

Exploration and Practice of Volume Fracturing Technology for Metamorphic Buried Hill

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Abstract: The metamorphic rock buried hill have a large amount of reserves. Because its low permeability in the matrix, most wells drilled in the field have to be fractured before production. It has large thickness of reservoirs, massive hydraulic fracturing is difficult, the cost is high. In this paper, successful cases of volume fracturing technology applied to metamorphic buried hills were introduced. The results prove its feasibility by theoretical calculation and numerical simulation, etc. Clustering perforation mode, low viscosity and low friction fracturing fluids were used in combination. With high rate of fracturing fluids, low proppant concentration, the technology could realize maximum communication among the natural fractures, greatly improving the overall permeability of the reservoirs, and realizing the three dimensional treatment to the reservoirs. Down hole micro seismic fracture monitoring results indicate that the induced fracture volume increased by 28.8% compared with that in conventional fracturing. In addition, average single well production increased by over 50% after fracturing with this technology compared with that by conventional fracturing of vertical wells from the same block. Since 2013, in addition, average single well production increased by over 50% after fracturing with this technology compared with that by conventional fracturing of vertical wells from the same block.

Keywords: Metamorphic Rock, Volume Fracturing Technology, Natural Fracture, Fracture Monitoring

1. Introduction

With the deepening of oil field exploration and development, metamorphic buried hill has become an important exploration replacement field [1-2]. In metamorphic buried hill reservoirs, the matrix permeability is very low, natural fractures are developed, the sky fracture is the space for oil storage, the natural productivity of oil wells is low, and most of them need fracturing transformation. The more natural fractures and the larger the volume affected by fracturing, the higher the output after fracturing. Sufficient reconstruction volume is the key to fracturing transformation of metamorphic buried hill [3]. According to rock mechanics test results, the maximum and minimum horizontal stress difference of metamorphic rocks is 10-20 MPa. Although the stress difference is much higher than the lower limit of 5 MPa generally recognized in the industry, the author believes that the difference between metamorphic rocks and shale and sandstone is great, and the role of natural fracture

development in the formation of fracture net is greater. Therefore, relevant research and practice have been carried out [4-6].

2. Basic Characteristics of Metamorphic Buried Hill Reservoir

The buried hill is characterized by complex lithology and various reservoir types. Taking XLT buried hill as an example, the lithology is composed of metamorphic rocks and intrusive rocks. The reservoir is mainly composed of mixed granite, biotite plagioclase gneiss and migmatite. The reservoir space types are mainly structural fractures and fractured intergranular pore, in which structural fractures dominate [7].

Oil wells deployed in buried hill area need to be fractured because of the great difference of fracture development near the wellbore zone, some wells have no natural productivity, or the natural productivity is low. Compared with clastic rock, metamorphic rock fracturing is more difficult and easy to form

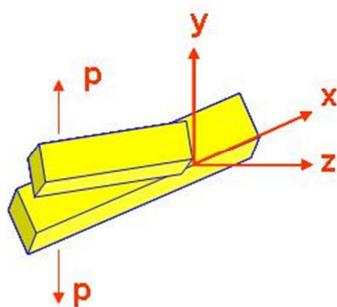
sand plugging. In the early stage, the main idea is "large sand volume, large displacement, medium-low sand ratio, long fracture formation". The fracturing transformation technology of "high temperature resistance, filtration reduction, sand control and fast back drainage" has been formed, which solves the early sand plugging problem of conventional fracturing [8]. For low-grade buried hills with poor oil-bearing property, conventional fracturing has limited stimulation effect, which brings great cost pressure to the development of such reservoirs. How to achieve efficient development at low cost poses a great challenge to the fracturing technology of metamorphic buried hills [9-10].

