

## Research Article

# Mechanism of Fracture Generation in the Hole and Research on Optimization Design of Drilling Fracture Parameters

Wei Jianguang, Chen Yongda and Chen Xi

School of Petroleum Engineering, Northeast Petroleum Engineering University, Daqing,  
Heilongjiang 163318, China

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**Abstract:** In order to increase the production of low permeability reservoir inclined or straight well, establish effective communication between the sand and improve development effect. For Daqing periphery low permeability oil field properties, such as large sandbody permeability difference, plane fast phase transition, narrow sandbody and scattered distribution. A straight and inclined well hydraulic fracture stimulation modification technology research and field application was launched. Studied the mechanism of crack generation in the hydraulic drilling hole and analyzed factors of crack situation in the hole of hydraulic drilling fracture, given parameter optimization method of hydraulic drilling fracturing, carried out hydraulic drilling fracturing on spot well selection test. The results show: At reservoir heterogeneity geo stress conditions, after the hydraulic drilling, the fracture cracks always rupture on contact surface of well and hole and then the crack extend along the direction of maximum horizontal stress. So reservoir heterogeneity is a necessary condition for generation of cracks in the hole. To make cracks in a certain position of hole after the hydraulic fracturing, reservoir heterogeneity must be a prerequisite, that there exists natural fractures in reservoir or geo stress heterogeneity. Pressure curve and fracture pressure curves intersect multiple cases. In these cases there will be many perforations along the crack. Considering the stress orientation, petrophysical, sedimentary facies, hole geometry parameters, the overall design system of hydraulic drilling fracturing parameters optimization is given. On spot selected well got a good effect. Liquid production increased to 4.8 from 1.7 tons. Oil production increased to 4.2 from 0.9 tons.

**Keywords:** Fracturing construction parameters, hydraulic perforation, on spot test, stimulation

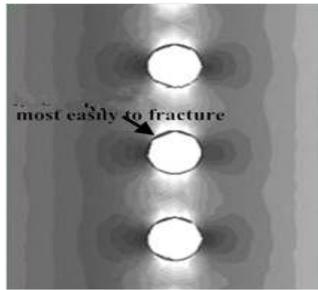
## INTRODUCTION

Daqing periphery oil field is low pressure, low permeability and low abundance oil field (Chen and Luo, 2006). It is an oil field with poor properties, reservoir performance for thin reservoir, small differences in the barrier and large differences in permeability, narrow sandbody. (Smaller than 300 m) and scattered distribution. Resulting in a small single well controlled area, difficulties in communication between wells and low production wells effect. In order to increase the area of a single well control, improve well production and improve performance, it needs to establish effective communication between the plane sand, this is conducive to the fluid flow information (Surjaatmadja, 1998). The hydraulic drilling fracturing can construct multiple parallel fractures among oil wells (Ni and Wang, 2004). Make banded range controlled by the crack extended to both sides, Promote inter-well, different phases matrix communication and improve development performance (Tian *et al.*, 2008).

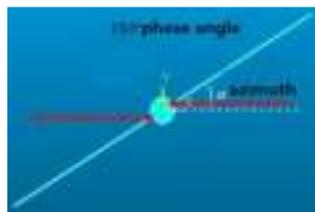
In this study, in order to increase drainage area and the production. Hydraulic drilling and hydraulic fracturing techniques combined method was used and many cracks formed around the well. On the basis of the generation of holes by hydraulic drilling, reservoir fracturing techniques were applied to improve the use of the degree. Production of hydraulic fracturing wells are mainly affected by the direction and length of the crack extension (Zhang *et al.*, 2010). Affected by formation stress distribution, after the formation is fractured and the length and the extension direction of the crack may not develop according to the design of the expected results. The best yield results cannot be got, there for study law for crack extension has important guiding significance on improving fracture effect (Luo *et al.*, 2007). Systematic analysis stimulation mechanism of hydraulic drilling fracturing well. Given hydraulic drilling parameter optimization design method, provide theoretical guidance to optimal design parameters for hydraulic drilling and fracturing wells fracture parameters optimization.

