Parameter optimization of acid fracturing in ultra-deep fault zone carbonate reservoir

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Abstract. The characteristics of fracture development are complex in Shunbei area. The natural fracture development is different between different fault zones and in different locations of the same fault zone. Not all natural fractures can be activated during acid fracturing, and not all natural fractures can contribute to well productivity after acid fracturing. The use of natural fractures can not only improve the seepage capacity of the reservoir, but also improve the well productivity. Therefore, the influence of artificial fracture on the opening and fracture conductivity maintenance of natural fracture is studied, and finally the acid fracturing roceand parameters based on the change of natural fracture are formed.

1. Fracture distribution in fault zone

The distribution of large fault zones is dense and complex in the Shunbei region, which is a ultra-deep carbonate reservoir in Tarim Basin. There are great differences in the internal structure of large fault zones, and the characteristics of fracture development are complex. The natural fracture development is different between different fault zones and in different locations of the same fault zone.
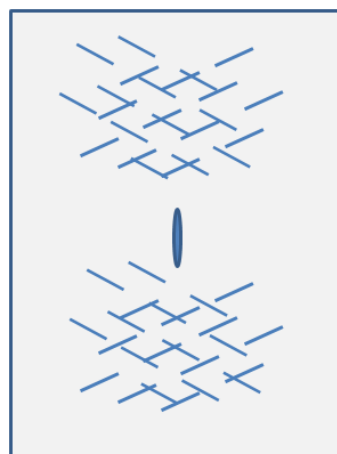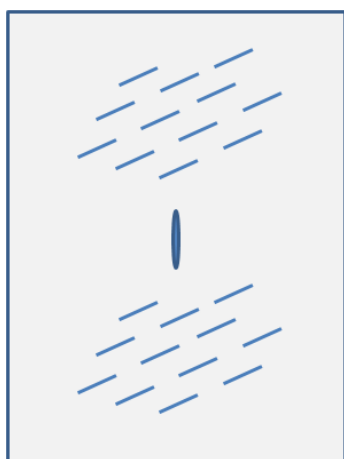

Figure 1. Two intersecting modes of artificial fracture and natural fracture.

According to the internal distribution characteristics of the large fault zone, the surrounding area of the large fault zone can be divided into central fracture zone and induced fracture zone. In the central fracture zone, the stress concentration changes greatly, the rock fracture is seriously broken, and the fracture is dense. In the induced fracture zone, the stress dispersion is small, the rock fragmentation is weak, and the fractures are sparse. In the process of acid fracturing, artificial fractures may pass through the central fracture zone with dense fractures and the induced fracture zone with sparse fractures.

Due to the influence of stress changes in the fault zone, there must be stress inversion in the area near the fault, and the distribution of fractures around the fault should be staggered or reticulated with high fracture density. However, the fractures far away from the fault zone are less affected by stress changes, and the fracture direction distribution is single and the fracture density is smaller.

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According to the fracture characteristics of natural fractures at different distances from the fault zone, two intersecting modes of artificial fracture and natural fracture are proposed: (1) Artificial fracture intersects with a single mode natural direction. (2)Artificial fracture intersects with two modes natural directions (Fig.1).

2. Analysis of regional reconstruction technology of fault zone

According to the above distribution characteristics of natural fractures near the fault zone, the XFEM extended finite element model was established. As shown in Figure 2, the natural fracture is in the state of intersection, and the artificial fracture approaches the natural fracture at a certain Angle. The smaller the Angle between natural fracture and artificial fracture, the more easily artificial fracture is captured by natural fracture, and continue to expand along the direction of maximum principal stress.
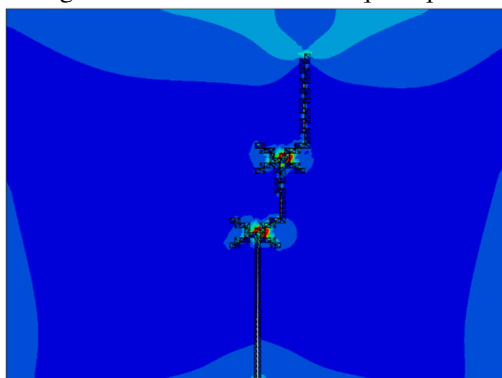

Figure 2. Artificial fractures communicate two kinds of intersecting natural fractures.