3. Theoretical Basis of Slip-Slip Fracturing in Metamorphic Buried Hill

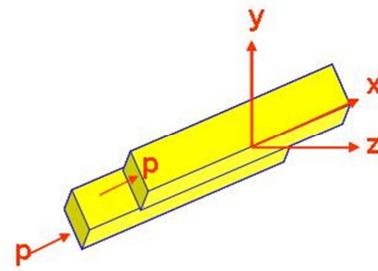
In recent years, with the development of volume fracturing, a new development concept has been provided for the development of fracturing technology. Volume fracturing refers to the continuous expansion of natural fractures and shear slip of brittle rocks in the process of hydraulic fracturing, forming a fracture network interlaced with natural fractures and artificial fractures, thus increasing the volume of reconstruction, increasing initial production and ultimate recovery. The concept of volumetric fracturing originated from the transformation of North American shale gas, and now extends to the fields of shale oil and gas and tight oil and gas. The lithology is shale, tight sandstone, Compact Carbonate rock, etc. No corresponding research and implementation reports have been reported on special lithologic reservoirs such as metamorphic buried hills.

3.1. Fracture Morphology Analysis

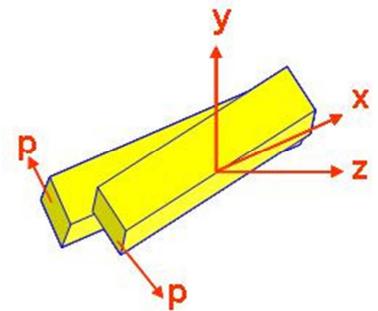
In theory, fracturing fractures are mainly open-type in reservoirs with pore as main reservoir space, while metamorphic buried hills are fractured reservoirs. Fracturing fractures are mainly slip-type and tear-type. Irregular or uneven geometric shapes are formed on the surface of rock strata, and fractures with self-supporting characteristics have the main effect of stimulation (Figure 1). It depends on the volume of modification rather than the strength of sand addition [11-13]. Therefore, in theory, the metamorphic buried hill reservoir has the basis of slip water fracturing volume fracture.



(a) Open type



(b) Sliding type



(c) Avulsion type

Figure 1. Fracture morphology of artificial fracturing.

3.2. Analysis on the Mechanism of Fault Movement of Fracture Surface in Formation with Natural Fracture

Research by some researchers shows that the existence of natural cracks affects the expansion of hydraulic cracks. It is considered that the approximation angle and horizontal principal stress difference between hydraulic cracks and natural cracks are the main factors affecting the direction of hydraulic cracks. Based on the fracture morphology formed by fracture propagation in fractured formations, a calculation model of fracture surface dislocation in fractured formations is established. Because in-situ stress acts continuously on the formation, the dislocation of fracture surface occurs in the process of hydraulic fracturing. Therefore, the contact of fracture wall is neglected in the establishment of fracture surface dislocation model.

The model consists of two parts. The first part simulates the influence of Young's modulus of rock on the dislocation momentum of fracture surface under different Young's modulus and the same deviation stress. The results show that the dislocation momentum of fracture surface decreases with the increase of Young's modulus in strata with natural fractures, and the dislocation between Young's modulus and fracture surface is formed. Power function relation. The second part simulates the influence of deviation stress on the dislocation momentum of crack surface under the condition of different deviation stress and the same Young's modulus. The results show that there is no clear correspondence between the deviated in-situ stress and the dislocation momentum of the crack surface, but it can also be seen that the magnitude of the deviated stress affects the dislocation range of the crack surface. The larger the deviated stress, the larger the dislocation range of the crack surface.

4. Volume Fracturing Technology of Metamorphic Buried Hill

Sliding water fracturing is a kind of reservoir reformation, which uses sliding water as working fluid to form hydraulic fracture in formation by hydraulic force. It has the advantages of low damage and low cost. Because of the poor sand carrying capacity and low sand concentration, the effect of sliding water fracturing depends on whether there is a favorable natural fracture system and their response to pressure and in-situ stress [14].

4.1. Study on Perforation Mode Optimization of Volume Fracturing

According to elasticity theory and rock fracture criterion, the crack initiation surface is always perpendicular to the direction of minimum principal stress. Because the direction of minimum principal stress is perpendicular to the direction of maximum principal stress, the crack initiation is along the direction of maximum principal stress. In conventional fracturing, when the maximum principal stress and the minimum principal stress in the treatment area are quite different, the fracturing result is usually a symmetrical principal fracture along the direction of the maximum stress. But if the maximum and minimum principal stresses in the formation stress field are very small or equal, it is difficult to determine the fracture initiation direction [15]. At this time, the fracture initiation is affected by the direction of perforation and the natural fracture in formation.

