Research on Formation and Control Method of Volume Fracturing Network in Tight Reservoir Based on Computer

Guangwen Yu¹

¹Daqing Oilfield Co., LTD. No.7 Oil Production Company, China, 163517

*Corresponding author e-mail: dq_yugw@petrochina.com.cn

Abstract. With the maturity and application of the concept of volume fracturing, the development of tight reservoirs has gradually become a strategic goal of unconventional oil and gas resources development. However, there are still some difficulties and problems in the theory of volume fracturing fracture opening. Based on this, this paper first studies the feasibility evaluation of volume fracturing in tight reservoir, then analyses the formation mechanism of volume fracturing network in tight reservoir, and finally gives the formation control method of volume fracturing network in tight reservoir based on computer.

Keywords: Volume Fracturing Network, Tight Reservoir, Computer, Control Method

1. Introduction
Because of the characteristics of tight reservoir, such as tight lithology, low natural productivity, low porosity and permeability, it is difficult to exploit, and the effect of exploitation is not satisfactory. With the development of production technology, especially the maturity and application of volume fracturing concept, the development of tight reservoir has gradually become the strategic goal of unconventional oil and gas resources development [1]. Volume fracturing technology improves the volume of oil and gas reservoir and maximizes the contact of fractures with oil and gas reservoir, so as to improve the single well production by obtaining larger oil and gas release capacity. At present, the exploration and development technology of tight oil and gas is still in the exploration stage, and the enrichment law of tight oil and gas needs further study. Besides, the theoretical calculation results of volume fracture opening are quite different from the actual situation. In addition, the adaptability application, recovery enhancement and economic development of complex geology in China need further improvement. Based on this, it has important practical value to study the formation and control method of volume fracturing network in tight reservoir based on computer.

2. Feasibility Evaluation of Volume Fracturing in Tight Reservoir

2.1. Reservoir conditions realized by volume fracturing
In the mineral composition of tight reservoir rocks, sedimentary rocks account for a higher proportion, and sedimentary rocks are composed of brittle and plastic rock components, in which the complex fracture network is more likely to be formed under the condition of a larger proportion of brittleness.
The purpose of volume fracturing is to improve the oil and gas supply capacity of tight reservoirs [2]. Because the extension of hydraulic fractures is significantly affected by natural fractures, the interaction between artificial hydraulic fractures and natural fractures is generally analyzed by computer finite element method. The interaction relationship between artificial fracture and natural fracture under specific relative net pressure coefficient is shown in Figure 1.

**Figure 1. Interaction between artificial fracture and natural fracture**

Where there is a large pressure in the natural fracture, the fracture will propagate along the direction perpendicular to the hydraulic fracture to form a fracture network system. In addition, in the process of fracture extension, the increase of pressure in the fracture will produce new natural fracture direction in the fracture, thus promoting the formation of the seam mesh.

2.2. **Complex fracture pattern of volume fracturing in tight reservoir**

Under the condition of specific tight reservoir characteristics, it is difficult for conventional fracturing main fracture to improve vertical seepage capacity, resulting in low fracturing production. Through the monitoring, it is found that there are irregular cloud charts around the fracturing well, and the fracturing fluid injected around the main fracture can explore the fine line fracture, induce the micro fracture to open or form, so as to improve the formation seepage area [3]. After the hydraulic fracture intersects with the natural fracture, the crack initiation and extension characteristics of the branch fracture will determine the geometric size and complexity of the fracture network.

2.3. **Analysis of the factors influencing the formation of radial seam net**

There are two main reasons for the formation of radial fracture network. First, there are several equivalent fracture points with similar fracture pressure around the well of tight reservoir. Secondly, the fracture extension pressure is higher than the fracture pressure, and the rise of bottom hole pressure causes the equivalent fracture point to crack and extend. In addition, other factors such as perforation friction, fracture surface roughness, wellbore pressure build-up and so on will affect the formation of radial fracture network [4]. The fracture initiation criteria of composite fracture are as follows:

\[
p_f' > \sigma_4 = \left| \sigma_1 \cos^2 \alpha + \sigma_2 \cos^2 \beta + \sigma_3 \cos^2 \gamma \right| + T_0
\]  

(1)

The criterion for the extension of composite fracture is the theory of maximum circumferential stress:

\[
(\sigma_\theta)_{\text{max}} = \frac{1}{2\sqrt{2\pi r}} \cos \frac{\theta_0}{2} \left[ K_i \cos^2 \frac{\theta_0}{2} - \frac{3}{2} K_{ii} \sin \theta_0 \right]
\]  

(2)

The dominant size of volume fracturing is different with different seepage level. Because the lower the reservoir permeability is, the more obvious the contribution of fracture network in the production capacity is [5]. Therefore, the better the effect of volume fracturing is.