Due to the length and height of natural fractures in real reservoirs, artificial fractures are more likely to directly intersect with natural fractures when approaching them. In this case, the model can be simplified as the intersection between artificial fracture and one of the intersecting natural fractures. After the first natural fracture is opened, another natural fracture intersects with the natural fracture communicated by artificial fracture. Therefore, the natural fractures that have been communicated can be regarded as artificial fractures at this time, and the first natural fracture that has been communicated continues to communicate with the second natural fracture. This intersecting pattern creates a more complex hydraulic fracture system. Figure 3 shows the intersection simulation of artificial fracture and single kind natural fracture.
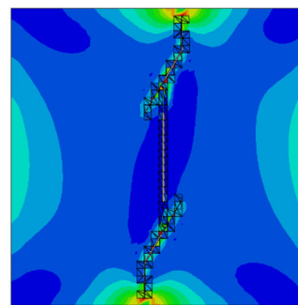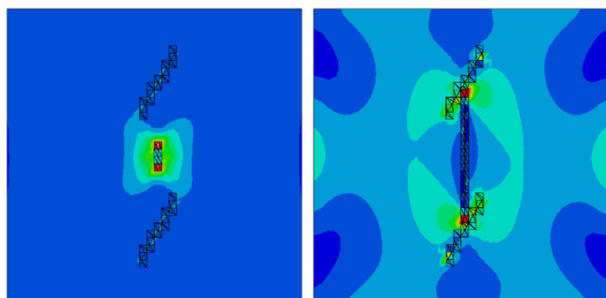

Figure 3. Artificial fractures communicate with single natural kind fractures.

Natural fractures can be extended by artificial fractures. The extension of natural fracture is due to the stress concentration at the tip of artificial fracture. The stress difference increases at the stress concentration position of artificial fracture tip. Under the condition of the increase of stress difference, the shear stress value on the wall of natural fracture increases and leads to the opening and extension of natural fracture (Fig.4).
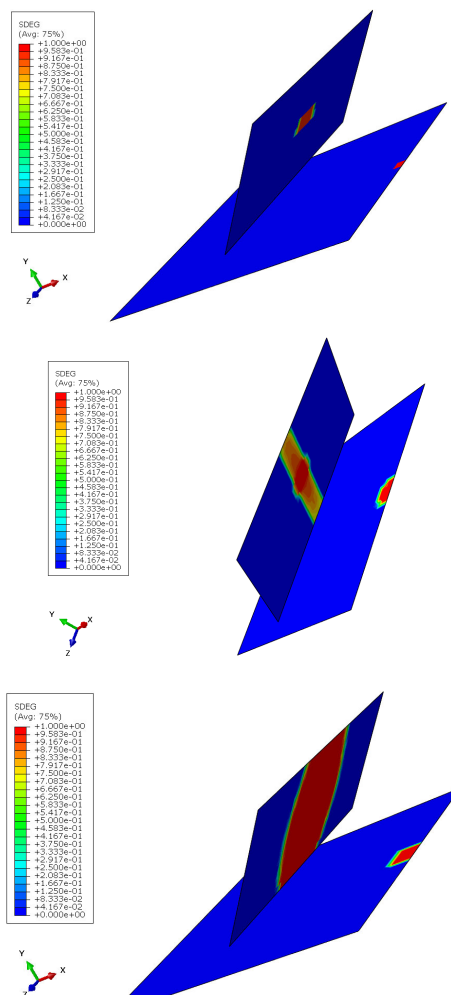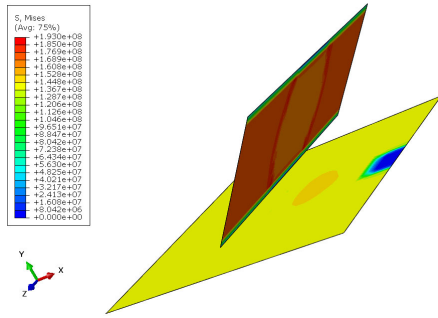
Figure 4. Natural fractures open under the interference of artificial fractures.

