a thick layer according to the thickness. The expansion of the fracture in the height direction will reduce the extension of the fracture in the length direction. To increase the drainage area, it is necessary to control the height of the fracture and try to build long fractures in the production layer. Commonly used fracture height control technologies include reservoir stress differential control of fracture height, construction displacement control of fracture height, and variable displacement control of fracture height.

2.1 Control seam height technology

2.1.1 Controlling Fracture Height Using Reservoir Interlayer Stress Difference

When the oil layer is thin or the upper and lower interlayers are weakly stressed layers, or there are other complex situations, the height of the fractured fractures tends to exceed the pay zone, it will cause channeling, as shown in Figure 1.

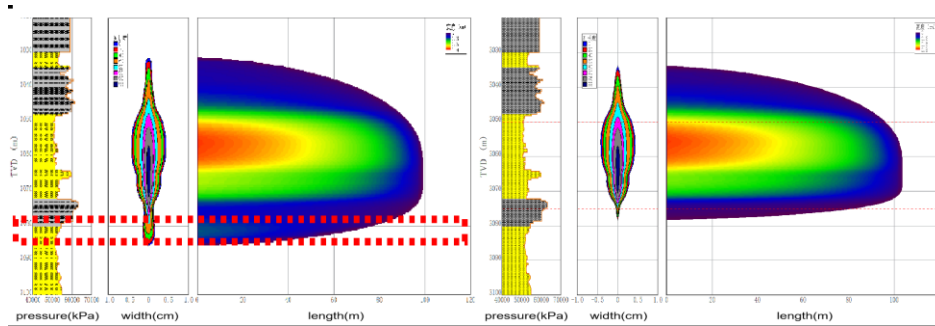


Figure 1: The effect of channeling on fractures

The minimum horizontal principal stress difference between production and barrier in the target well area is 2~4MPa, the thickness of the reservoir is 5~15m, and the thickness of the upper and lower barriers is 2~20m. The Mfrac simulation was used to calculate the change of the longitudinal height of the fracture with the displacement under the conditions of the thickness of the production layer of 5 m and different thickness of the reservoir and interlayer and stress difference. The results are shown in Figure 2.

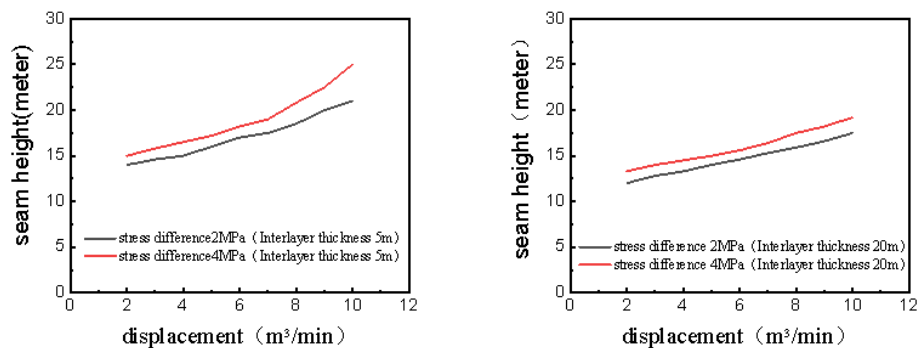


Figure 2: Variation of seam height with displacement

It can be seen from Figure 2 that when the stress difference increases from 2MPa to 4MPa, the crack height decreases by 0.5~4.3m, and the decrease is not large.

2.1.2 Controlling Crack Height by Construction Displacement

During the fracturing process, the hydraulic kinetic energy of the high-displacement fracturing fluid is large, and the high-intensity hydraulic pressure will increase the fracture height. The study found that there is a proportional relationship between the construction displacement and the fracture height. The construction displacement and the crack height are related as equation (1):

$$H = 7.32e^{1.03Q} \quad (1)$$

where H , e , Q , are crack height, Euler number, pump displacement.

According to the production site of each oil and gas field, combined with the characteristics of the reservoir, through the adjustment of the field test, the suitable construction displacement is optimized, which can meet the high technical requirements of fracture control.

