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Research on Ultra-low Permeability Oil Development System Based on Oilfield Fracturing Water Displacement System

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Abstract. In order to realize the effective water injection development of oilfield reservoirs, large-scale fracturing technology was introduced. The simulation confirmed that the large-scale fracturing well has the characteristics of high initial production, fast water injection effect, and rapid water cut rise after the effect., the research results show that compared with elastic development, water injection development can solve the problem of rapid formation energy depletion, and at the same time increase the reservoir producing area and displacement time. The final water content of water injection huff and puff is about 25% lower than that of conventional water injection, and advanced water injection can increase the production of conventional elastic development by about 30% in the early stage. It can be seen that these two new development methods are conducive to suppressing water flooding and improving oil recovery.

Key words. Oil field fracturing, water displacement system, ultra-low permeability oil, development system, volume fracturing, newly added reserves.

1. Introduction

Low permeability reservoirs have poor physical properties, substantial heterogeneity, and low productivity. Industrial oil streams are usually only available by implementing acid fracturing measures. Low permeability reservoirs have complex subsurface fluid flow patterns [1]. During the development process, there are often problems such as difficulty in water injection, insufficient reservoir energy, rapid drop in information pressure, and low natural productivity. As a result, low-permeability reservoirs typically have lower recovery factors. It is of great significance to study the law of single good productivity and its influencing factors in tight oil reservoirs for the overall deployment of tight oil development. The oil field fracturing water drive system generally forms multiple fractures during the development of ultra-low permeability oil in the oil field. Due to the difference in the stress of the oil field fracturing and water displacement system and the limitation of fracturing technology, the multiple fractures formed are not the same in length and conductivity. The main fracturing parameters such as fracture length, fracture spacing, and conductivity coefficient of the oil field fracturing water drive system will impact productivity. Therefore, it is of great significance to optimize the parameters of the oil field fracturing and water displacement system to improve the production and ultimate recovery of tight oil and gas reservoirs. In this paper, the numerical simulation method is used to simulate and calculate the influence of the parameters of the oil field fracturing and water displacement system on productivity. The above parameters are optimized accordingly to provide a theoretical basis for the actual production.

2. There are problems with the current low-permeability seepage model

2.1 Assumptions in model derivation

For the convenience of research, the author gives the seepage equation:

$$v = \frac{K}{\mu}\left[1 - \frac{\xi_1}{\frac{\Delta p}{L}} - \frac{\xi_1 \xi_2}{\frac{\Delta p}{L}\left(\frac{\Delta p}{L} - \xi_2\right)}\right]\frac{\Delta p}{L} \tag{1}$$

The porous media flow model is equivalent to a fine straight pipe flow model. The crude oil flowing in the tiny pore throats is regarded as a non-Newtonian fluid, and its flow obeys the Bingham flow pattern. It is considered that the seepage flow in porous media is similar to the flow in a straight circular tube, and there is a boundary layer effect [2]. According to rheological theory, the relationship between shear stress and shear rate can be expressed as:

$$\tau = \tau_0 + k\left(\frac{dv}{dy}\right)^n \tag{2}$$

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Bingham fluid flow requires external boundary motion conditions [3]. But whether the fluid flow mechanism with initiating pressure gradient is consistent with the fluid flow mechanism with yield stress has not yet obtained research results.

2.2 Model derivation problems

In view of the problems existing in the derivation of the fluid seepage model in low-permeability reservoirs, the author studied the equations given by some scholars:

$$\phi = N\pi r^2 \tag{3}$$

$$v = N\frac{\pi r^4}{8\mu}\left(1-\frac{\delta}{r}\right)^4\left[1-\frac{8\tau_0}{3r\left(1-\frac{\delta}{r}\right)\frac{\Delta p}{L}}\right]\frac{\Delta p}{L} \tag{4}$$

If the boundary layer thickness is a function of the pressure gradient, then equations (3) and (4) are incorrect. If the boundary layer exists, the porosity expression (3) should be:

$$\phi = N\pi\left(r-\delta\right)^2 \tag{5}$$

3. Stimulation mechanism of large-scale fracturing

Large-scale fracturing means that on the basis of optimizing the combination of fracturing fluid and proppant, through high-displacement, high-fluid, and high-pressure construction, the formed artificial fractures and natural fractures are staggered and extended, thereby forming large-scale complex artificial fractures. Systematic fracturing technology, its stimulation mechanism is mainly reflected in two aspects.

