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# Numerical Simulation of Fracture Propagation in Low Permeability Reservoir

Zuxu ZOU<sup>1</sup>, Jianjun Liu<sup>1</sup>, Guihong PEI<sup>2</sup>, Jiwen Chen<sup>1</sup>

School of Civil Engineering& Architecture, Wuhan Polytechnic University, Wuhan 430027, China

School of Architectural Economics and Engineering Management, Hubei Business College, Wuhan 430079, China

523814151@qq.com

**Abstract:** In order to reveal fracture propagation law of low permeability oil reservoir, using RFPA software, a series of simulation models were built. Through numerical simulation, the maximum shear stress, the minimum main stress and pore pressure changes under different water injection pressure were got. The results shown that the process of fracture extension can be divided into three stages: the front stage, the microcrack stage and the rupture stage, the water injection pressure at 25 ~ 30MPa is the best result. The founding provides important theoretical guidance for low permeability reservoir reconstruction and optimization of well layout in the process of waterflood development.

## 1. Introduction

Waterflood development is the most economical and effective technique for the development of low permeability reservoir and has been widely used at home and abroad. On the macro: when the injection pressure through the hours, not effectively complement formation energy, crude oil recovery factor will be greatly decreased, however, when the water injection pressure, injection water may enter the fracture zones, resulting in a decline in water injection swept volume and will also reduce the oil recovery degree. On the micro level, the results of microcosmic displacement mechanism show that, for the crack - pore dual medium, the flow velocity is lower, and the suction and discharge of the capillary force is easy to be used. When the seepage velocity is higher, the driving force can be used. Therefore, it is very important to seek reasonable injection-extraction parameters from macroscopic or microscopic scale.

By means of numerical simulation, this paper reveals the dynamic mechanism of the dynamic change of reservoir fracture in the development process, and the influence of the influence factors such as waterflood parameters on the crack extension. Using rock failure process analysis system (RPFA) of reservoir fracture under the condition of different injection-production parameters of expansion process are simulated, the comprehensive analysis of the fracture reservoir seepage, stress, such as dynamic change rule.

## 2. Influence of Water Injection Pressure on Reservoir Fracture Propagation

### 2.1 Simulation model

Core observation found that micro seam group is to show the seam group is the same, the joint



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development has a certain direction, and show the direction of the seam to parallel, reflect the formation mechanism of micro stitch and sew the same, are the tectogenesis. Based on paleomagnetic study of micro seam direction, the orientation of the micro seam with north east  $120^\circ$  natural seam in parallel, and there are obvious with nature. In-situ observation data show that the principal stress direction cracks open will make water cut rise, lead to critical water, and with the main stress direction cracks through overlapping each other, which will be recorded in the whole reservoir "postage stamp", eventually reduce recovery. Model used in this section, therefore, on the basis of common laboratory sample size diameter, the selection of  $400\text{ mm} \times 400\text{ mm}$  rectangle model, the mesh is  $173 \times 173$  units, the model about two hole aperture of 10 mm, model horizontal and vertical direction effect of confining pressure to 10 MPa, along the direction of maximum principal stress is decorated four artificial fracture, and assumes that always has the stable seepage field in the reservoir (as shown in figure 1). Rock material is homogeneous, consisting of the mesoscopic unit of the rock body parameters meet the Weibull probability distribution, the basic mechanical parameters (elastic modulus, tensile/tensile strength, poisson's ratio and friction Angle, etc) referring to the field test data values of a certain oil block, homogeneous degree, permeability coefficient and coefficient of residual strength coefficients can be carried out in accordance with the RFPa value recommendation table selection, are shown in table 1 below.

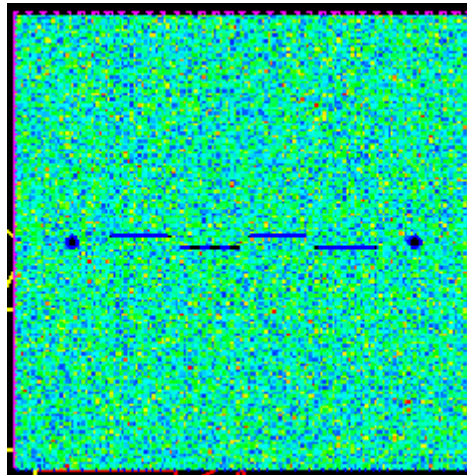


Figure.1 Calculation model

Table 1 Mechanical parameters of the calculation model

homogeneous degree	Modulus of elasticity E/GPa	Poisson's ratio $\nu$	Compressive strength $\sigma_c$ /MPa	tensile strength $\sigma_t$ /MPa	friction angle $\phi$ ( $^\circ$ )	permeability coefficient /(m/d)	Residual strength coefficient $\lambda$
3	50	0.25	70	7	30	0.05	0.1

According to the actual and indoor experiment, the five groups of water injection pressure in this paper are shown in table 2.