2.1.3 Variable displacement control seam height

In the early stage of fracturing operation, the pre-fluid is mainly used to create fractures. The high-displacement pre-fluid will often break through the shielding layer in the early stage of fracturing, and the proppant carried by the sand-carrying fluid itself has a certain shielding ability. Therefore, in the process of fracturing stimulation, low-displacement pre-fluid is used to create fractures to avoid fractures penetrating the reservoir effect.

If the construction displacement is too small, it will lead to aggravation of fracturing fluid filtration and cause early sand plugging. If the construction displacement is too large, the fracture height will be out of control for thin reservoirs, penetrate the reservoir, and at the same time, to a certain extent Reduced seam length. Therefore, it is particularly important to optimize the construction displacement for the optimal fracture length under different reservoir thicknesses.

Through research on the basis of the recommended displacement of different reservoirs, the optimization of the variable displacement process is carried out. In the case of low displacement, the pre-fluid is more conducive to creating long seams and controlling seam height.

2.2 Construction Displacement Design

1)When the reservoir thickness is 5.0m, the fixed displacement, and variable displacement design fracture height, as shown in Table 1

Table 2: Design table of fixed displacement and variable displacement under the condition of reservoir thickness of 5.0m

Reservoir thickness (meters)	Interlayer thickness (meters)	reservoir stress difference (MPa)	Fixed displacement (m ³ /min)	Variable displacement (m ³ /min)
5.0	2.0	2.0	0.8	0.6~1.0
		4.0	1.0	0.8~1.2
	5.0	2.0	1.0	0.8~1.2
		4.0	1.4	1.2~1.6
	8.0	2.0	1.4	1.6~1.8
		4.0	1.8	1.6~2.0

Fracture distribution of different interlayer thicknesses on the same scale, as shown in Figure 3

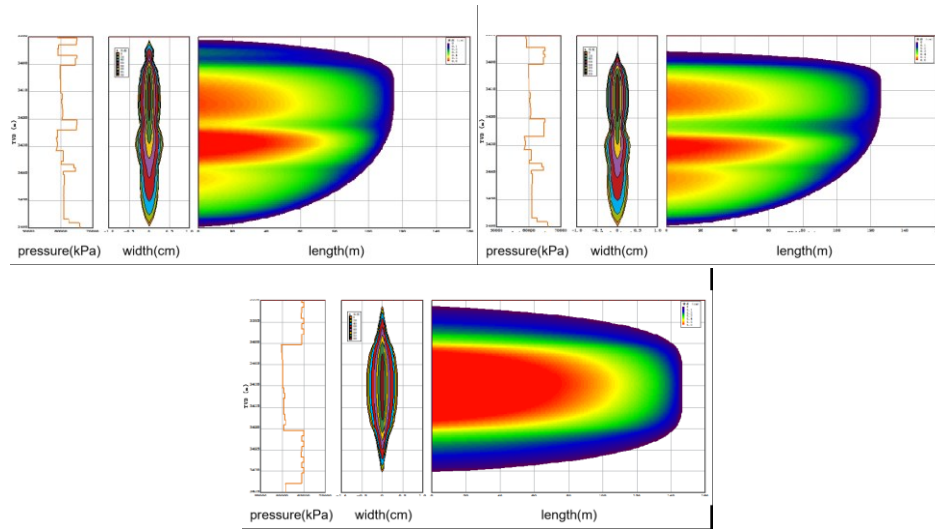


Figure 3: Crack morphology after increasing thickness of interlayer

The variable displacement seam height has different degrees of reduction, the better the interlayer condition, the better the seam height control effect. Since the thin layer is more sensitive to displacement, the displacement leads to a large change in the seam height. These conclusions can be seen from Figure 4.

