CSCanada
Advances in Petroleum Exploration and Development
Vol. 9, No. 1, 2015, pp. 70-73
DOI:10.3968/6546

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

Research on the Initiation Mechanism of Artificial Fracture in the Fractured Reservoir

LI Siqi[a]; YAN Tie[a]; LI Wei[a],*; ZHANG Yang[b]; KOU Hongbin[c]

[a] Petroleum Engineering College, Northeast Petroleum University, Daqing, China.
[b] Oil and Gas Engineering Institute of Tarim Oilfield Co., Ltd., Kuerle, China.
[c] The Seventh Oil Production Plant of Daqing Oilfield, Daqing, China.
* Corresponding author.

Supported by National Natural Science Foundation Major Project of China (51490650); Graduate Student Innovation Research Projects of Northeast Petroleum University (YJSCX2014-011NEPU).

Received 26 January 2015; accepted 15 March 2015
Published online 30 March 2015

Abstract

The low permeability reservoir which has a significant proportion of oil and gas reserves is the focus on mining in the future. Hydraulic fracturing technology is a major means in achieving such reservoir exploitation. In this paper, the initiation mechanism of artificial fracture in the fractured reservoir is studied. Also, the crack condition is given. Then, the influence factors of initiation mechanism of artificial fracture are analyzed and the theoretical models are further verified through the field application. The results show that: for fixed size cracks, the integrating factor decreases with the increasing of the crack spacing; for fixed crack spacing, the integrating factor increases with the increasing of the crack size; for the same *d/a*, the larger the size of crack is, the more easily crack extends. By studying on the initiation mechanism of artificial fracture of fractured reservoir, provide theoretical basis for hydraulic fracturing technology being applied in low permeability fractured reservoir. So that the efficient development of special oil and gas reservoirs can be achieved.

Key words: Fractured reservoir; Artificial fracture; Initiation mechanism; Field application

Li, S. Q., Yan, T., Li, W., Zhang, Y., & Kou, H. B. (2015). Research on the initiation mechanism of artificial fracture in the fractured reservoir. *Advances in Petroleum Exploration and Development*, *9*(1), 70-73. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/6546 DOI: http://dx.doi.org/10.3968/6546

INTRODUCTION

Low permeability reservoirs are widely distributed in each main basin and have a significant proportion of oil and gas reserves. It is an important foundation for oil and gas production growth quite a long time in the future[1]. Due to rock is well compacted and its compactness is strong in low permeability reservoir, the brittleness is enhanced. What's more, in the role of stress field,the complex and crisscrossed natural fracture system is often produced,which is mainly embodied in low permeability fractured reservoir[2].In order to improve theproduction and economic benefit of the reservoir, hydraulic fracturing technology is usually adopted in mining.Thus the research on artificialfractureis the key part of current study[3-4].

There are some scholars have studied on the artificial fracture[5]. Caibo et al.[6] have established a new mathematical model of fracture face skin with segmentation characteristic using fracture mechanics and fluid coupling method. Xu Jianguo et al.[7] have established the mechanical model of horizon wellbore and the computational model of fracture initiation angle and have analyzed artificial fractureinitiation law by analyzing the force condition and stress distribution of horizontal wellbore.An analysis has been carried out on the relationships between artificialfractures and earth stress and natural fractures by Wan Xiaolonget et al.[8], so that the coupled relationship between artificial and natural fractures is studied.DuanHuiet et al.[9] have studied the characteristics of artificial fracture for fissure-cavern carbonate reservoirs.But in the present research results,the study oninitiation mechanism of artificial fracture is not common[10].

In this paper, the initiation mechanism of artificial fracture in the fractured reservoir is studied and the crack condition is given. Also, the influence factors of initiation mechanism of artificial fracture are analyzed and the theoretical models are further verified through the field application.It can provide theoretical basis for hydraulic fracturing technology being applied in low permeability fractured reservoir.

1. INITIATION MECHANSIM OF ARTIFICIAL FRACTURE

There are a large number of micro cracks in fractured reservoir. In hydraulic fracturing operations,vertical artificial cracks along the shear direction of natural fracture and horizontal artificial cracks along the opening direction of natural fracture will be produced which are interconnected to form a seam network.