Through the study, the following conclusions are drawn:

- (1) Around the initial crack, the induced stress is the largest in the direction of the original minimum horizontal principal stress, the largest in the direction of the original maximum horizontal principal stress, the smallest in the direction of the original maximum

horizontal principal stress, and the smallest in the direction of the original maximum horizontal principal stress.

- (2) The magnitude of induced stress is related to the distance between the induced stress and the initial crack, which is the largest on the crack wall, equal to the net pressure in the crack. After three times the height of the half-crack, the influence of induced stress becomes very small and can be ignored.
- (3) The influence range of induced stress is related to the initial fracture height, and its size is affected by the initial fracture width and fracture height. Fracture height and width are controlled by fracturing fluid injection rate and high technology of fracture control. By controlling fracture width and height in construction, induced stress is obtained, and corresponding stress field is obtained.

According to the above calculation, perforation in horizons with good interpretation and low in-situ stress is selected. The cluster spacing is controlled between 10 and 20 m, 2 to 3 m per cluster, according to the simulation of fracturing software.

4.2. Simulation of Fracture Opening Process in Hydraulic Fracturing

The size of the model is 1000 m×400 m × 30 m (Figure 2). The maximum horizontal stress of 40 MPa and the minimum horizontal principal stress of 30 MPa are applied. In order to get the parameters near the crack surface, mesh refinement should be done at the crack. Through simulation, different construction displacement and time crack extension length can be obtained. By substituting the parameters of different blocks into the model, the relationship between crack propagation length and construction displacement in different blocks can be obtained [16].

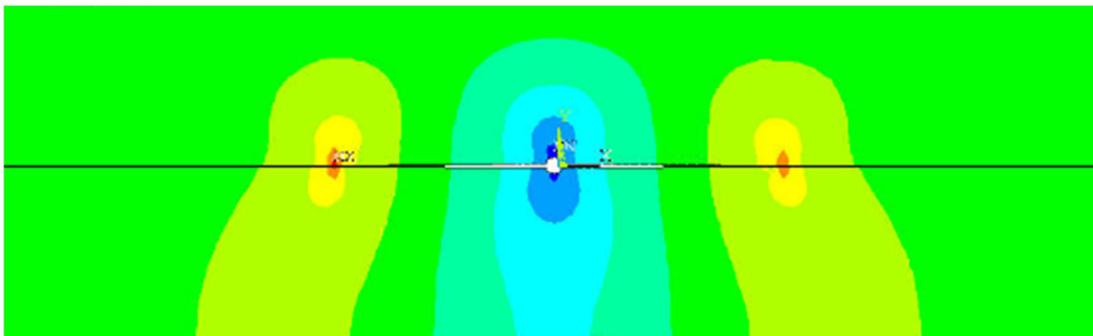


Figure 2. Fracture End Stress in Crack Propagation.

4.3. Slip Water Fracturing Fluid

The drag reduction effect of water skiing drag reducer is one of our most concerned parameters. The drag reduction effect of drag reducing agent is tested by pipeline rheometer. Slip water with different concentration is prepared by using the drag reducing agent. The pressure difference under different displacement is measured separately, and then the drag reduction rate is calculated. Through laboratory

experiments, the drag reduction effects of different concentrations of the existing drag reduction agent LCL-01 for sliding water were evaluated [17].

Laboratory experiments show that the drag reduction rate of polymer LCL-01 sliding water increases with the increase of displacement. Under the same discharge rate, the drag reduction rate of sliding water with LCL-01 configuration decreases with the increase of concentration [18]. The

optimum concentration of drag reducer is 0.5%~1%.

4.4. Segmented Multi-cluster Perforation Fracturing Technology

Segmental multi-cluster perforation fracturing utilizes interstitial interference to promote fracture turning, so as to realize complex network fractures and achieve the purpose of volume transformation (Figure 3). Multi-cluster perforation is carried out in the strata with good oil and gas display. Vertically, it is divided into multiple starting points and multi-segment fractures, which simultaneously initiate and interfere with stress between fractures. According to the number of perforations to determine the construction displacement, to ensure that each cluster can be fractured, and the formation of complex network fractures, compared with conventional fracturing, increased fracturing fracture sweep volume. At the same time, the perforation section is reduced by 70%, which saves the cost of perforation.