3.1 Improving the Conductivity of Oilfield Fracturing Water Displacement System

In large-scale fracturing operations, degradable fibers added to the fracturing fluid can temporarily plug the main fractures after they are formed, increase the net pressure to achieve diverted fracturing, and form a combination of main fractures and branch fractures in the formation. The oilfield fracturing water drive system (Fig. 1) improves the degree of control over the reservoir by fractures, and achieves the purpose of expanding oil drainage and increasing reservoir permeability in fractures[4]. At the same time, the degradable fibers have good sand-carrying and sand-fixing properties, which can maintain a good sand-laying profile and effectively improve the seepage conditions of ultra-low permeability reservoirs.

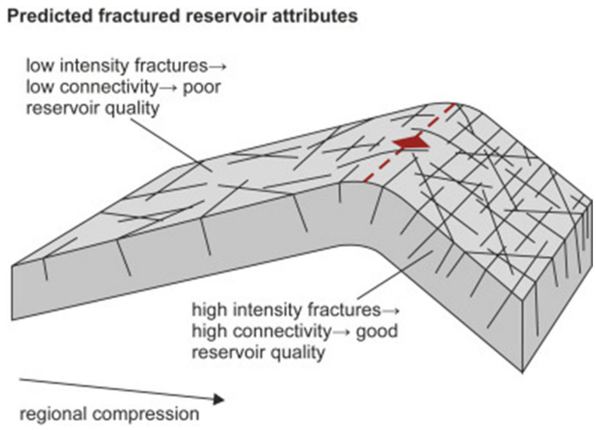

Figure 1. Fracture distribution of large-scale fracturing

The interlaced system of primary and secondary fractures formed after the oil field fracturing and driving the water system effectively improves the seepage conditions of the fracture system, resulting in essential changes in the seepage law of reservoir fluids. Under a certain production pressure difference, the relationship between seepage particle displacement and seepage time under different permeability conditions can be simulated [5]. After the implementation of large-scale fracturing, the permeability of the reservoir is greatly improved, which effectively shortens the time for fluid particles in the reservoir to flow to the wellbore, and achieves a substantial increase in oil well production.

3.2 Well spacing control technology of oil field fracturing water drive system

According to the geological characteristics of ultra-low permeability reservoirs and based on the large-scale fracturing numerical simulation and field practice of typical oilfield fracturing and water displacement systems, the fracture morphology and fracturing effect of conventional and large-scale fracturing were compared. For the water displacement system with the original injection-production healthy spacing of 250m, the fracture extension is short after the reformation of the oilfield water displacement system. The primary purpose is to improve the conductivity around the wellbore. After large-scale fracturing of the reservoir, the half-length of the fractures can reach 100-150 m, the multi-fracture system remains in the far-well area, and the fractures still have good conductivity. The purpose (Fig. 2 is quoted from "Shale Gas New Development Overview: Induced Seismic Activity Surface") is to reduce the distance of the oilfield fracturing and water displacement system from 250m to 150m, establish an effective oil-water healthy driving system, and realize the Development of ultra-low permeability oil reservoirs. . Development of effective water displacement systems.

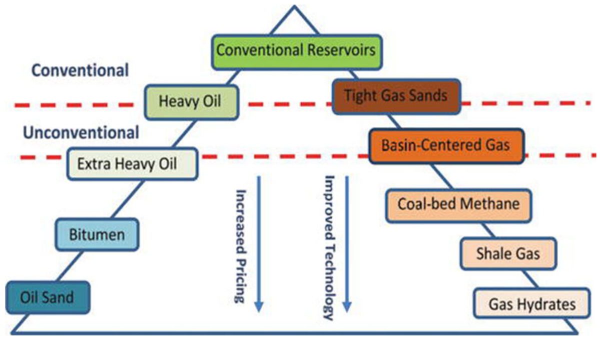

Figure 2. Comparison of injection-production well spacing with different fracturing methods

4. Characteristics and development law of huff and puff seepage in oilfield fracturing water drive system

4.1 Model building and production dynamics analysis

The research in this paper is to use the principle of fracturing the water drive system to simulate the production state and use constant pressure production. After the natural elastic energy development stage, eight production wells were reinjected at a constant pressure of 22.7 MPa. The water injection time is a natural month to replenish energy for the formation. Subsequently, the well was shut-in for 15 days to promote oil-water displacement [7]. Then the well is opened and produced for 12 months, which is one cycle, and this cycle is 20 cycles. Fig. 3 shows the variation of formation pressure with time (the picture is quoted from Graphene Oxide: An Effective Promotion for CO_2 Hydrate Formation). It can be seen that at the end of the initial elastic development, the formation pressure dropped to 14MPa, and the productivity dropped rapidly. Then the production well was transferred to the injection, and the pressure of the fracturing water drive system was 22.7MPa, the formation energy was supplemented, and the formation energy rose to 18MPa, and the well was opened and put into production.

