Optimization of fracturing parameters for tight sandstone gas reservoirs

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Abstract. Due to the poor physical properties of tight sandstone, the pore throat is small and the connectivity is poor. In the process of development, fracturing construction is often needed. Reasonable fracturing construction parameters are the key and difficult points of fracturing design, and also the key factor to determine the success of fracturing. Aiming at the optimization of fracturing parameters in tight sandstone, the optimization of fluid flow, net pressure balance, and displacement were studied respectively. The large displacement rate is conducive to the three-dimensional propagation of the fracture, and there is an optimization limit for the displacement rate as well as the construction scale. For large displacement optimization, the displacement of 10~20m³/min was set to calculate the fracture extension at each displacement, to define the influence of each displacement on fracture extension. Secondly, the liquid volume was set as 1000m³, 1200m³, 1400m³, 1600m³, 1800m³, and 2000m³ respectively for simulation calculation, and the calculation results were analyzed to find out the critical point and the optimal fracturing scale when the fracture perforated the layer. Finally, a method to optimize the number of perforations is proposed by calculating the frictional resistance of perforations. The experimental results show that the displacement is controlled at about 16m³/min, the construction fluid volume is controlled at about 1800m³, and the number of perforations is recommended to be controlled within 36-48 so that the fracturing operation effect can achieve the best.

1. Preface
Tight sandstone oil and gas fields play an important role in the distribution of oil and gas fields in China and even in the world. However, most of these oil and gas resources are buried deep, with low permeability, and difficult to develop. Hydraulic fracturing is an effective technique for oil and gas reservoir development. After fracturing, a channel with high conductivity is formed inside the oil layer, which can increase the crude oil output and achieve the purpose of increasing oil production and enhancing oil recovery. In the process of hydraulic fracturing, the viscous fluids injected include pre-pump, sand-carrying fluid, and displacement fluid, etc., and the parameters such as pre-pump amount, displacement fluid amount, total fluid amount, sand-adding amount, and mixing ratio have a significant influence on the effect of fracturing production enhancement. Under certain geological conditions, how to select the values of these parameters in order to minimize the material cost and make the best oil increase effect, is necessary to optimize the design of fracturing operation parameters. Scholars at home...
and abroad have used a variety of methods to optimize fracturing parameters. Previous studies have found that the larger the fracturing displacement is, the better, but there is an optimal range. Secondly, when analyzing the fracturing effect, it is found that the most influential factor is the size of the injected fluid. The larger the amount of injected fluid, the more complex the fracture network formed by fracturing, and the more obvious the increase of productivity. Similarly, reservoirs with different physical properties have different fracture complexity and different potential of volumetric fracturing, so different fracturing schemes for reservoirs with different properties can effectively improve productivity [1-4]. The above conclusions only carry out qualitative research on fracturing construction displacement, liquid injection volume, and fracture complexity, etc., without quantitative research on optimization parameters. In this paper, an experimental study on displacement, liquid volume, and net pressure is carried out to find out the optimal parameter range.

2. Displacement optimization

According to the wellbore storage effect, the increase of construction displacement is conducive to the rapid pressure suppression in the wellbore, thereby increasing the net pressure and contributing to the three-dimensional fracture propagation [5,6]. In addition, increasing fracture width, reducing fluid loss, and improving fracturing fluid efficiency require large flow rates, which are directly used to improve sand carrying capacity due to reduced proppant settling time and viscosity degradation due to increased injection rate and reduced pumping time associated with proppant settling. As with the construction scale, there is an optimization limit for the displacement.

In this section, the displacement is set to 10~20m³/min to calculate the fracture extension at each displacement, so as to define the influence of each displacement on fracture extension. The calculated results are shown in Figure 1 to Figure 6:

Figure 1. Fracture morphology under 10m³/min displacement

Figure 2. Fracture morphology under 12m³/min displacement

Figure 3. Fracture morphology under 14m³/min displacement

Figure 4. Fracture morphology under 16m³/min displacement
As can be seen from Figure 7, when the displacement is increased to 16 m³/min, the growth of fracture length begins to slow down, and when the displacement is equal to 18 m³/min, the fracture length, width, and height decrease because the fracture is partially embedded in the interlayer at this time. Although there is no out-of-control fracture height at 20 m³/min, the fracture has a tendency to press through the barrier layer. If the displacement is further increased, the fracture height may be out of control. Therefore, the construction displacement is recommended to be controlled at about 16 m³/min.