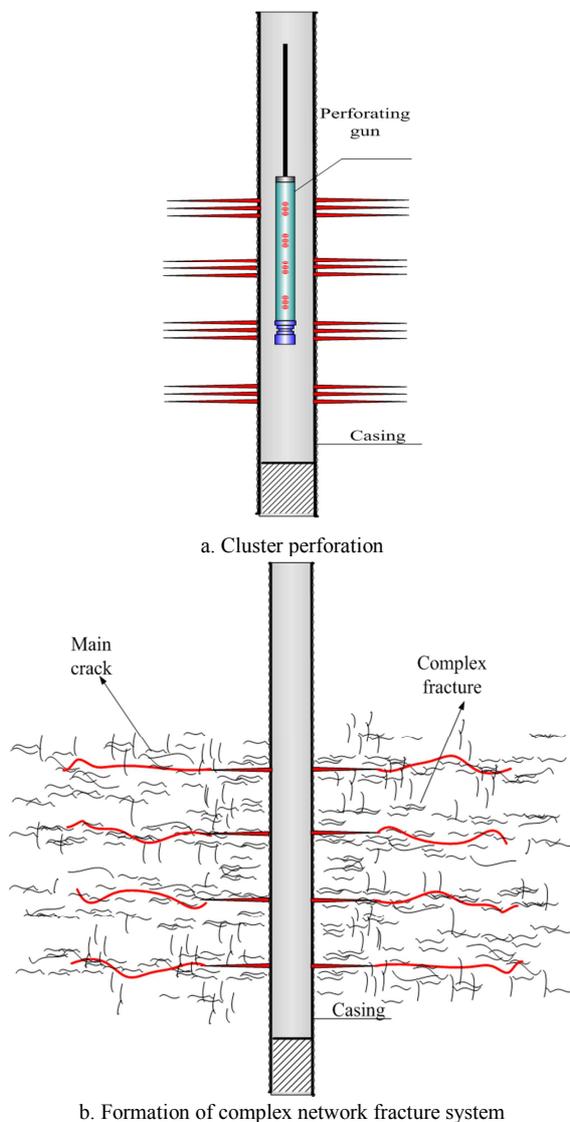


Figure 3. Schematic Chart of Cluster Perforation Fracturing with Fracture Mesh.

4.5. Fracturing Effect

The cumulative completion of 96 wells of sliding water fracturing in metamorphic buried hill resulted in an average daily oil increase of 13.2 tons per well after fracturing, which is 2.3 times the daily production of conventional fracturing in the same block. At the same time, the cost of perforation and fracturing is reduced by more than 15%, which achieves the purpose of cost reduction and efficiency increase.

5. Conclusion and Knowledge

- (1) There are many problems in metamorphic buried hill reservoirs, such as poor reservoir physical properties and low natural productivity. Fracturing is needed to obtain industrial oil and gas flow. The natural fracture of metamorphic buried hill reservoir is well developed. Theoretically, it is easy to form slip and tear fractures, so it has the basic conditions for the formation of complex fracture net.
- (2) Through the analysis of the fault mechanism of the fracture surface in the stratum with natural cracks, it is considered that the approximation angle and horizontal principal stress difference between the hydraulic cracks and the natural cracks are the main factors affecting the trend of the hydraulic cracks. In the process of fracturing metamorphic rocks, the condition of dislocation of fracture surface provides a theoretical basis for the development of volumetric fracturing.
- (3) The developed slip water fracturing fluid has low viscosity and frictional resistance, and it is helpful to open and extend natural fractures to the greatest extent in combination with large displacement construction. The results of microseismic fracture monitoring in wells show that the sweep volume of slip water fracturing is significantly larger than that of conventional guar gum fracturing.
- (4) On the basis of theoretical calculation and numerical simulation, the cluster perforation mode is optimized, and the fracture steering is promoted by using the interfracture interference, which is conducive to the formation of complex network fractures and the improvement of the effect of fracturing transformation.
- (5) Field tests of 96 wells show that cluster perforation slip fracture network fracturing technology has achieved good stimulation effect in metamorphic rock buried hill, and can save fracturing cost, which has good popularization value.