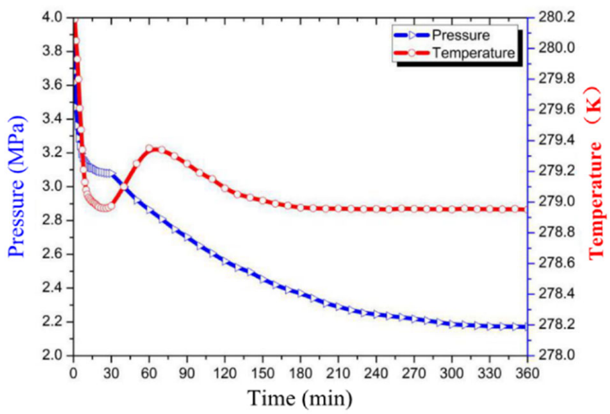

Figure 3. Variation of formation pressure over time

4.2 Comparison of development characteristics of oilfield fracturing water drive systems

Fig. 4 is the water cut curve under the development model of the oilfield fracturing and water displacement system (the picture is taken from the analysis of the influencing factors of imbibition in tight oil reservoirs and the evaluation of the imbibition effect). The solid line in the figure represents the development of the water content of huff and puff, and the final water content is 50%. The dotted line represents the development water content of the conventional water flooding system, and the final water content reaches 75%. It can be seen that the huff and puff development of the water flooding system can control the oil well capacity far more than the development model of the conventional water flooding system.

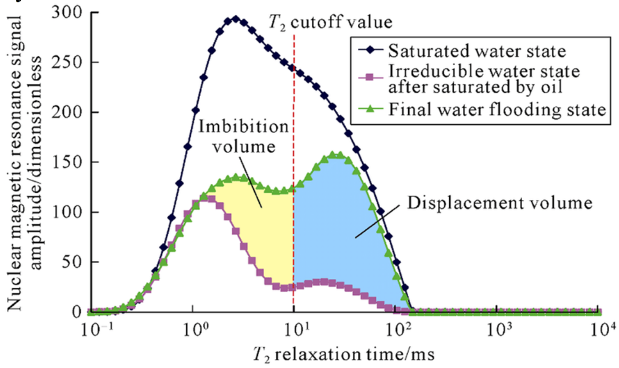

Figure 4. Water cut under conventional waterflooding and waterflooding huff and puff development methods

4.3 Water drive system

Advanced water injection can be viewed as a deformation of the flooding system's huff and puff. The physical properties of the actual formation are poor. Therefore, taking fracturing measures to increase the amount of fracturing fluid to drive water, the fracturing fluid remains in the formation and does not flow backward. Shut down the well for a while. Compared with the conventional fracturing stimulation method, this method is beneficial to replenish the reservoir energy. Drilling measures redistribute oil and water, and the oil displacement efficiency is significantly improved [8]. In this paper, an advanced water system model is established using reservoir numerical simulation software. Before the production and development of the production well, the pressure difference was set to 22.7MPa, and the water was driven for 1, 2, 3, and 4 months to increase the formation energy. After 15 days of good closure, according to the development and production of the block, the influence of water displacement and drilling time on the development effect of the huff and puff cycle was analyzed. In the elastic development mode, with the consumption of formation energy, the recovery degree is rapidly stabilized, and the final production is low. However, the growth rate of production in the 3 and 4 months of water injection is within 0.2%, and there is little change. Therefore, as the advanced water injection time continues to increase, the increase in production will become lower and lower and eventually tend to a certain level. Due to the working principle of water injection huff and puff for reference, advanced water flooding can also be divided into three stages: water flooding and propulsion, well shut-in and replacement, and well-opened oil production (Table 1).

Table 1. Productivity variation under different borehole time

Borehole time/d	15	30	60	90
Initial capacity/m3	76	78	83	88
Half-year production capacity/(m3/d)	23	24	24	24
Production capacity per year/(m3/d)	3	3	3	3
Ultimate recovery factor/%	0.989	0.992	0.994	0.996

From Table 1, it can be seen that in the fracturing water drive system, the drilling time has a great influence on the initial productivity of the production well. As the formation energy is depleted, the impact of the drilling time on the product development is almost the same. Therefore, The increase in ultimate recovery is mainly due to the increase in initial production capacity.

5. Conclusion

Considering the influence of factors such as geology, engineering, cost, etc., it is necessary to optimize the fracturing parameters such as fracture spacing, fracture length, and conductivity coefficient of the fracturing water-flooding system to improve the development efficiency of tight oil reservoirs.

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