**Corresponding Author:** Wei Jianguang, School of Petroleum Engineering, Northeast Petroleum Engineering University, Daqing, Heilongjiang 163318, China

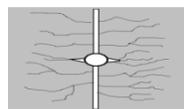
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(a)



(b)



(c)

Fig. 1: (a): Homogeneous reservoir simulation results; (b): Homogeneous reservoir fracture extends schematic; (c): Heterogeneous reservoir fracture extension schematic

## MATERIALS AND METHODS

### Analysis the mechanism of generation of cracks in the hydraulic perforation hole:

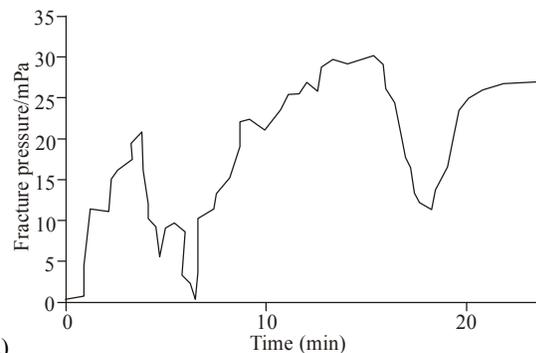
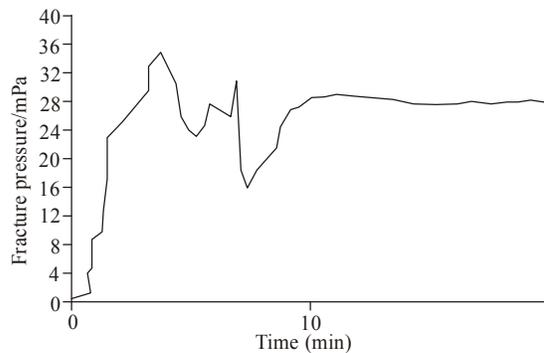
**Reservoir heterogeneity is a necessary condition for the formation of cracks in the hole:** By finite element simulation results show that: Reservoir at condition of situ stress heterogeneity hydraulic drilling hole and borehole wall contact surfaces are most likely to rupture area. The reason is that the hydraulic drilling hole and borehole wall contact surface produces stress concentration effect (Fig. 1a). At the same time under the stress of heterogeneity reservoir condition, crack

always generated along the direction of maximum horizontal stress after hydraulic fracturing drilling (Fig. 1b). That is to say fracture after hydraulic drilling under the conditions of heterogeneity situ stress reservoir. Cracks are always broken in the hole with the contact surface of the wellbore and extending along the direction of maximum horizontal stress. Through the above analysis: Reservoir heterogeneity is a necessary condition for the formation of cracks in the hole, that to make fracturing after the hydraulic punch, generation of cracks in a certain location of the hole. Reservoir heterogeneity must be a prerequisite. That reservoir presence of natural fractures or stress heterogeneity (Fig. 1c). Due to the large aperture, deep penetration while drilling. So there is small loss of pressure after fluid into the hole and can flow into the formation deeper parts. The cracks form in the hole in the lower fracture pressure micro fracture zone (Van de Ketterij and de Pater, 1997).

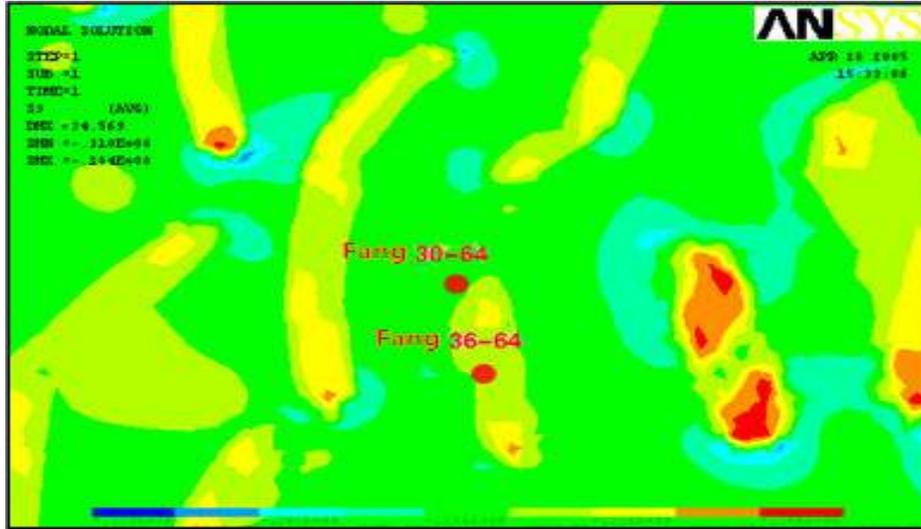
**Plane stress heterogeneity analysis:** Based on pressure curve of a horizontal well in Daqing oil field low permeability Putaohua layer (PI3 layer): There are significant differences in burst pressure and fracture at different time (Fig. 2a) Using the finite element simulation method, max horizontal main stress distribution of low permeability Putaohua layer in Daqing oil field is given, as can be seen that reservoir stress heterogeneity is obvious (Fig. 2b). It proves that the reservoir plane to stress and fracture pressure heterogeneity are obvious based on these results.