1.1 Shear Initiationalong the Natural Fracture

The tangential stress σ_θ of rock of borehole wall is,

$$\sigma_\theta = (1-2\cos\theta)\sigma_H + (1+2\cos\theta)\sigma_h - P_i + \frac{\alpha(1-2\upsilon)}{1-\upsilon}(P_i - P_p) . \quad (1)$$

The vertical stress σ_Z of rock of borehole wall is,

$$\sigma_z = \sigma_v - 2\upsilon(\sigma_H - \sigma_h)\cos 2\theta + \frac{\alpha(1-2\upsilon)}{(1-\upsilon)}(P_i - P_p) . \quad (2)$$

Considering the natural fracture is non-filled, the criterion of shear initiation along the natural fracture is,

$$\sigma_z - \sigma_\theta = \frac{2\mu_w \sigma_\theta}{(1-\mu_w \cot\beta)\sin 2\beta} . \quad (3)$$

Take Equations (1) and (2) into Equation (3), the corresponding fracture pressure P^t_f will be got,

$$P_f^t = \frac{m_1 - m_2 - k_2 m_1 + k_1 k_2 P_p}{1 + k_1 k_2 - k_2} . \quad (4)$$

Where, θ is polar angle, °; β is the angle between structural plane and the maximum main stress, °; σ_H and σ_h are the horizontal principal stress, MPa; σ_θ is the circumferential stress, MPa; P_i is the fluid column pressure, MPa; P_p is the pore pressure, MPa; α is the Biot coefficient; μ_w is the internal friction coefficient. $m_1 = (1-2\cos\theta)\sigma_H + (1+2\cos\theta)\sigma_h$; $m_2 = \sigma_v - 2\upsilon(\sigma_H - \sigma_h)\cos 2\theta$; $k_2 = 2\mu_w/(1-\mu_w \cot\beta)\sin 2\beta$.

1.2 Opening Initiation Along the Natural Fracture

In the process of hydraulic fracturing of fractured reservoir, another way of initiation of artificial fracture is that the natural fracture on the wall cracks first. The condition of the initiation occurrence is,

$$P_f^t \geq \sigma_N - \alpha P_p . \quad (5)$$

Where, σ_N is the normal stress of natural fracture surface, MPa.

There are multiple small cracks on the borehole which will converge to seam in hydraulic fracturing. The simplify distribution model of crack on the borehole is built, as seen in Figure 1. The crack system contains evenly spaced, periodic and same size cracks with an infinite number.

The stress intensity factor K_I on the tip of crack is,

$$K_I = \gamma P_{net}\sqrt{\pi a} = \gamma(P_i - \sigma_N + \alpha P_p)\sqrt{\pi a} . \quad (6)$$

Where, γ is the shape factor, $\gamma = \sqrt{\frac{2d}{\pi a}\tan\frac{\pi a}{2d}}$ and α is the half length of crack, m.

According to the K criterion, the critical pressure of crack system instability is,

$$P_f^J = \sigma_N - \alpha P_p + \frac{K_{IC}}{\gamma\sqrt{\pi a}} . \quad (7)$$

Where, $\gamma\sqrt{\pi a}$ is integrating factor which has nothing to do with the stress factor and it is represented by Γ.

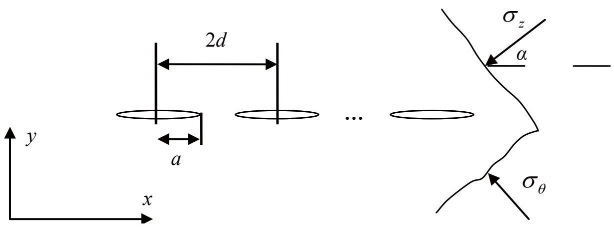

Figure 1
The Distribution Model of Collinear Crack System

2. ANASLYSIS OF INFLUENCE FACTORS

Draw the change curves between Γ and α, and Γ and Figure 3.

