Fracture Optimization for Highly Deviated Wells in Low Permeability Reservoir

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Abstract—Hydraulic fracturing has a certain direction. For Water-flooding development reservoir, if the fracture direction is perpendicular to the Water-flooding direction, it can enhance oil displacement efficiency of water-flooding. Otherwise, it will reduce water-flooding displacement efficiency, even flood oil layers. When selecting the Blasting Parameters of hydraulic fractures, we should consider fracture and Water-flooding direction. In the article, the effects on well production rates and ultimate recovery of different fracture directions and fracture penetration ratios are studied by numerical simulation. So we can provide basis for hydraulic fracturing design.

Keywords—hydraulic fracture; fracture direction; numerical simulation; fracture penetration ratio; oil recovery

I. INTRODUCTION

Horizontal well is popular used in low permeability reservoir development. It’s necessary to control the length and direction of fracture. For staged fracturing, the direction of fracturing and optimization of parameters should be combined with water well location. So we study on the change law of oil production and oil recovery in different fracture direction.

II. THREE-DIMENSIONAL MODEL AND THE SOLUTION METHOD

A. Basic Hypothesis

Basic hypothesis: oil and water two-phase flow in three-dimensional reservoir; Reservoir is heterogeneous, permeability is anisotropic; formation and fluid are both slightly compressible, and the compressibility is fixed; No affected by gravity and capillary pressure.

Hypothesis about fracture: the direction of fracture is vertical; The fracture is homogeneous, permeability is isotropic; ignorance the change of fracture with time.

B. Reservoir Mathematical Model

\[
\frac{\partial}{\partial x} \left( K \frac{\partial p}{\partial r} \right) + \frac{\partial}{\partial y} \left( K \frac{\partial p}{\partial s} \right) + \frac{\partial}{\partial z} \left( K \frac{\partial p}{\partial t} \right) = \frac{\partial}{\partial x} \left( \rho \phi \frac{\partial S_o}{\partial r} \right) - \phi \frac{K_{rl}}{K_{rw}} \left( S_w - S_o \right)
\]

(1)

Nomenclature:

L. o for oil, w for water

\( K_x \): permeability in X-direction, \( \mu m^2 \)

\( K_y \): permeability in Y-direction, \( \mu m^2 \)

\( K_z \): permeability in Z-direction, \( \mu m^2 \)

\( K_{rl} \): relative permeability in matrix of reservoir

\( K_{rw} \): relative permeability of water in matrix of reservoir

\( p_r \): reservoir pressure, MPa

\( \phi \): porosity of reservoir

\( S_o \): oil saturation

\( S_w \): water saturation

C. Mesh Generation

Fracture and reservoir is a whole. We treat fracture by local grid refinement based on the reservoir model.

D. The Solution Method for Equation

Based on Boundary Conditions, we get difference equations by Finite Difference Method. Then we calculate the difference equations by conjugate gradient method. After that, we can know the pressure and oil saturation at any time. It can help us investigate the oil production, water injection and the development effect of reservoir.

III. SIMULATION OF FRACTURE SIZE AND WELL NET

Based on the physical parameter of dagang oil field. We built four different models. The angles between fracture and interwell connectivity are 0°, 30°, 60°, 90° in different fracture direction, we study the oil production and oil recovery from...
different fracture penetration ratio through numerical simulation.

![Figure II: Simulation of Oil and Water Well](image)

**FIGURE II. SIMULATION OF OIL AND WATER WELL**

**A. Simulation Analysis for 0°**

According to the result of numerical simulation, we get the oil production change in different length of fracture (Figure III).

It shows that oil increased with the increasing of length of fracture firstly. After a period of production, oil production reduce after water breakthrough. If the longer of the fracture, the more quickly of the oil production decreased.

It also shows that the longer of the fracture, the shorter of the stable period. Oil production is mainly controlled by fracture parameters before water breakthrough. So the longer of the fracture, the more of the oil production increase.

With the longer of the fracture, the water breakthrough more quickly. After that, the oil production decrease dramatically.

![Figure III: The Oil Production Change in Different Length of Fracture for 0°](image)

**FIGURE III. THE OIL PRODUCTION CHANGE IN DIFFERENT LENGTH OF FRACTURE FOR 0°**

according to the result of numerical simulation, we know the relationship between oil recovery and fracture penetration ratio (Figure IV).

**FIGURE IV. THE RELATIONSHIP BETWEEN OIL RECOVERY AND FRACTURE PENETRATION RATIO FOR 0°**

**B. Simulation Analysis for 30° and 60°**

The change law between fracture length and oil production is the same with the change law of 0°, so we emphatically analyzes the oil recovery change with different fracture length (Figure V, Figure VI). From the result, we can see the reasonable fracture penetration ratio is about 0.4 when the angles between fracture and interwell connectivity is 30°, the reasonable fracture penetration ratio is about 0.5 when the angles between fracture and interwell connectivity is 60°.

![Figure V: The Relationship Between Oil Recovery and Fracture Penetration Ratio for 30°](image)

**FIGURE V. THE RELATIONSHIP BETWEEN OIL RECOVERY AND FRACTURE PENETRATION RATIO FOR 30°**

![Figure VI: The Relationship Between Oil Recovery and Fracture Penetration Ratio for 60°](image)

**FIGURE VI. THE RELATIONSHIP BETWEEN OIL RECOVERY AND FRACTURE PENETRATION RATIO FOR 60°**

**C. Simulation Analysis for 90°**

We can get the relationship between fracture penetration ratio and oil production/oil recovery (Figure VII, Figure VIII).

When the angle between fracture and interwell connectivity is 90°, Figure VII shows that oil production increase gradually after water injection response. But oil production will decrease after water breakthrough. The oil production after fracturing is increased with the increase of the fracture penetration ratio. The water breakthrough time is changed with the different fracture, but it’s same in different fracture penetration ratio.

Figure VIII shows that oil recovery is increased with the increase of the fracture penetration ratio. When the fracture penetration ratio is up to a certain value, the amplitude of oil recovery increase is reduce gradually.
In a word, the optimum fracture length change with different angle between fracture direction and interwell connectivity.

We contrast the oil saturation for different fracture direction(Figure IX). The result shows that the waterflooding efficiency is improved when the direction of fracture is vertical to Waterflooding direction. The waterflooding efficiency is decreased when the direction of fracture is parallel to Waterflooding direction.

### IV. FIELD TEST

QiAH is a horizontal well in dagang oilfield. The length of horizontal interval is 525.6m. It fractured by four stages. There are two water injection wells around it. According to the fracture monitoring result of adjacent well, the direction of fracture is NE 30°~70°.

Base on the properties of this well, we optimize the length of fracture. The result shows in Table I. It can avoid water fingering in the direction of fracture effectively. before fracturing, the oil production is only 0.58t/d. after fracturing, the oil production is up to 35t/d. it has an obvious effect of stimulation.

| items             | Distance to water well/m | The angle of fracture and water well /° | Propped fracture length/m |
|-------------------|--------------------------|----------------------------------------|---------------------------|
| The first stage   | 305                      | 35                                     | 120~130                   |
| The second stage  | 292                      | 16                                     | 100~105                   |
| The third stage   | 290                      | 9                                      | 90~95                     |
| The fourth stage  | 310                      | 41                                     | 145~150                   |

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