### Heterogeneity analysis of longitudinally stress:

Formation stress distribution can be calculated based on sonic logs. Sonic logging of the time difference reflected the different propagation velocity of acoustic waves in different formations, reflected voids, cracks and stress situation of rock formation. In accordance with sonic logs, rock mechanical properties experiment results gives the stress profile along the wellbore. After the formation of stress distribution obtained, according to rock failure criteria, fracture pressure along the wellbore at different locations can be calculated (Ge *et al.*, 1998). Research shows: Formation fracture pressure

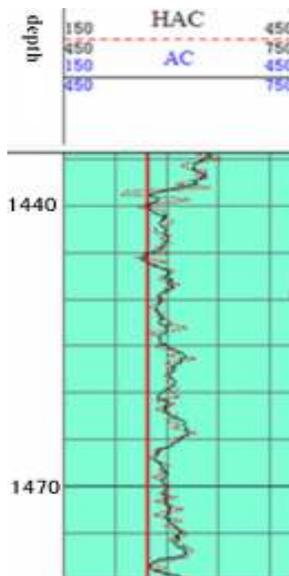


(a)  
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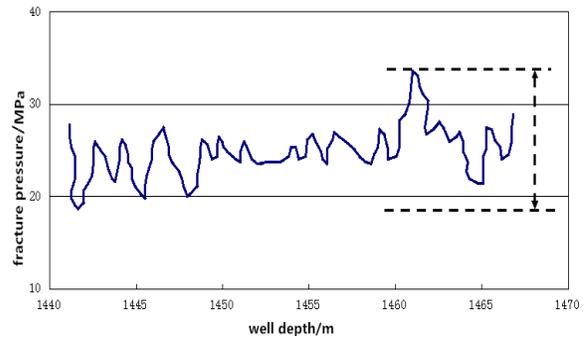


(b)

Fig. 2: (a): Two horizontal well fracturing pressure curve; (b): Maximum horizontal stress distribution

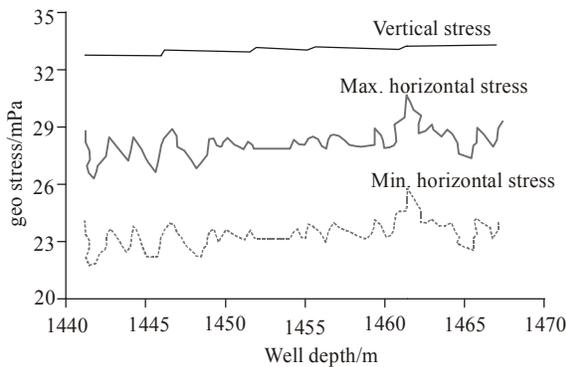


(a)



(c)

Fig. 3: (a): Sonic log; (b): Situ stress profile curve; (c): Fracture pressure profile curve



(b)

profile trends and ground stress distribution are in good agreement, that great geo stress with big burst pressure, At the same time we can see that the reservoir longitudinally stress section and fracture pressure profile heterogeneity are relatively obvious (Fig. 3). With advances in production engineering technology, if sonic log in the hole can be measured, Stress distribution from different depths within the hole can be drawn according to the calculation method and able to draw an accurate cracks open position within the hole (Cai *et al.*, 2009).