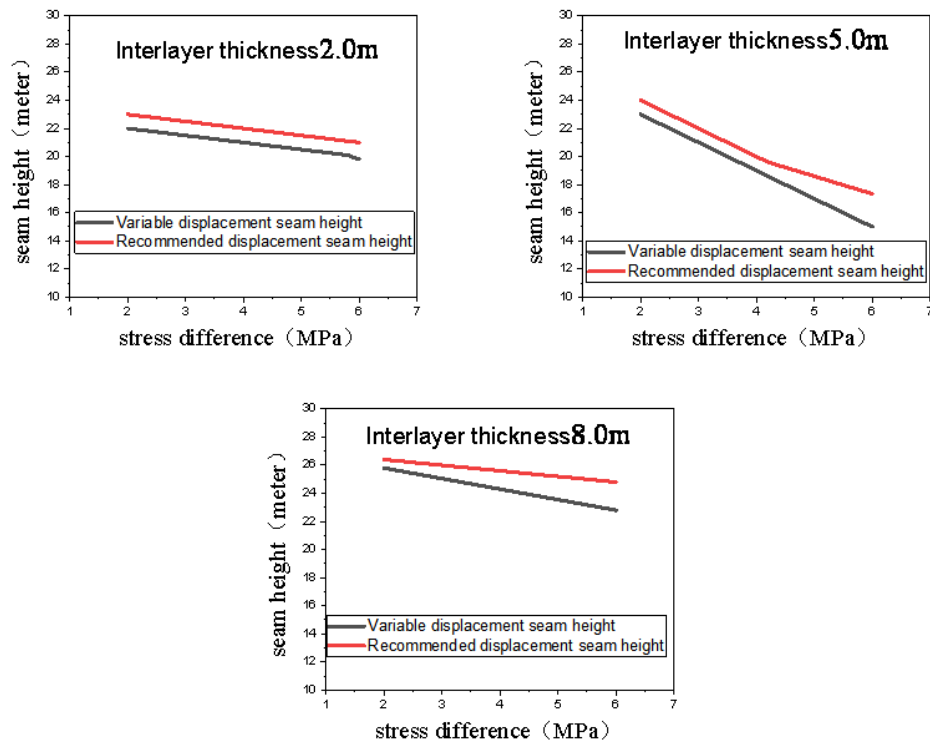


Figure 4: Comparison of fracture heights with different combinations of fixed displacement and variable displacement under the condition of reservoir thickness of 5.0 m

2) When the reservoir thickness is 10.0m, the fixed displacement, and variable displacement design fracture height, as shown in Table 2.

Table 2: Design table of fixed displacement and variable displacement under the condition of reservoir thickness of 10.0m

Reservoir thickness (meters)	Interlayer thickness (meters)	reservoir stress difference (MPa)	Fixed displacement (m ³ /min)	Variable displacement (m ³ /min)
10.0	2.0	2.0	1.5	1.4~1.6
		4.0	2.0	1.8~2.2
	5.0	2.0	1.0	1.8~2.2
		4.0	1.4	2.2~2.8
	8.0	2.0	1.4	2.2~2.8
		4.0	1.8	2.6~3.2

The principle of variable displacement optimization: when the target layer is thin or close to the water layer, a small displacement jump can be performed, such as 0.2-0.3 m³/min; when the target layer is thick or far away from the water layer, to improve the sand ratio. High, the displacement can change greatly, such as 0.5~0.6 m³/min. In the case of low displacement, the pre-fluid is more conducive to creating long seams and controlling seam height.^[9,10]

When the reservoir thickness is 10.0m, the fixed displacement and variable displacement design fracture heights are adopted (as shown in Table 2). It can be seen from Figure 5 that the variable displacement fracture height is reduced to different degrees. The better the interlayer condition, the higher the fracture height, better control. Influenced by the thickness of the reservoir as a whole, the sensitivity of displacement to fracture height is weaker than that of thin reservoirs.