Table 2 working condition

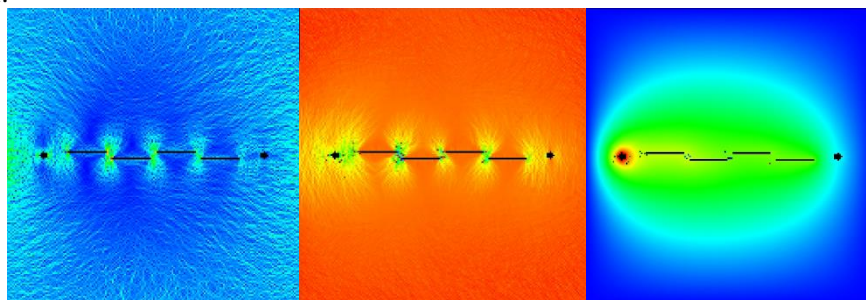
No. of Working condition	1	2	3	4	5
Initial water injection pressure(MPa)	20	25	30	35	40
Loading force (MPa)	0.3	0.3	0.3	0.3	0.3

## 2.2 Simulation Results and Analysis

From the following five kinds of working condition of the maximum shear stress and minimum principal stress and seepage field can be seen (figure 2 and figure 6), according to the curve of maximum shear stress and load steps, the whole process of rock failure can be divided into: crack before stage, the micro crack stage, stage of instability. Stage, in front of the crack between the adjacent natural fracture appear stress concentration phenomenon, individual unit within the reservoir

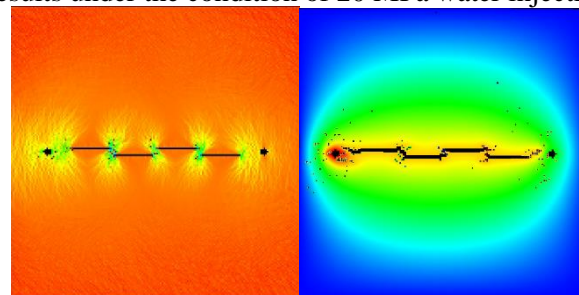
began to appear, this is because the material unit within the reservoir properties have heterogeneity, therefore appeared in the reservoir damage in the unit has a certain randomness, reservoir internal stress changes linearly. But when entered the stage of micro cracked rock failure process under the sustained load of water injection pressure, the randomness of the rupture units weakened gradually, and along the direction of maximum principal stress distribution, the stress concentration area appears more and more breakdown of unit, cracks began to appear the crack tip and extension phenomenon, reservoir stress remained within the linear change at this time.

Burst phase: according to the basic equation of crack extension, with the increase of injection pressure and maximum tensile stress in the reservoir is more than the critical stress of rock burst, natural fractures in the reservoir continues to extend to completely craze, and connectivity of the connection between adjacent cracks, but the overall direction of crack propagation along the direction of maximum principal stress of reservoir remain unchanged, in this stage, the reservoir in shear stress changes faster.



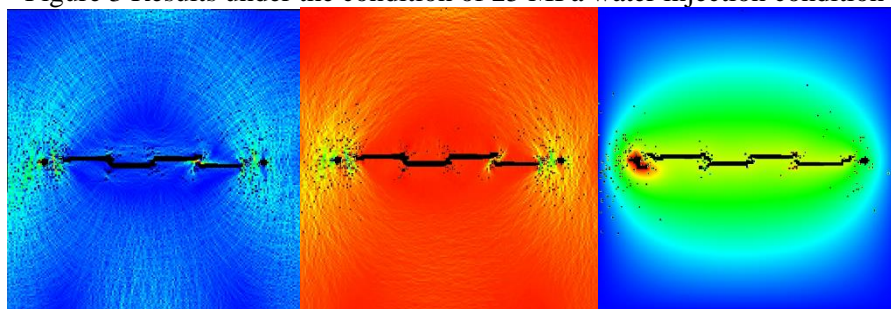
(a)maximum shear stress distribution(b)Minimum main stress distribution(c) Water Pressure Distribution