3. **Formation Mechanism of Volume Fracture Network in Tight Reservoir**
3.1. Formation mechanism of stress-induced fracture
In the fracture of tight reservoir, the tip of the fracture is affected by the concentrated stress, so the induced fracture will occur when the stress exceeds a certain value, so that the total displacement of the fracture opening reaches the peak value. In addition, in the condition of stress induced crack formation, because the critical pressure at the crack tip is positively related to the horizontal stress difference, it is easy to form induced shear crack. As for the artificial fracture, it will release the stress gradually in the process of extension and produce the fracture. After the induced crack is produced and the pressure in the crack reaches a certain value, the release joint will be connected into a seam net.

3.2. Analysis of artificial fracture extension in tight reservoir
Fracture criterion is the core problem of fracture mechanics, which is proposed for a specific scale and level. In order to study the condition of cross extension of hydraulic fracture and artificial fracture, based on the Renshaw and Pollard criterion, it can be judged that when the stress at the other end of the interface is enough to open the fracture, the stress at the crack tip on the interface can prevent the fracture from sliding \(^6\).

![Figure 2. Diagram of induced stress](image)

4. Control Method of Formation of Volume Pressure Fracture Network in Tight Reservoir

4.1. The formation method of volume pressure fracture network in tight reservoir
Among the important parameters controlling the formation of volume pressure fracture network in tight reservoir, the brittleness of tight reservoir is positively related to the formation of bifurcated fracture, while the horizontal stress difference is negatively related to the formation of stress-induced fracture. In addition, the opening degree of natural fractures in the reservoir is positively related to fracture network, and its development degree and direction have an important influence on the formation of fracture network. In addition, by means of computer monitoring technology, it can be found that the linear fracture is related to the magnitude of horizontal principal stress difference, and the volume fracture network formed by natural fracture is often due to the smaller horizontal principal stress difference and other reasons. Therefore, it is necessary to take some technical measures to reduce the stress difference in order to create favorable conditions for the formation of fracture network.

4.2. Process design and control method of formation of fracture network in tight reservoir
Through the analysis of the formation mechanism of the volume pressure fracture network in the tight reservoir, it can be found that optimizing the fracture spacing and reducing the two-dimensional stress difference are helpful to the formation of the fracture network. Because the artificial fracture will turn along the natural fracture under the action of net pressure in the fracture, the increase of net pressure in the fracture will promote the generation of complex fracture network. In the aspect of seam spacing control, through computer simulation analysis, it is found that the reduction of stress difference in the
process of multi seam extension will make the stress turn, which will cause the main crack to turn and extend. The reconstruction of high viscosity fracturing fluid is not conducive to the formation of complex fracture network, but the opposite is that the fracture expansion after the reconstruction of low viscosity fracturing fluid is more sufficient.

In addition, in terms of injection process control, through the monitoring of underground fractures by computer sensors, it is found that the injection of slippery water can improve the control form of the seam network and promote the extension of the seam network, as shown in Figure 3 below.

![Figure 3. Monitoring diagram of fracture formation by slick water fracturing](image)

5. Conclusion
In summary, the successful factors of volume fracturing in tight reservoir include rock mineral composition, natural fracture development and rock mechanical characteristics. Based on the analysis of the formation mechanism of stress-induced fracture, it is found that the critical pressure at the crack tip is positively related to the horizontal stress difference, and the induced shear fracture is easy to form when the horizontal stress difference is low. In addition, to optimize the gap and reduce the two-dimensional stress difference is helpful to the formation of the seam network, and the use of slippery water injection can promote the extension of the seam network.

Acknowledgments
Demonstration project of tight oil development in Songliao Basin.

References
[1] Y. Y. Cheng Yuan, X. Chang, Y. W. Sun, Fracture network extension morphology of shale reservoir based on fracture mechanics. Natural Gas Geoscience, 2014, 25 (4) 603-611.
[2] J. Z. Zhao, J. W. Xu, Y. M. Li, New evaluation method of shale gas reservoir compressibility. Natural Gas Geoscience, 2015 (06).
[3] L. H. Pan, J. L. Cheng, Y. Zhang, Numerical simulation of multi-stage cluster fracturing initiation pressure in shale horizontal wells. Geotechnical Mechanics, 2015 (12) 3639-3648.
[4] C. Li, Research and application of fracture induced stress field in Dagang tight oil reservoir. Southwest Petroleum University, 2016.
[5] L. F. Liu, Q. Q. Ran, X. Wang, R. Li, Optimization method of interval of volume fracturing in horizontal well of tight reservoir. Oil Drilling and Production Technology, 2015, 3 (73) 84-87.
[6] H. Wang, Study on the evaluation of high energy gas fracturing compressibility of horizontal wells in qingshale gas reservoir. Xi'an University of petroleum, 2016.