In the process of artificial fracture propagation, although the filtration loss of working fluid is increased to a certain extent under the action of acid, the action of acid can change the mechanical properties of formation rock and increase the propagation distance of artificial fracture. The proper use of acid changes the mechanical properties of the formation rock, allowing artificial fractures to communicate with a wider range of reservoirs (Fig.5).
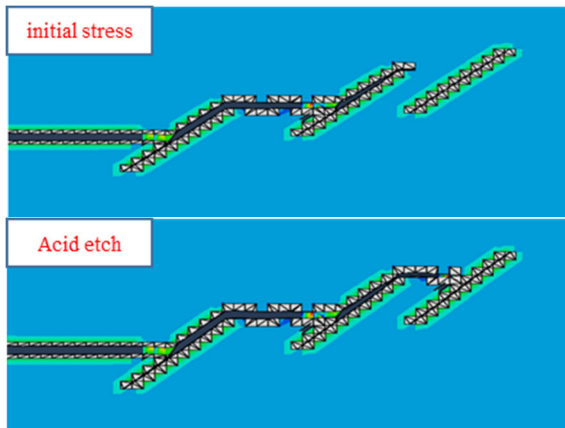

Figure 5. Effect of acid on communication distance.

First, high-viscosity fracturing fluids should be used to open the formation before acid is used, because acid reduces the range of artificial fracture-induced stress interference. Under the action of fracturing fluid, artificial fractures continue to expand. Under the action of induced stress of artificial fractures, natural fractures near artificial fractures are opened. At the same time, the intersection of artificial fractures and natural fractures can also open some natural fractures.

Weak acid or low acid concentration should be added after natural fractures near artificial fractures are opened. Under the pressure of the injected fluid, the acid filtrates into the formation near the fracture for preliminary dissolution of the formation. Under the action of acid, Poisson's ratio and Young's modulus of rock near artificial fractures will decrease in different degrees, which is conducive to the communication of more natural fractures when artificial fractures intersect with natural fractures. When the artificial fracture expands to a certain scale, conventional acid is injected to dissolve the formation on a large scale. At this time, the acid plays a role of forming dissolution fractures with certain conductivity.

3. Organization of the Text

3.1 Liquid scale optimization

In the process of reservoir stimulation, the scale of fluid has a decisive influence on the scale of stimulation volume. Under the same injection parameters of the model, different injection time can represent different liquid injection scales. The longer injection time, the farther the artificial fracture extension distance, and the larger the sweep range of stress concentration zone at the tip of artificial fracture extension. In the area swept by the stress concentration zone at the artificial fracture tip, most natural fractures will open, so the larger the fluid size, the better.
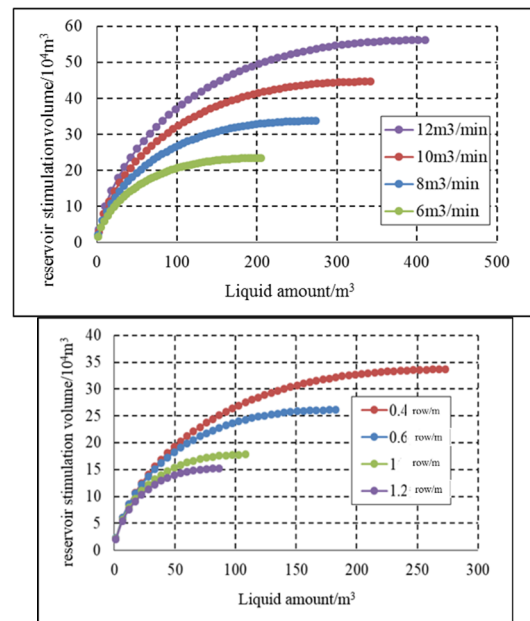

Figure 6. Reservoir communication volume with different acid amount.

According to the volume model established by the natural fracture communication mode in the study area, the reservoir communication volumes under different construction fluid volumes under different pumping rate and different fluid volumes under different natural fracture densities are analyzed, as shown in Figure 6. Due to the high degree of fracture development near the fault zone, the volume of reservoir stimulation volume during conventional fracturing is limited. It can be seen from the stimulation volume simulation, within the range of formation and wellbore conditions, the pre-fracturing fluid of 400m³ can achieve better stimulation effect.