**Study the influence factors of burst position in the hole:**

**Calculate method of pressure drop in the hole:** As length of hole of hydraulic perforator is long, it ranges from dozens of meters to hundreds of meters. When fluid flows along the hole of hydraulic perforator, pressure drop can't be neglected (Fu, 2007). Formula of pressure drop in the hole is:

Table 1: Flow distinguish and calculation expression of friction coefficient

Flow	Reynolds number range	Empirical expression
Laminar flow	$Re \leq 2000$	$f = \frac{64}{Re}$
Hydraulically smooth	$3000 \leq Re \leq \frac{59.7}{\epsilon^{7/4}}$	$f = \frac{0.3164}{\sqrt[4]{Re}}$
Mixed friction	$\frac{59.7}{\epsilon^{7/4}} \leq Re \leq \frac{665 - 765 \lg \epsilon}{\epsilon}$	$\frac{1}{\sqrt{f}} = -1.8 \lg \left[ \frac{6.8}{Re} + \left( \frac{\Delta}{3.7d} \right)^{1.11} \right]$
Hydraulically rough	$Re > \frac{665 - 765 \lg \epsilon}{\epsilon}$	$f = 1 / \left( 2.1 \lg \frac{3.7d}{\Delta} \right)^2$

Table 2: Flow coefficient of hole under different conditions

Hole diameter (mm)	Single hole flow (m <sup>3</sup> /min)	Fluid viscosity (mPa.sec)	Flow coefficient C
30	0.1	20	1.8149
		40	1.8031
		80	1.7173
	0.2	20	1.9142
		40	1.7819
		80	1.6898
	0.5	20	1.8474
		40	1.7141
		80	1.6281
50	0.1	20	1.8925
		40	1.7618
		80	1.6714
	0.2	20	1.8574
		40	1.7265
		80	1.6319
	0.5	20	1.7879
		40	1.6303
		80	1.5659

$$\Delta P = f \frac{L}{d} \frac{\rho v^2}{2} C \quad Re = \rho d v / \mu$$

where,

- $\Delta P$  = Flow pressure drop in the hole, Pa
- $f$  = Coefficient of friction, dimensionless
- $L$  = Length of flow, m
- $d$  = Diameter of hole, m
- $\rho$  = Density of fluid, kg/m<sup>3</sup>
- $v$  = Velocity of flow, m/sec
- $C$  = Flow coefficient in the hole, dimensionless
- $\mu$  = Fluid viscosity, Pa.sec
- $Re$  = Reynolds number, dimensionless

According to Reynolds to determine the fluid flow pattern within the hole, different flow patterns conditions have different friction coefficients, calculate formula of friction coefficient under different flow patterns is shown in Table 1. The hole flow coefficient under different conditions is shown in Table 2 hole flow coefficient measurement experiment scheme and procedure is as follows:

- Making 4 Cement pipes with an inner diameter of the hole 30, 40, 50 and 60 mm, respectively and absolute roughness is 0.5 mm and length is 1.0 m.
- Use 9,500,000 molecular weight HPAM polymer of different concentration. Viscosity is 20, 40 and 80 mPa.sec, respectively.

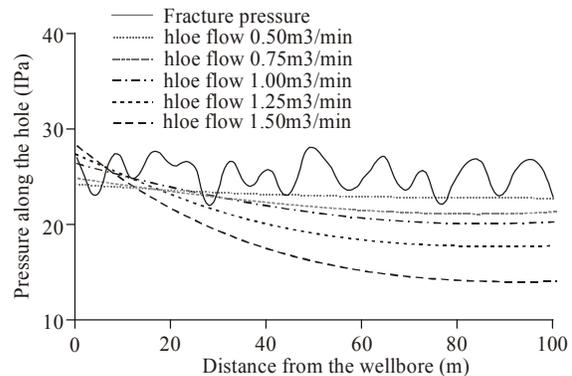


Fig. 4: A fluid viscosity of 20 mPa.sec hole pressure drop

- Use Particle diameter of 0.5 mm sand to make 10% solid content concentration.
- Then at different viscosities, different displacement conditions, cement pipe at both ends of each pressure drop 30, 40, 50 and 60 mm were measured, respectively.
- Calculate the flow coefficient at different conditions.

**Factors hole rupture location analysis:** Calculated by the above method is given in Fig. 4. Under the conditions of heterogeneous reservoir, generation of cracks in the hole can be seen when the hole fracture