References

- [1] Zhu Yixiu, Wang Huan, Shan Junfeng, Yang Chengyu. Lithology and reservoir space characteristics of Archean bedrock reservoir in Ciyutuo buried hill, Liaohe Depression. OIL & GAS GEOLOGY, 2018, Vol. 39 (6), 1225-1236.

- [2] Liu Xingzhou, Preliminary study on hydrocarbon accumulation in the interior of metamorphic buried hill in Liaohe Depression. *Petroleum geology and Engineering*, 2009, Vol. 23 (1), 1-7.
- [3] Chen Wenling, Zhou Wen. Important exploration areas in Petaliferous basins-The basement hydrocarbon reservoirs. *Journal of Southwest Petroleum University (Science & Technology Edition)*, 2012, 34 (5), 17-24.
- [4] Xue Shangyi, Characteristics and reservoir distribution of Anfutun buried hill reservoir in Damintun. *Henan Petroleum*, 2006, Vol. 20 (1), 8-13.
- [5] Hou Jianxiang, Meng Qingyou, Tao Tao. Study on structure and reservoir of Shen 223-229 buried hill in Damintun, *Henan Petroleum*, 2004, Vol. 18 (3), 7-12.
- [6] Li Xiaoguang, Guo Yanmin, Cai Guogang. Reservoir-forming conditions and exploration of subtle buried hills in Damintun. *Petroleum Exploration and Development*, 2007, Vol. 34 (2), 135-141.
- [7] Zhang Jichang, Luo Yuqing, Chen Heping. Fractured Reservoir of Niuxintuo Metamorphic Rock in Liaohe Basin. *Henan Petroleum*, 1998, Vol. 12 (1), 9-13.
- [8] Liu Xingzhou. Reservoir Identification and Characteristics of Buried Hills in Western Liaohe Oilfield and Damintun Depression. *Petroleum geology and Engineering*. 2007, Vol. 21 (4), 5-8.
- [9] Wu Weitao, Gao Xianzhi, Liu Xingzhou. Formation and distribution of basement rock reservoir. *Geological Science and Technology Information*, 2014, 33 (1), 107-113.
- [10] Zhu Yixiu, Yang Chengyu, Wang Huan. Petrological characteristics of the Archeozoic metamorphic reservoir in Niuxintuo Liaohe Depression. *Petroleum Science Bulletin*, 2017, 2 (03), 327-335.
- [11] Sun Lixun. Reservoir Characteristics of Metamorphic Rock Reservoirs in Xinggu Buried Hill. *Journal of Changjiang University*. 2011, Vol. 8 (5), 62-64.
- [12] Chen Zuo, Xue Chengjin, Jiang Tingxue. Suggestions on Application of Volume Fracturing Technology in Shale Gas Wells in China. *Natural Gas Industry*. 2010, Vol. 30 (10), 30-32.
- [13] ZHAO Zhengchao, LIU Dezhu, LIU Wei, et al. Development of Systematic Hydraulic Fracturing Technology for a Naturally Fractured Reservoir. *SPE Europe/EAGE Annual Conference*, 13-16 June, 2005, Madrid, Spain.
- [14] Shao Limin, Jin Baojun, Li Aishan. Research and Application of Slip Water Fracturing Fluid in Unconventional Oil and Gas Reservoirs. *Turpan-Hami Oil and Gas*. 2012, Vol. 17 (4), 383-387.
- [15] Luo Tianyu, Wang Jiahuai, Zhao Jinzhou. Study on the influence of natural fracture on hydraulic fracturing. *Journal of Petroleum and Natural Gas*. 2007, Vol. 29 (5), 38-41.
- [16] Yao Fei, Chen Mian, Wu Xiaodong. Physical Modeling of Hydraulic Fracture Extension in Natural Fractured Formation. *Oil Drilling & Production Technology*. 2008. Vol. 30 (3), 26-29.
- [17] Wang Gaihong, Liao Lejun, Guo Yanping. The development and application of a recyclable clear fracturing Fluid. *Drilling Fluid & Completion Fluid*, 2016, 33 (6), 101-105.
- [18] Meng Lei, Zhou Fujian, Liu Xiaorui, Yang Zhao, Shi Huaqiang. Friction reducers for slick water: performance evaluation and friction prediction. *Drilling Fluid & Completion Fluid*, 2017, 34 (3), 105-110.