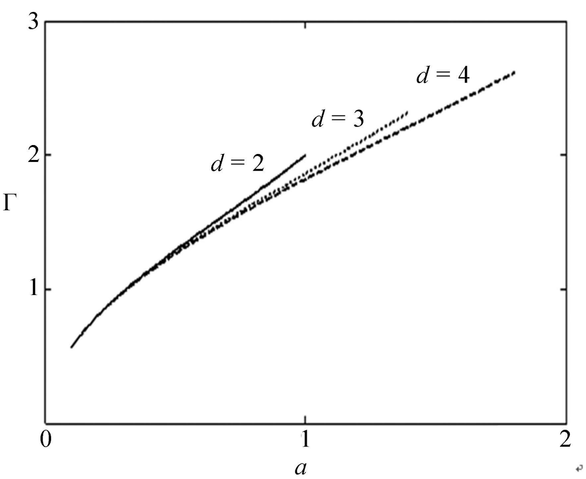

Figure 3
The Relation Curves Between Γ and *a* in Different *d*

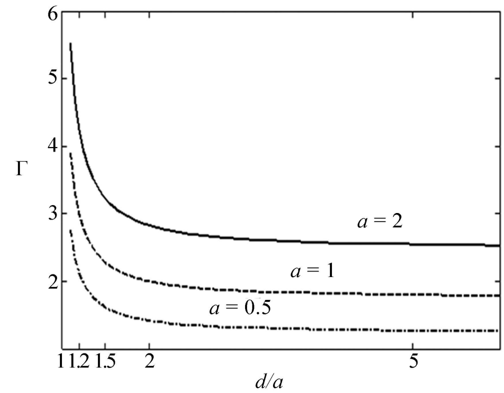

Figure 4
The Relation Curves Between Γ and *d/a* in Different *a*

As can be seen from Figure 3 and Figure 4, for fixed size cracks, the integrating factor decreases with the increasing of the crack spacing and for fixed crack spacing, the integrating factor increases with the increasing of the crack size. Besides, for the same *d/a*, the larger the size of crack is, the more easily crack extends. Therefore, it can be concluded that the greater the size of single crack is and the smaller the gap between cracks is, the more easily cracks gather into a seam.

3. VALIDATION OF THEORETICAL MODEL

In order to validate the prediction model of crack initiation given in this paper is correct, the fracturing well which has been completed in Daqing oilfield is selected to predict. Then evaluate whether the initiation model is accurate by comparing the field construction data.

In the block, the minimum horizontal principal stress is σ_h = 43.76 MPa, the maximum horizontal principal stress is σ_H = 48 MPa, the direction of maximum horizontal geostressis 117°, the vertical principal stress is σ_v = 55 MPa, the pore pressure is P_p = 19.1 MPa, the Boit coefficient is α = 0.81 and the tensile strength is S_t = 3.5 MPa. Take X well as an example.The dip of crack is 70° which is consistent with the direction of maximum horizontal stress and the internal friction coefficient of crack plane is μ_w = 0.23.

It can be obtained by calculating that the crack pressure of vertical artificial cracks along the shear direction of natural fracture is P^{τ}_{f} = 63.51 MPa and the crack pressure of horizontal artificial cracks along the opening direction of natural fracture is P^{t}_{f} = 45.61 MPa. So the X well is opening initiation along the natural fracture and its crack pressure P_f is 45.61 MPa.

