Optimization of Multi-stage and Multi-cluster Fracturing Technology for Horizontal Wells in Jilantai Buried Hill

Hanbin Feng¹*, Yuanzhao Jia¹, Zhengdong Xu¹, Jiefeng Cao¹, Gangfei Wu¹

¹ Engineering Technology Research Institute of Huabei Oilfield Company, Renqiu, Hebei, 062552, China

*Corresponding author’s e-mail: hbytslg_fhb@petrochina.com.cn

Abstract. The Jilantai oil field is rich in reserves of metamorphic rock potential reservoirs. Some wells drilled in the early stages, recorded wells see better oil and gas display, but the oil test yield is low, so it needs fracturing to put into production. Conventional fracturing has a small range, low output and short stable production period. In order to improve the effect of reservoir reconstruction, multi-segment and multi-cluster fracturing technology for Jilantai metamorphic rock horizontal wells has been developed. According to the well trajectory and logging interpretation results of well s1-1, we have formed a volume fracturing mode of "large-scale + large displacement + low sand ratio plug-in plus sand" by optimizing the staged cluster perforation scheme, fracture pattern scale and operation parameters, thus communicating more natural fractures and forming a complex fracture network system. The well is divided into 10 sections and 28 clusters of fracturing, after pressure of 49.2t daily oil, 31.49t of daily oil, the current production is stable, the effect of fracturing increase yield is remarkable. Through the successful application of multi-stage and multi-cluster fracturing technology in this well, a new technology of volume fracturing for metamorphic reservoir in Jilantai formed, which lays a foundation for the efficient development of this area.

1. Introduction
The Bayanhetao exploration area in Inner Mongolia is a key reserve replacement area for the exploration and development of Huabei Oilfield during the 14th Five-Year Plan period. Jilantai metamorphic rock is located in Hetao Basin, which shows a good prospect of exploration and development. Some wells drilled in the early stages, recorded wells see better oil and gas display, but the oil test yield is low, so it needs fracturing to put into production. Conventional fracturing has a small range, low output and short stable production period. In order to improve the effect of reservoir reconstruction, multi-segment and multi-cluster fracturing technology for Jilantai metamorphic rock horizontal wells has been developed

2. Fracturing difficulties and technical countermeasures
The lithology of Jilantai buried hill is metamorphic rock mainly composed of gneiss and amphibolite. The matrix has poor fluid supply capacity to fractures, high elastic modulus, poor brittleness and poor volume crushing capacity. Therefore, high angle natural fractures are mainly used as reservoir space and permeability channel. Therefore, we adopt a large-scale, large-displacement, composite fracturing fluid system, multi particle proppant composition slug sand volume fracturing mode, and the result is to communicate the far well reservoir and natural fractures build complex
fracture network, increase the volume of reservoir reconstruction, and improve the effective utilization rate of metamorphic rock reservoir in buried hill[2].

3. Optimization of S1-1 segmented and clustered volume fracturing technology

This well is the first horizontal well to be drilled in the region. The fracturing was completed at the end of 2019. The drilling depth was 1422m and the horizontal section length was 938m. Logging explained that type I fractures were 84.4m/20 layers, and type II fractures were 218.6m/55 layers. According to the situation of s1-1 well, the suitable volume fracturing process scheme of buried hill metamorphic rock horizontal well is formed by optimizing the staged cluster perforation scheme, fracture pattern and construction parameters[3].

3.1. Optimization of Segmented Cluster Perforating Parameters

① Fracture stage optimization: comprehensive analysis of geological engineering sweet spots, it is preferred that the acoustic time difference is high, the gas survey shows good, the type I and type II fractures are relatively developed, as the fracturing target well section, through the analysis of the fluid migration between the seepage zone, the matrix and the seepage zone, combined Fracture monitoring data, avoid inter-section collusion, and numerical simulation software for production optimization, as shown in Figure 1, it is recommended that the optimal section length ≤ 60m.

![Figure 1: Comparison of cumulative production curves of different segment lengths](image)

② Optimization of fracturing cluster spacing: based on elastic mechanics, a balanced differential equation is established. Through analysis, reducing the cluster spacing can locally appear stress reversal areas on the plane, and optimizing the cluster spacing 20-30m can ensure that the stress reversal areas appearing between clusters and on both sides are maximized. As shown in Figure 2, improve the turning of the crack network on the plane.
3. Optimization of perforation parameters

③ Optimization of perforation parameters: the use of conventional uniform perforation is prone to uneven liquid inflow between clusters, and the efficiency of cluster reconstruction is low. Adopting the limit flow method, using the equal aperture perforation process, optimize the number of openings for each shower, adjust the pumping displacement, control the perforation friction, realize the uniform liquid injection of each cluster, and improve the degree of transformation[4].

3.2. Optimization of fracture parameters

Based on the characteristics of the reservoir of S1-1 well adjacent wells and related logging data, the simulation model of horizontal well fracturing was established by using the seam fracturing simulation software to simulate the displacement parameters required to achieve the optimized fracture parameters. To the yield as the goal, the main fracture length is 120-130m and the fracture height is 30-40m.