Figure 2 Results under the condition of 20 MPa water injection condition



(a)Minimum main stress distribution(c) Water Pressure Distribution

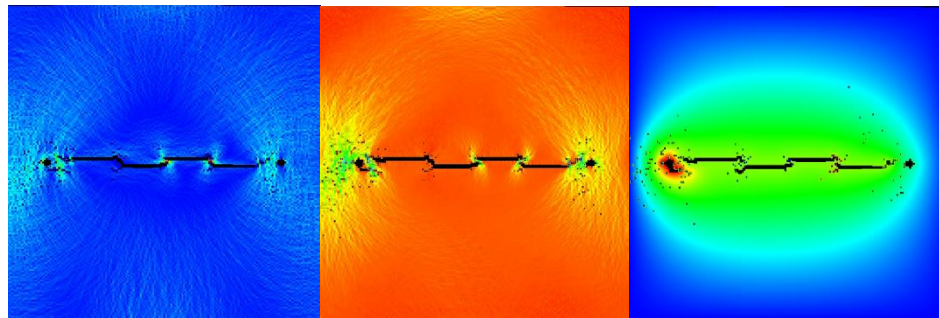
Figure 3 Results under the condition of 25 MPa water injection condition



(a)maximum shear stress distribution(b)Minimum main stress distribution(c) Water Pressure Distribution

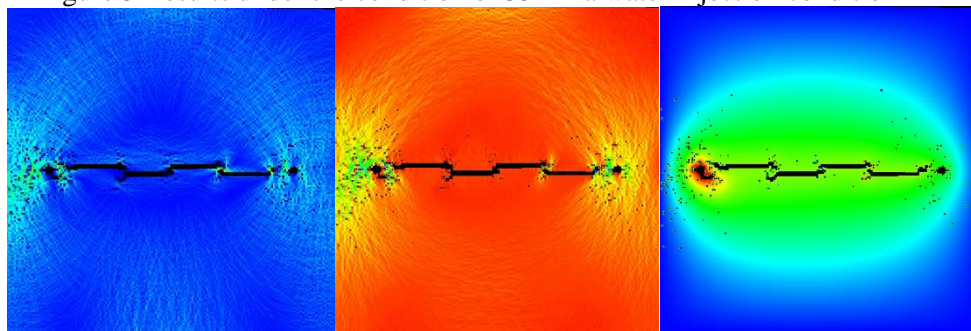
Figure 4 Results under the condition of 30 MPa water injection condition





(a)maximum shear stress distribution(b)Minimum main stress distribution(c) Water Pressure Distribution

Figure 5 Results under the condition of 35 MPa water injection condition



(a)maximum shear stress distribution(b)Minimum main stress distribution(c) Water Pressure Distribution

Figure 6 Results under the condition of 35 MPa water injection condition

Compared the maximum shear stress of the above 5 working conditions, it can be seen from the simulation results that the maximum shear stress with increasing load steps is roughly, the red circle part of a display of maximum shear stress exists the phenomenon of mutation, the phenomenon of mutation occurred in before rock failure stage, due to the breakdown in reservoir unit increase gradually, with the increase of injection pressure, cracks began to expand, the adjacent cracks appear, lead to stress redistribution of the whole reservoir.

Comparing the above five kinds of working conditions, the minimum principal stress calculation results, can be found that with the increase of injection pressure and phase in front of the crack and crack stage, basic no change, the minimum principal stress when entered the stage of fracture, the minimum principal stress increased significantly. Rock cracks under the condition of 4, 5, the time needed for the shortest, because of its high water injection pressure in the working condition of 4, 5, can cause the rock failure time is shorter, but from figure 5-8, the failure process can be seen that 5-9, cracks between the penetration and borehole wall rupture happened almost at the same time, it's not good for waterflood recovery. In addition, the injection water is cut along the crack direction, resulting in the injection of water through the crack, thus reducing the reservoir recovery. On the contrary, the time required for working condition 1 is longer, while the time required for the working condition 2 and 3 is normal. The water injection pressure is the best when the water injection pressure is 25 ~ 30MPa.

### 3. Conclusions

(1). The process of fracture extension can be divided into three stages: the front stage, the microcrack stage and the rupture stage. In the pre-crack phase, the reservoir unit was randomly broken. During the microcrack phase, with the increase of water injection pressure, the unit fracture develops along the main stress direction, crack and expansion phenomenon; During the fracture phase, the crack propagation phenomenon is obvious and the adjacent cracks penetrate each other.

(2). Through the analysis of the impact of water injection pressure, maximum shear stress with the

increase of injection pressure as a whole is on the rise, the rock burst phase before the phenomenon of the maximum shear stress change, this is due to the expansion of cracks, leading to the whole of the reservoir stress field distribution. The water injection pressure at 25 ~ 30MPa is the best result, which provides important theoretical guidance for low permeability reservoir reconstruction and optimization of well layout in the process of waterflood development.

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