CSCanada
Advances in Petroleum Exploration and Development
Vol. 10, No. 2, 2015, pp. 64-66
DOI:10.3968/7103

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
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Study on Unproppant Waterfrac Flow Conductivity Mechanism and Test Method

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Received 28 May 2015; accepted 18 October 2015
Published online 31 December 2015

Abstract

The main reason for the success of unproppant water-fracs is that uneven crack surface can form a self-supporting which achieves the objectives of diversion. It needs two conditions, one is the surface roughness of the crack surface, the other is the shear-slip between fracture surfaces. In this paper, the influential factors and influence law of slippage and the mechanism of forming residual space when the crack closed are exposed with the finite element method. The preparation method of water-fracs self-supporting fracture surface combination and test method of flow conductivity are established. It supply the means by knowing water-fracs increasing production mechanism and suitable reservoir conditions.

Key words: Water-fracs; Numerical simulation; Fracture diverting; Flow conductivity

Wang, L., Yan, T., & Wang, H. L. (2015). Study on unproppant waterfrac flow conductivity mechanism and test method. *Advances in Petroleum Exploration and Development*, *10*(2), 64-66. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/7103
DOI: http://dx.doi.org/10.3968/7103

INTRODUCTION

At present, many scholars at home and abroad through the field practice and use qualitative analysis the reason of waterfrac increasing production and using effect[1-3], but not fundamentally reveals its increasing production mechanism, influence factors and influence law, become a bottleneck restricting the popularization and application of the waterfrac technology[4-5]. Laboratory evaluation method of water without sand fracturing increasing production mechanism and flow conductivity, for further understanding water-fracs increasing production mechanism and suitable reservoir conditions.

1. THE FRACTURE TIP STRESS AND PROPAGATION DIRECTION

Morphology of waterfrac fracture is I-II type compound fracture. The polar coordinates in the vicinity of the crack tip stress component:

$$\sigma_\theta = \frac{1}{\sqrt{2\pi r}}\cos\frac{\theta}{2}\left(K_{\mathrm{I}}\cos^2\frac{\theta}{2} - \frac{3}{2}K_{\mathrm{II}}\sin\theta\right), \qquad (1)$$

$$\tau_{r\theta} = \frac{1}{\sqrt{2\pi r}}\left[K_{\mathrm{I}}\sin\theta + K_{\mathrm{II}}(3\cos\theta - 1)\right]. \qquad (2)$$

Where the r and θ is calculation points in local polar coordinates; σ_θ for normal stress; $\tau_{r\theta}$ for shear stress; K_{I}, K_{II} for the intensity factor of I-II type cracks respectively.

The fracture steering angle is the angle between the existing fracture direction and next step of extension direction, which is the parameter representing the fracture extension direction, sometimes called fracture propagation angle. The positive and negative of the angle is determined by the relative slippage direction of the fracture surface. According to the maximum tensile stress theory, the initial extension direction of the fracture is the direction of maximum circumferential normal stress σ_θ, satisfying the following conditions:

$$\left.\begin{aligned} \frac{\partial\sigma_\theta}{\partial\theta} &= 0 \\ \frac{\partial^2\sigma_\theta}{\partial\theta^2} &< 0 \end{aligned}\right\},$$

$$K_{\mathrm{I}}\sin\theta + K_{\mathrm{II}}(3\cos\theta - 1) = 0. \qquad (3)$$

The θ angle meet Equation (3) is the crack steering angle.

2. FRACTURE STEERING ANGLE

Using numerical simulation method to simulate the crack steering and slip value, under different working conditions. Literatures [7-13] analyze and explain the reasons and influencing factors, set 4 kinds of operating mode as shown in Table 1.

Table 1
The Parameters of Four Kinds of Working Conditions

Working conditions number	Angle between fracture initial direction and maximum principal stress direction /°	Rock properties	Elastic modulus / MPa	Poisson's ratio	Stress deviation / MPa
1	45	Anisotropic	12,688	0.112	0
2		Isotrope			10
3	0	Anisotropic			10
4		Isotrope			10