### 3. Optimization of liquid volume

Under the same conditions, the fracturing scale, the greater the formation of the greater the size of the crack in all directions, so through the way of enlarging the fracturing scale can achieve a certain effect, but taking into account the cost factors, not the bigger the better, because after the fracturing scale increases to a certain degree, the expansion of the crack is slowing, and that there is an optimal fracturing scale and can meet the requirements of wear layer fracturing, and can effectively control the cost [7-8].

Analysis of the purpose of this section is to find out the critical crack wearing layer and the optimal fracturing scale.

In this section, the liquid volume is set as 1000 m³, 1200 m³, 1400 m³, 1600 m³, 1800 m³, and 2000 m³ respectively for simulation calculation, and the calculation results are analyzed. Figure 8 to Figure 13 shows the propagation patterns of fractures at the above fracturing scales:
Figure 8. Fracture morphology under 1000m³ liquid consumption scale

Figure 9. Fracture morphology under 1200m³ liquid consumption scale

Figure 10. Fracture morphology under 1400m³ liquid consumption scale

Figure 11. Fracture morphology under 1600m³ liquid consumption scale

Figure 12. Fracture morphology under 1800m³ liquid consumption scale

Figure 13. Fracture morphology under 2000m³ liquid consumption scale

Figure 14. Influence of fluid volume on fracture morphology
As can be seen from Figure 14, no out-of-control phenomenon of fracture height appears in all the calculation models after controlling the displacement of 1,600m$^3$. When the displacement is increased to 1,800m$^3$, the growth of fracture length begins to slow down. Therefore, it is recommended to control the construction liquid volume at about 1,800m$^3$.

4. Net pressure balance

Net pressure is the power of artificial fracture, in the case of high seam controlled more help to get more and more wide net pressure fractures, but the hydraulic energy flow along the path and partial loss will lead to a drop in net pressure, the friction except with effective drag reduction agent, there is no other effective method with constraints, while perforation friction can be artificially adjusted by perforation density and perforation clusters, under control engineering parameters, so this section of perforation friction calculation of the number of optimization of perforation method$^9$.

Combined with the small-scale test fracturing data of Qiuulin 10-H1 well, it was calculated that the frictional resistance of a single stage with 36 holes was 14.6MPa, as shown in Figure 15. However, the adjacent well Qiuulin 16 in the same block perforated 67 holes, and the hole friction was only 4.0MPa, as shown in Figure 16, indicating that the hole friction generated by the existing technological measures and liquid system in the Qiuulin area was highly sensitive to the perforation number.

According to the classical hydraulics formula, the influence of the number of perforations on the hole friction was calculated, and through the calibration of measured data from two Wells, Qiuulin 16 and Qiuulin 10-H1, the corresponding chart of the number of perforations and the hole friction in Qiuulin area was obtained, as shown in Figure 17.

The net pressure in the slit and the friction of the perforation under different perforation numbers were calculated and compared in the same coordinate system, as shown in Figure 18.
Figure 18. Correspondence between net pressure and hole friction in autumn forest area

The two curves in Figure 18 can be roughly divided into three sections: the net pressure in Zone I is low because the small number of holes leads to a large local loss of hydraulic energy. Therefore, with the further increase of the number of holes, the friction decreases, and the net pressure increases. Zone II represents the reasonable interval of the number of holes, in which the net pressure and hole friction change within a small range and the net pressure can reach the maximum value at this time. III area on behalf of the perforation as the further increase of the number of, fall became smaller, to reduce the pressure loss of perforation by increase the number of perforation friction reduction method can not obtain the significant effect, and the interval net pressure is on the decline because after perforation number increased, on the one hand, reduces the concentration of hydraulic energy, on the one hand, improve the liquid inside seam flow area, the effect of the friction inside seam began to dominate. Considering the net pressure in the fracture and the balance of perforation friction, the number of perforations is recommended to be controlled within zone II.

5. Conclusion

(1) according to the wellbore storage effect, the construction with large displacement pressure-out quickly is advantageous to the wellbore, thus improve the net pressure, when construction displacement control at about 16 m³/min when fracture of the most popular, when construction emissions increased to 20 m³/min high seam crack did not appear out of control, but has interlayer fracture pressure wear trend, further improve the seam displacement may cause a high spin out of control.

(2) There is no out-of-control phenomenon of fracture height in all calculation models after controlling the fluid volume at 1600m³. When the displacement is increased to 1800m³, the growth of fracture length begins to slow down. Therefore, it is recommended to control the construction fluid volume at about 1800m³, which can not only meet the requirements of fracturing through layers but also effectively control the cost.

(3) From the perspective of considering the balance between net pressure in the fracture and hole friction, it is recommended to control the number of perforations within 36-48. Within this interval, net pressure and hole friction change within a small range, and the net pressure can reach the maximum value at this time.

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