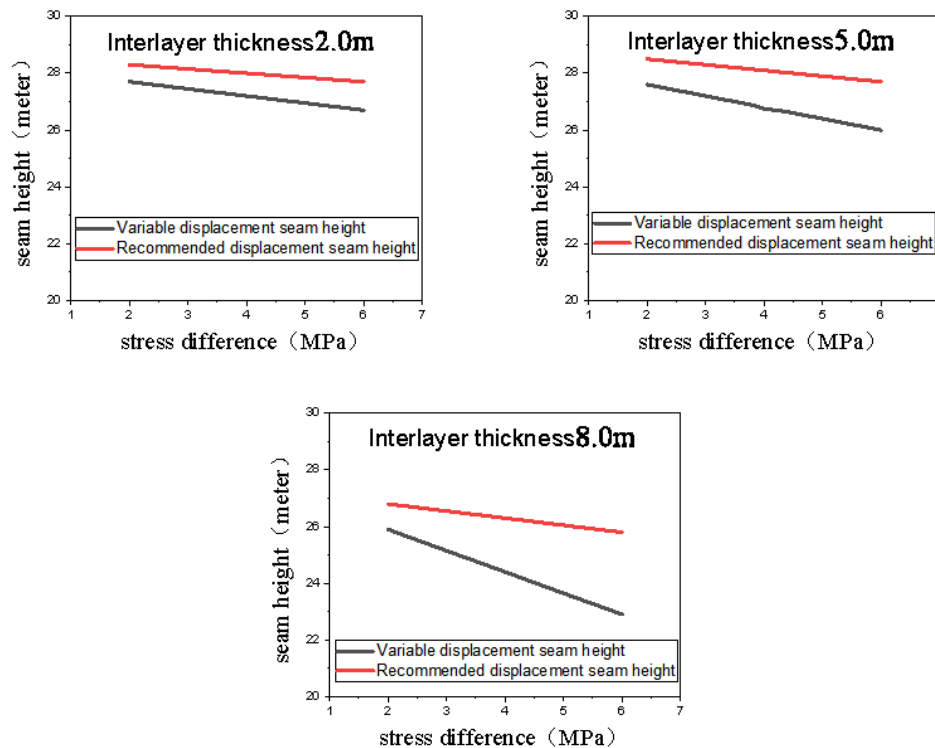


Figure 5: Comparison of fracture heights with different combinations of fixed displacement and variable displacement under the condition of reservoir thickness of 10.0 m

2.3 Preliminary fluid volume optimization

In the fracturing process, the pre-fluid mainly plays the role of creating fractures and is an important part of the fracturing construction process. Excessive pre-fluid volume is helpful for fracture formation, but on the one hand, it is not conducive to fracturing fluid flow back, and on the other hand, it will greatly damage the permeability of the matrix and affect the fracturing effect; if the pre-fluid volume is too large. If it is small, the filtration will be completed in advance during the fracturing process, which is not conducive to fracture formation and sand-carrying migration of proppant.

Because the base fluid in the pre-fluid stage of the well area has low viscosity, large filtration loss, and low liquid efficiency. To solve the problem of low fracture-making efficiency, the methods of increasing the injection displacement and increasing the proportion of pre-fluid are generally adopted. For the consideration of fracture height control, based on the combination optimization of variable displacement, the method of optimizing the proportion of pre-fluid is adopted.

When drilling into the lower part of the oil layer, the mudstone in the lower layer cannot be effectively blocked, the fracture height is out of control, and the supporting fracture length is reduced. The fracturing effect can be ensured by adjusting the number of pre-fluid slugs and the amount of sand carried by the slugs.

For reservoirs with strong mudstone blocking ability, the longitudinal expansion of fractures is limited. When the fracture initiation point is close to the barrier, the fracture length, and fracture height change. According to the MFRAC pumping procedure, the linear glue ratio is adjusted to increase the vertical up/down swept volume.

The percentage of pre-fluid is related to the thickness of the reservoir, filtration coefficient, etc. For a new block, the usual practice is to use the ratio of the half-length of the supporting fracture to the half-length of the fracture to determine the pre-fluid volume at about 80%. The calculation chart of the percentage of pre-fluid under the conditions of different thicknesses of 15m, 10m, and 5m was obtained through the calculation of the fracture simulation software, as shown in Figure 6.

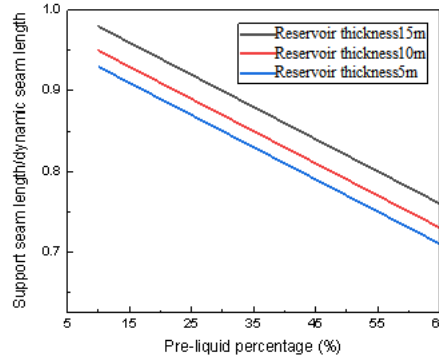


Figure 6: Pre-liquid ratio optimization chart

The simulation results are based on the general situation that the half-length of the support is 80% of the half-length of the seam. Therefore, the percentage of pre-fluid is selected to be 45-55%, and it can also be adjusted according to the on-site test conditions.