Table 3: Perforator fracturing drilling parameter optimization reference

The number of holes	Hole diameter (mm)	Fracturing fluid displacement (m <sup>3</sup> /min)			
		20.0 mPa·sec	40.0 mPa·sec	80.0 mPa·sec	120.0 mPa·sec
2	30.0	0.6~0.8	0.5~0.6	0.4~0.5	0.3~0.4
	40.0	1.3~1.6	1.2~1.4	1.1~1.2	0.9~1.0
	50.0	2.3~2.6	2.0~2.2	1.8~2.0	1.3~1.6
4	30.0	1.2~1.6	0.9~1.2	0.7~1.0	0.6~0.8
	40.0	2.8~3.2	2.3~2.8	2.0~2.4	1.6~2.0
	50.0	4.4~5.2	3.8~4.4	3.2~4.0	2.5~3.2
6	30.0	1.9~2.4	1.3~1.8	1.1~1.5	0.9~1.2
	40.0	3.6~4.8	3.0~4.2	2.8~3.6	2.4~3.0
	50.0	6.6~7.8	5.0~6.6	4.4~6.0	4.0~4.8

pressure in the hole is lower than the fracture pressure near the wellbore. Due to the influence of stratigraphic conditions, fracture pressure along the perforated hole is uneven (Li *et al.*, 2013). This will make fluid pressure in the drilling hole greater than the fracture pressure several times. This will form the multiple fractures. Figure 4 shows the relation between internal pressure and fracture pressure under different conditions of hole fluid flow along the perforation 40 mm diameter hole. As can be seen from the Fig. 4. Fluid pressure drop within the hole decreases with increasing of diameter of the perforations and increases with the increasing of flow. Under some conditions of the combinations flow parameter. Pressure curve and fracture pressure curves intersect multiple cases. In these cases, multiple fractures will generate along the perforations. The first intersection of flow pressure and fracture pressure can also be seen from the Fig. 4, the distance of first crack produced to wellbore related to the fluid viscosity, flow, hole diameter, the degree of heterogeneity.

**Fracturing drilling parameter optimization method:** According to analysis of factors of hole rupture location, the larger displacement of the hole, the closer the location of cracks within hole to wellbore (Jilei *et al.*, 2003). By a large number of calculations are given under different conditions of generation of cracks when the naked hole 20 m away from the wall. The upper limit of displacement was given. Meanwhile, in order to ensure the generation of cracks in the hole can be considered under conditions of flow of fluid loss, the low limit of the porous hole fracturing fluid displacement is given in Table 3 (Su *et al.*, 2011).

**Design the construction parameters and analysis application result:**  
**Well selection principle:**

- Field that cannot establish an effective system of displacement, preferably a large thickness sandstone reservoir, auxiliary hydraulic perforating wells and long fracturing technology to shorten the well spacing, increasing the affected area, to improve production.
- To establish an effective system of oil

displacement, for the remaining oil-rich sands, implement auxiliary hydraulic perforating and long fracturing technology, mining remaining oil.

- Well those preferred the design orientation under a single hydraulic drilling conditions and in accordance with the orientation of the design under fracturing conditions as close as possible.
- Preferably those deep hydraulic penetrating drilling and auxiliary fracturing technology can effectively increase the plane sweep area and improve the effect of vertical connectivity wells.

**Drilling depth orientation and design:**

- For wells digging remaining oil, analysis residual oil distribution area, perforating in the direction of remaining oil-rich region, the design of depth from the rich region should be closer as much as possible.
- For injection and production wells corresponding to establish an effective displacement, drilling direction should be avoided in a straight line. Taking into account the target displacement distance design direction and length.
- For releasing pollution wells near wellbore zone, according to the degree of pollution, determine drilling distance, while maximizing the number of punch to plugging to solve the stoppage effect.
- Base on stress direction, the angle between the direction of the hydraulic drilling and maximum principal stress direction increases as far as possible.
- Fulfill the geological and construction requirements.

**Field test well design:** The selected test wells principle is to get remaining oil close to the fault, weak water direction, easy to form multiple fractures. Design principles are to further tap the potential of remaining oil and expand the well drainage area plane; Taking into account the high pressure zone caused by difficult water injection around wells. To expand in the plane swept volume of injection wells, improve water effects, improve injection-production ratio, based on the conditions of hydraulic drilling, conducted fracturing drilling. Hydraulic drilling azimuth design results is shown in Fig. 5.