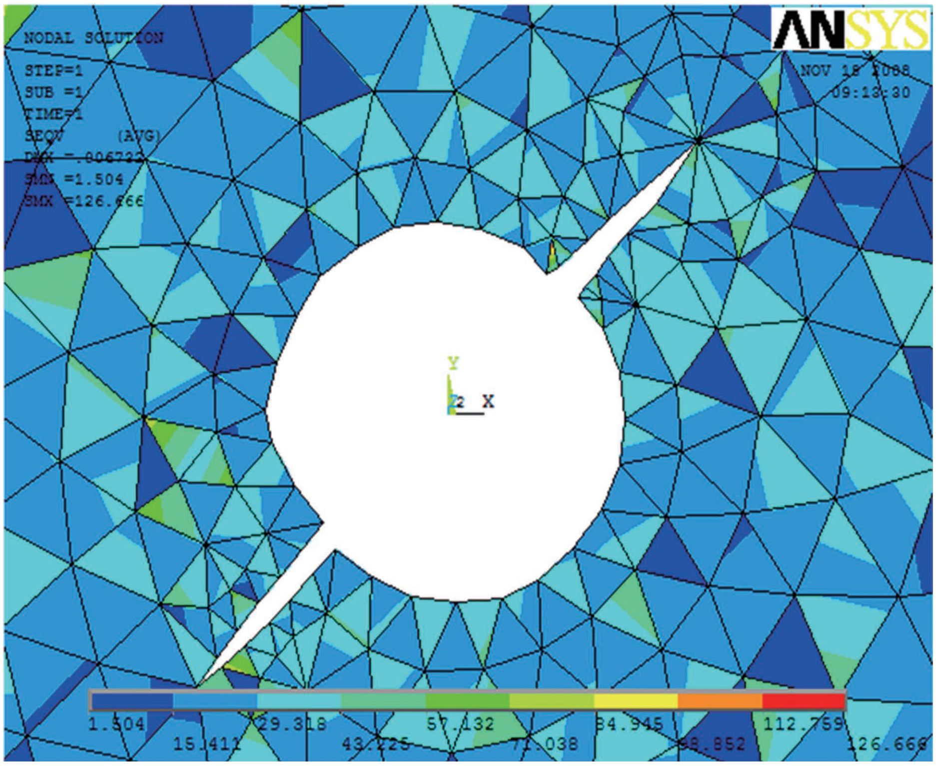

Figure 1
The Stress and Strain of Condition 1

Through the numerical simulation, the stress and deformation under four kinds of working conditions can be obtained.

Four kinds of working condition of the crack tip stress intensity factor and fracture steering angle as shown in Table 2.

Table 2
The Numerical Simulation Results of Working Condition

Working conditions number	Intensity factor of type I fracture	Intensity factor of type II fracture	Fracture steering angle /°
1	7.6808	0.56845	8.7
2	1.6418	3.3739	65.1
3	5.4318	0	0
4	12.663	1.1834	10.5

Through the above analysis: the anisotropism of rock, the In-situ stress deviation, the crack initial direction and the maximum principal stress direction angle are the root causes of inducing fracture change directions and slips.

3. LABORATORY EVALUATION FLOW CONDUCTIVITY

The hydraulic fracturing fracture in the wall is uneven, and has a certain roughness[7]. In the process of flowback, due to the shear slip two cracks in the wall concave and convex body can't completely mesh, there exist void space. The preparation of after shearing slip combination of cracks in the wall of self support of meshing through laboratory test as shown in Figure 2

Applying AB glue to its two ends evenly, the sample is put into JHLS intelligent core flow tester to wait setting for 24 hours. Simulating the underground temperature and pressure environment, the flow conductivity is tested and its calculation method is shown as the following equation.

Figure 2
The Non-Intermeshing Fracture Wall Combination Schematic Under the Condition of Core Splitting (Left) Slipping (Middle) and Rubdown (Right)

$$C = K_f W_f = \mu \frac{L}{B} \frac{q}{\Delta p}. \quad (4)$$

Where μ is the fluid viscosity, Pa·s; K_f is the fracture permeability, μm^2; W_f is the fracture height, cm; q is the flow through the core, cm^3/s; L is the core length, cm; B is the fracture width, cm; and ΔP is the pressure difference at both ends of core, MPa.

4. APPLICATION EXAMPLES

A well F horizon core, splitting, slip 3.2 mm. To prepare waterfrac combination of cracks in the wall of self support and test its diversion ability under different closure pressure as shown in Figure 3.

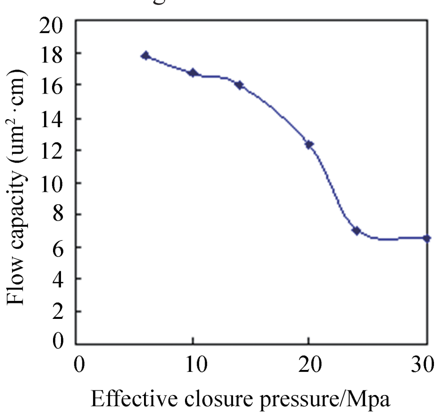

Figure 3
The Flow Conductivity in Different Closure Pressure

The flow conductivity of the self-supporting fracture is 6.5 um^2·cm. It is able to provide adequate flow conductivity for reservoir. The formation is suitable for waterfrac.

CONCLUSION

(a) The anisotropism of rock, the In-situ stress deviation, the crack initial direction and the maximum principal stress direction angle are the root causes of inducing fracture change directions and slips.

(b) Set up the preparation of waterfrac combination of cracks in the wall of self support and the test method of diversion ability under different closure pressure. To provide reliable basis to evaluation the feasibility of clear water without sand fracturing.

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