2.4 Sand Scale Optimization

Different shielding layer conditions will lead to different fracture-making difficulties. Under the condition of better upper and lower shielding layer conditions, the fracture reconstruction effect can be greatly improved. The well trajectory profiles under different barrier conditions are shown in Figure 7.

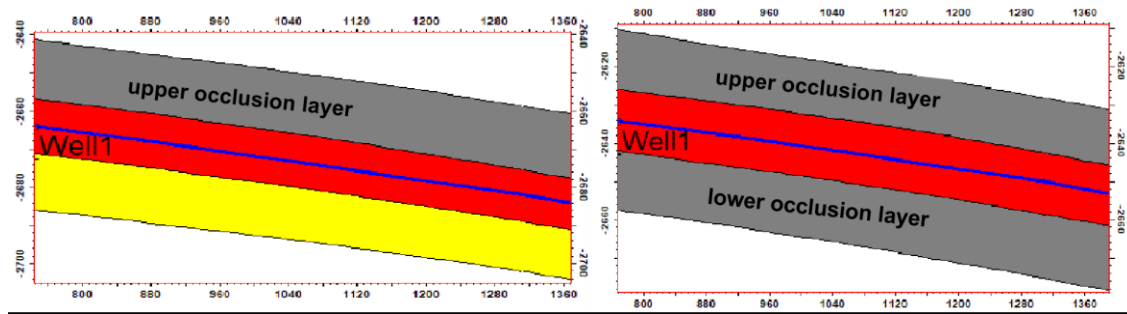


Figure 7: Well trajectory profiles for different barrier conditions

1) When the condition of the bottom barrier layer is poor, and gradually increase the amount of fluid and sand, the fracture morphology, as shown in Figure 8

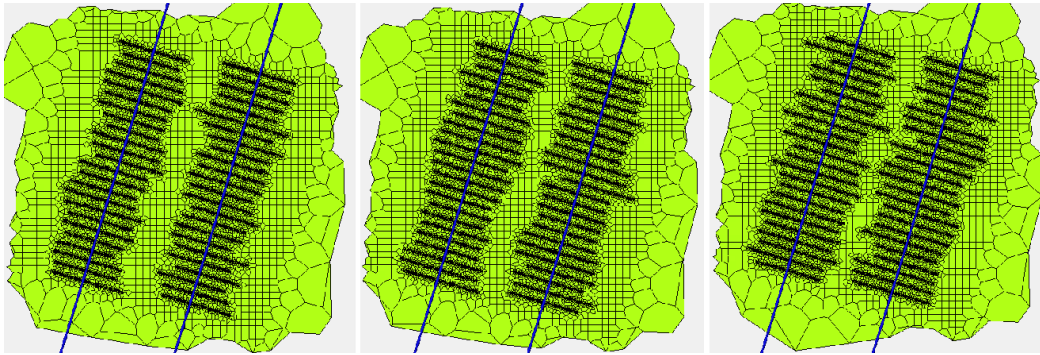


Figure 8: Crack pattern with little effect

The well spacing is 200m, the lower part is poorly shielded, and the fracture height is difficult to control. By increasing the fracturing operation scale, it is difficult to grow fractures, the effect is not obvious, and the reservoir between wells cannot be fully reformed.

2) When the conditions of the upper and lower barrier layers are good, and gradually increase the amount of fluid and sand, the fracture morphology, as shown in Figure 9

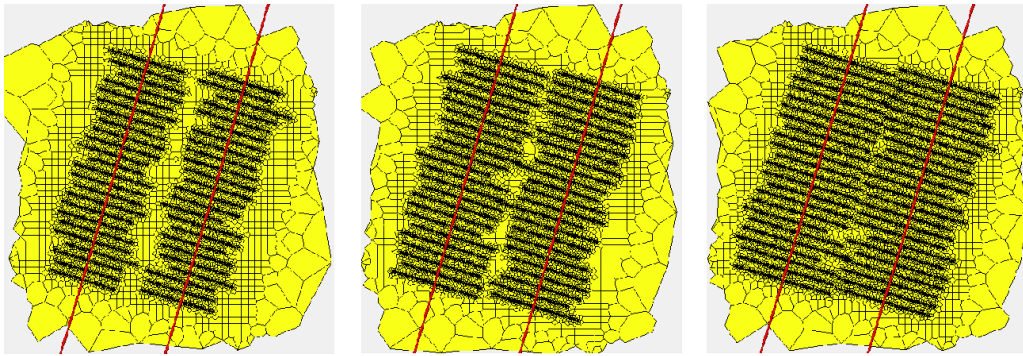


Figure 9: Crack pattern with obvious effect

The well spacing is 200m, there are good shielding layers up and down, and the fracture height is controllable. By increasing the scale of fracturing operations, the effect of long fractures is obvious, and the reservoir between wells can be fully reformed.