3.3. Optimization of construction parameters

Using the orthogonal experimental scheme, through range analysis, the optimized displacement range is 12-14m³/min, combined with CMG software simulation, when the fracture length is about 120m and the seam net width is about 75m, the optimized sand addition is 100m³ and the optimized liquid volume is 1300-1500m³.

3.4. Optimization of fracturing materials

①Fracturing fluid system: the natural fractures in the target layer are relatively developed, mainly high angle fractures and complex fracture extension. The mixed fracturing mode (slick water + base fluid) is used to communicate more natural fractures and build a complex fracture network[5].

②Proppant: the proppant system uses a combined particle size to fill multi-level fractures. In the initial stage, 40/70 mesh quartz sand is used to effectively achieve perforation polishing, supporting natural cracks and micro-cracks, and temporarily plugging and turning. In the middle stage, 40/70+20/40 mesh quartz sand is used to support secondary cracks. In the sand stage, 20/40 mesh quartz sand is used to support the main fractures to realize multi-scale support of the full fracture network, so that the remote natural fractures can fully contribute.
3.5. **Optimization results of horizontal wells**

Through analysis, the method of "large-scale + large displacement + low sand ratio slug sand" is adopted for volumetric fracture network fracturing, which communicates with natural fracture systems on a large scale, and adopts hydraulic pumping bridge plug volume fracturing technology with single-stage displacement 12-14m³/min, total sand volume of 1055m³, total liquid volume of 13859m³, optimized flow-limiting perforation, optimized cluster spacing and number of perforations, combined with real-time microseismic fracture monitoring system, completed 28 clusters in section 10 of S1-1 well volume fracturing construction. The simulated crack effect is shown in Figure 3.

![Figure 3](image1)

**Figure 3** Schematic diagram of fracture section and fracture network

4. **Fracturing effect analysis**

4.1. **Fracturing construction overview**

S1-1 completed the fracturing construction at the end of 2019. The accumulated hydraulic fracturing fluid was 1,4001.69m³, the sand volume was 1080.57m³, the average sand ratio was 14.1%, the displacement was 13-14m³/min, the highest sand ratio was 24.14%, and the fracture pressure was not obvious.

4.2. **Fracturing analysis**

Through the analysis of the fracturing operation curve in Figure 4, the main fracture is formed in the pre fluid stage, and the pressure is relatively stable in the whole sand adding stage, which proves that the formation enters the fluid and sand and migrates to the far end of the fracture at the same time; the natural fracture can be effectively channeled by using the displacement of 13-14m³/min, the reservoir can be fully reformed and the transformation scope can be increased; the overall construction pressure curve is stable and downward. It is proved that this kind of well has a good ability of fluid and sand injection, which proves that the reform idea is feasible.

![Figure 4](image2)

**Figure 4** Fracturing operation curve of S1-1 well (the fifth and fourth sections)
4.3. Construction effect analysis
Through the analysis and statistics of the actual operation parameters of S1-1 well, and the pressure fitting of the construction curve by Meyer software, combined with the micro seismic monitoring data [6], the results show that the fracturing effect is good. The total reconstructed volume is $1180 \times 10^4 \text{m}^3$. The well was put into production at the beginning of 2020. The current daily production fluid is 49.2t and the daily oil production is 31.49t. The current production is stable and the fracturing effect is remarkable.

5. Conclusion
According to the geological conditions and feasibility analysis of volume transformation of metamorphic rock reservoir in Jilantai buried hill, the reconstruction mode of "large-scale + large displacement + low sand ratio slug sand" volume fracture network fracturing can fully transform the reservoir, build complex fracture network and increase the volume of reservoir reconstruction. It provides a reference plan for volume fracturing of horizontal wells in tight reservoirs in China.

References
[1] YU, S.C. (2010) Hydraulic fracturing Technical Manual. Petroleum Industry Press Publishing, Beijing.
[2] Zhang, Z.M., Su, J., Zhang, W. C., R.A. (2016) Exploration and Practice of Stimulated Reservoir Volume Fracturing Technology for Metamorphic Rock Buried Hills Reservoir. J. Sino-Global Energy., 21: 12–15.
[3] Jia, Y.Z., Wang, X. C., Yu, D. H., R.A. (2017) Volumetric Stimulation Applied in Horizontal Wells in Tight Sandstone Gas Reservoir. J. Drilling & Production Technology., 40: 25–30.
[4] Li, Y. (2014) Study on Perforation Parameters Optimization of Volume Fracturing Wells. D. Xi'an, Shaanxi: Xi'an Shiyou University.
[5] Fan, X.M (2017) Study and Application of Fracturing Technology in Buried Hill Reservoir of Metamorphic Rock. D. Daqing Heilongjiang: Northeast Petroleum University.
[6] Su, C., Li, S. B., Liu, Z. Y., R.A. (2017) Study of Interference Law of Volume Fracture to the Stress Field. J. Journal of Beijing Institute of Petrochemical Technology., 25: 16–23.