3.2 Pumping rate optimization

It is known that in the in-situ stress field, the pumping rate is 6m³/min and the viscosity is 100mPa•s, and the angle range of the artificial fracture can open the natural fracture is 0°~55° (Fig.7). The pumping rate optimization study found that 60° natural fractures should be opened under the formation conditions in the study area, and it is recommended that the pumping rate during construction should be greater than 10m³/min.
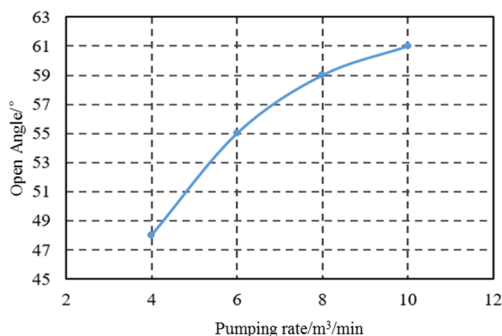
Figure 7. Effect of pumping rate on artificial fracture opening natural fracture.
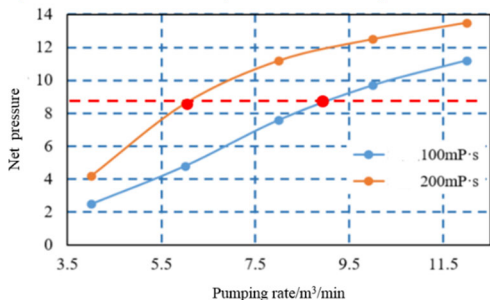
3.3 Optimization of liquid viscosity

Figure 8. Net pressure under different pumping rate and viscosity.

When the pumping rate is 6m³/min, the corresponding viscosity is 200MPa•s. The Angle between the natural fracture and the maximum horizontal principal stress in the study area ranges from 30° to 60°. The net pressure required for the intersection and communication of the 60° natural fracture is about 9MPa, the liquid pumping rate is 9m³/min, the net pressure reaches 9MPa, and the liquid viscosity is 100mPa•s (Fig.7). The liquid pumping rate is 6m³/min and the net pressure reaches 9MPa. The required liquid viscosity is 200mPa•s. In the actual construction, if the pumping rate is higher, the viscosity can be appropriately reduced and the natural fractures with an approaching Angle of 60° can be opened.

4. Conclusion

(1) In the area near the fault zone, artificial fractures continue to expand under the action of high viscosity fracturing fluid, and natural fractures near artificial fractures are opened under the action of induced stress induced by artificial fractures. At the same time, natural fractures are opened by the intersection of artificial fractures and natural fractures.

(2) After natural fractures near artificial fractures are opened, weak or low-concentration acids are added. Under the action of acid, Poisson's ratio and Young's modulus of rock near artificial fractures will decrease in different degrees, which is conducive to the communication of more natural fractures when artificial fractures intersect with natural fractures.

(3) When the artificial fracture expands to a certain scale, conventional acid is injected to dissolve the formation on

a large scale. At this time, the acid plays a role of forming dissolution fractures with certain conductivity. The retardance acid was used as the pre-acid to etch the distal fractures, and the crosslinked acid system with a viscosity greater than 200mPa•s was used as the main acid to etch the fractures, and the acid pumping rate should be greater than 10m³/min as the fracturing fluid.

Acknowledgments

References

1. Wang S.B. Key techniques for improving the length of acid corrosion fractures in Leikoupo gas reservoir in Weatern Sichuan. Southwest Petroleum University.

2. Zhang Z.W. Research on Spatial Evolution Law of Acid Etching Fractures in Carbonate Rocks. Chengdu University of Technology.

3. Huang W.Q. Research on factors influencing effective carbonate fracture volume caused by acid fracturing. Chengdu University of Technology.

4. Shen Y.X, Feng Z.C, Zhou D, et al. Study on numerical simulation of effect on natural fractures to hydraulic fracture propagation in shale reservoirs. Coal science and technology,2021,49(8):195-202.

5. Sheng G.L, Huang L.Y, Zhao H, et al. Integrated Simulation Approach for Fracture Network Propagation and Gas Flow in Shale Gas Reservoirs. Journal of Southwest Petroleum University（Science & Technology Edition）,2021,43(5):84-96.

6. Zhu H.Y, Song Y.J, Xu Y, et al. Four-dimensional in-situ stress evolution of shale gas reservoirs and its impact on infill well complex fractures propagation. Acta Petrolei Sinca, 2021, 41(9):1224-1236.

7. Xiong J, Liu J, Wu J, et al. Fracture propagation law and fracability evaluation of the tight reservoirs. Natural GasGeoscience, 2021, 32(10): 1581-1591.