3. CONCLUSION

- 1) It can be seen from the simulation calculation that for thin reservoirs, the stress difference between reservoirs and interlayers has little effect on the fracture height, and the space to control the fracture height simply by forming artificial interlayers to increase the stress difference is limited.
- 2) For low-permeability and thin-differential layers in the well area, the application of high fracture control technology using the combination of low displacement, variable displacement, and control of the percentage of pre-fluid has achieved good results.
- 3) According to the special drilling points in the well area, the fracturing stimulation effect is guaranteed by optimizing the main fracturing operation parameters.

ACKNOWLEDGMENTS

This work was supported by National Natural Science Foundation of China (Grant No. 42172342) of "Study on the Reaction of Drilling Fluid in EGS Reservoir Environment and Its Damage Mechanism" and National Natural Science Foundation of China (Grant No. 41872184) of "Properties of Colloid Gas Aphron Drilling Fluid and Its Mechanism of Loss and Formation Protection for High Temperature Geothermal Reservoir".

REFERENCES

- [1] Du Hongling, Xu Jiangwen, Li Wei, et al. Development and Deepening of Beneficial Development of Tight Sandy Conglomerate Reservoirs in Xinjiang Oilfield—Practice and Consideration of Geology-Engineering Integration in Mahu Area [J]. PetroChina, 2018, 023(002):15-26.
- [2] Xu Zhidan, Xiong Youming. Research on fracturing technology of CJ-JMSR tight oil wells[J]. Chemical Management, 2015(30):115+117.

- [3] Bai Yunyun, Ma Yan, Gu Haohao. New progress in fracturing technology for tight sandstone oil and gas reservoirs[J].Journal of Yulin University,2019,29(06):34-36.
- [4] Liu Jiankun, Jiang Tingxue, Wan Youyu, Wu Chunfang, Liu Shihua. Research and application of thin-layer fracturing technology in tight sandstone[J].Lithologic Reservoirs,2018,30(01):165-172.
- [5] Zeng Fanhui, Guo Jianchun, Liu Heng, Yin Jian. Optimal design and application of staged fracturing in horizontal wells in tight sandstone gas reservoirs[J]. Chinese Journal of Petroleum, 2013, 34(05): 959-968.
- [6] Gou Guiming, Hu Renquan. Fracture height control and thin layer fracturing[J]. Oil and Gas Well Testing, 2004(05): 48-51+107-108.
- [7] Xu Chuangchao, Chen Cunhui, Wang Bo, Wu Yahong, Peng Changjiang. Optimization of fracture parameters for horizontal well fracturing in low permeability tight oil reservoirs[J]. Fault Block Oil and Gas Fields, 2014, 21(06): 823-827.
- [8] Wu Qi, Xu Yun, Liu Yuzhang, Ding Yunhong, Wang Xiaoquan, Wang Tengfei. Current Situation of U.S. Shale Gas Volume Stimulation Technology and Its Enlightenment to my country [J]. Petroleum Drilling and Production Technology, 2011, 33(02): 1-7.
- [9] Liu Tao, Shi Shanzhi, Zheng Zijun, Ji Yongjun, Wang Lei. The practice of geology-engineering integration in the development of tight sandy conglomerate horizontal wells in the Mahu sag[J]. China Petroleum Exploration, 2018, 23(02): 90-103.
- [10] Zhou Xiang, Zhang Shicheng, Zou Yushi, Pan Linhua, Liu Kaiyu, Zhang Xiong. Fracture propagation and productivity simulation of volume fracturing in horizontal wells in tight oil reservoirs[J]. Journal of Xi'an Shiyou University (Natural Science Edition), 2015, 30(04): 53-58+7.