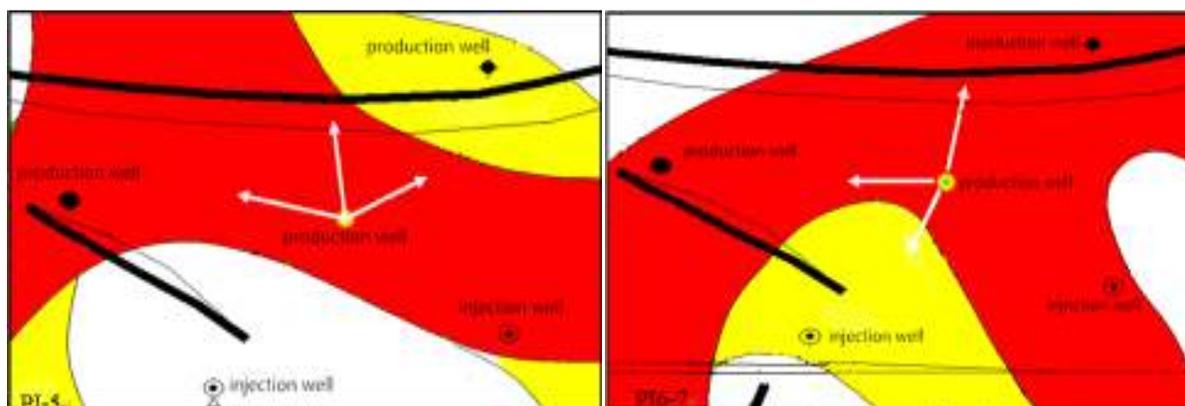


Fig. 5: Sedimentary facies maps and hydraulic drilling azimuth of PI5 and PI6-PI7 layer

Table 4: Fracture parameters optimization design of experimental well

Layer	Perforation interval (m)	Construction scale		Avg. sand proportion (%)	Displacement (m <sup>3</sup> /min)
		Silica sand (m <sup>3</sup> )	Ceram site (m <sup>3</sup> )		
PI5	1449.7-1453.7	9.0	3.0	26	2.6
PI6-7	1456.9-1460.8	9.5	3.5	27	2.8

Avg.: Average

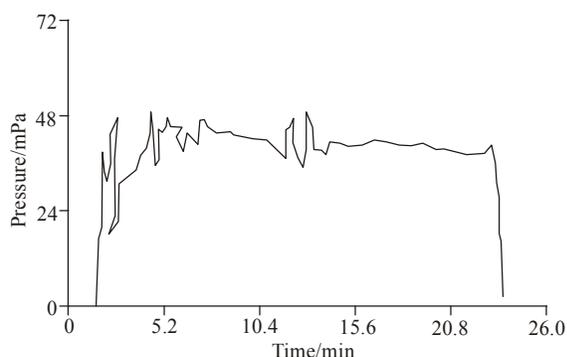


Fig. 6: PI6-7 layer of Sheng 27-35 well test fracturing curve

Fracturing fluid thickener preferably has better thermal stability, shear resistance, low residue content, the modification fracturing fluid has a viscosity of greater than 45 mPa.sec. Table 4 is optimized design table for test wells fracturing parameters, the table shows the amount of water used in drilling wells and proppant segment, the average ratio of sand, fracturing displacement parameters.

**Measure effectiveness analysis:** When PI6-7 layer of fracturing, measuring the injection pressure, changes in flow injection with injection time curve (Fig. 6). As can be seen from the Figure inject pressure significant fluctuations in pressure in PI6-7 layer fracturing process and there is sand blocking phenomenon. Description fracturing the formation of the main crack formed at the same time form a number of micro-cracks.

After fracturing of PI6-7 layer is completed, use micro-earthquakes to detect the development of the situation after the fracture (Fig. 7). For analysis of the

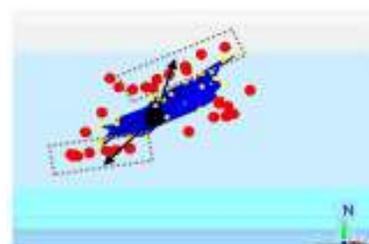


Fig. 7: PI6-7 layer fracturing perspective top view

monitoring fracture results curve, PI6-7 layer after fracturing approximately 10° north east and north east drilling direction about 270° drilling direction exist cracks and obvious fractures exists around the well, expanding the seepage area.

Production curve of experimental well before and after hydraulic perforation hydraulic is shown in Fig. 8. We can find that the on spot experiment got a good application effect from Fig. 8. Liquid production improved from 1.7 to 4.8 ton, oil production improved from 0.9 to 4.2 ton. This research has an important meaning in the low permeability reservoir well stimulation, setting up connection among sand body and improving development effect.