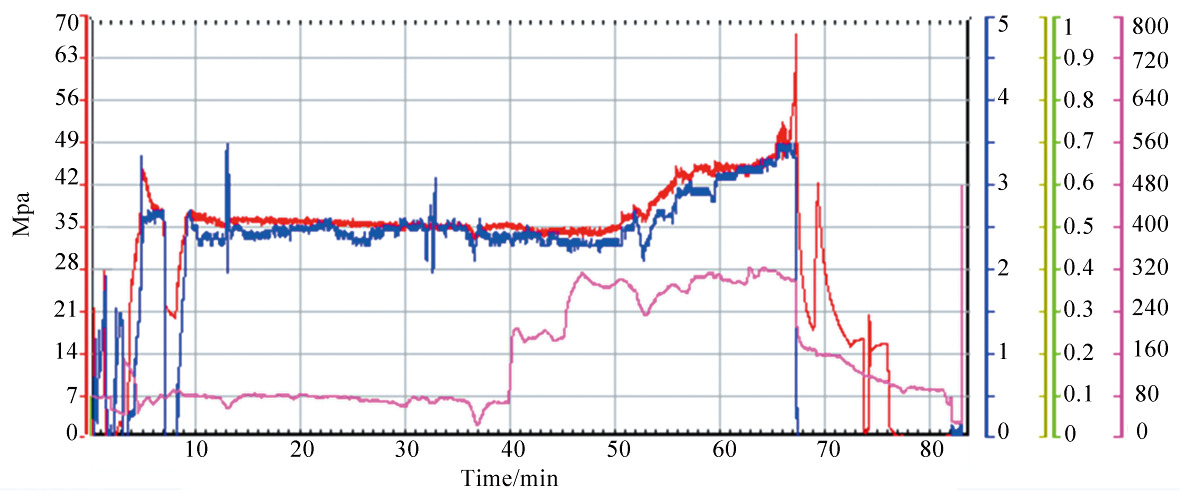

Figure 5
The Fracturing Construction Materials of X Well. Red Ordinate Represents the Pressure, Mpa. Blue Ordinate Represents the Displacement, m^3/min; Yellow Ordinate Represents the CO_2 DISplacement, m^3/min; Green Ordinate Represents the Crosslinking Agent Displacement, m^3/min; Pink Ordinate Represents the Density of Sand, kg/m^3

Figure 5 is the fracturing construction materials of X well. It can be seen that the crack pressure is 45.5 MPa in the hydraulic fracturing operation which is very close to the predicted pressure.Therefore, the prediction model of crack initiation built is feasible.

CONCLUSION

(a) Two ways of crack initiation of artificial fracture in fractured reservoir are given, which are shear initiation along the natural fracture and opening initiation along the natural fracture. Also, the corresponding calculation models of crack pressure are presented.

(b) It can be concluded that the greater the size of single crack is and the smaller the gap between cracks is, the more easily cracks gather into a seam.

(c) The feasibility of prediction models of crack initiation of fractured reservoir are validated by field application.

REFERENCES

[1] Zeng, L. B., Qi, J. F., & Wang, Y. X. (2007). Origin type of tectonic fractures and geological conditions in low-permeability reservoirs. *Acta Petrolei Sinica*, *28*(4), 52-56.

[2] Yang, X. P., Zhao, W. Z., & Zou, C. N. (2007). Origin of low-permeability reservoir and distribution of favorable reservoir. *Acta Petrolei Sinica*, *28*(4), 57-61.

[3] Jiang, R. Z., Jiang, T. X., & Wang, Y. L. (2004). Present development and prospecting of hydraulic fracturing technology. *Oil Dril. & Prod. Tech.*, *26*(4), 52-56.

[4] Chen, X. B., Chang, Y. W., & Wang, Y. L. (2011). Percolation mechanism and application of a production-decline model in low-permeability reservoirs. *Acta Petrolei Sinica*, *32*(1), 113-116.

[5] Beugelsdijk, L. J. L., De Pater, C. J., & Sato, K. (2000, April). *Experimental hydraulic fracturing propagation in multi-fracturingd medium*. Paper presented at SPE Asia Pacific Conference on Integrated Modelling for Asset Management, Yokohama, Japan.

[6] Cai, B., Wang, X. D., & Wang, X. (2011). Mathematical study of fracture face skin in hydraulic fractures. *Journal of China University of Mining & Technology*, *40*(6), 938-942.

[7] Xu, J. G., Liu, Z. D., & Dong, Y. X. (2009). Research on manmade fracture break regulars and treatment countermeasures in fractured horizontal well. *Drilling & Production Technology*, *32*(4), 36-38.

[8] Wan, X. L., Gao, C. N., & Wang, Y. K. (2009). Coupled relationship between created and natural fractures and its implication to development. *Journal of Geomechanics*, *15*(3), 245-252.

[9] Duan, H., & Wu, Y. H. (2010). The characteristics of artificial fracturing for fissure-cavern carbonate reservoirs. *Journal of Oil and Gas Technology*, *32*(3), 152-155.

[10] Zhang, S. C., Zhang, X. Y., & Ma, X. F. (2003). Mechanism study of fracture extending in volcanic reservoir. *Chinese Journal of Rock Mechanics and Engineering*, *22*(1), 2236-2240.