## RESULTS AND DISCUSSION

- Under the condition of homogeneous reservoir ground stress, crack will always burst in the hole and well wall interfaces and extend along the maximum horizontal principle stress. So heterogeneous reservoir is an essential condition to form cracks in the hole. It means that in order to fracture a crack in a certain position of the hole after hydraulic perforation. Heterogeneous

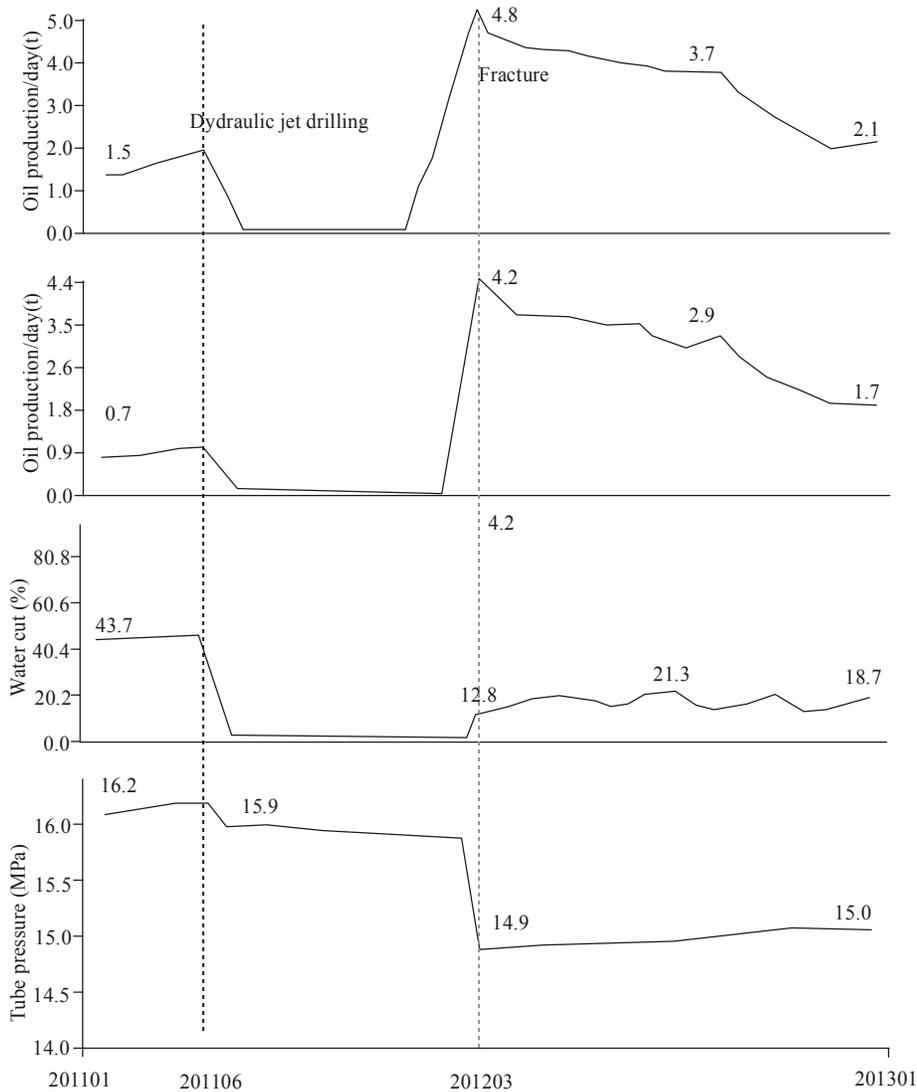


Fig. 8: Production curves of test wells before and after measures

reservoir is the prerequisite, that is to say there exists natural cracks or heterogeneous ground stress.

- As the hole has big diameter and deep penetrate, pressure drop is lower when fluid enter the hole and it enters a deeper position of the formation. Cracks will form in the hole where burst pressure is low and has lots of micro-cracks. Curve of pressure of the hole cuts curve of burst pressure several times, under this condition, many cracks will generate along the hole.
- Based on the numerical simulation research result of crack generation in the hydraulic perforation hole in the heterogeneous reservoir and reservoir sedimentary facies map. Take ground stress direction, petrophysical parameter, sedimentary facies and hole geometry parameter into consideration and parameters optimization design of hydraulic perforation fracturing was given.
- Wells selected on spot and experiments on wells show a better application effect, liquid produced increased from 1.7 to 4.8 ton, oil produced increased from 0.9 to 4.2 ton.

**ACKNOWLEDGMENT**

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