Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (12): 2321-2325, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2321.2325

Influence of Perforation Parameters on Hydraulic Fracture Initiation

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Abstract: Perforation well fracture extension is a key factor to the success or failure of hydraulic fracture, this study combines with the rock mechanics, percolation mechanics and elastic-plastic mechanics, establish hydraulic fracture extension mechanical model of low permeability reservoir perforation layer. The numerical analysis method is adopted on the basis of considering fluid-structure interaction and dynamic effect, then the hydraulic fracture extension form of perforation layer can be acquired. The influence of perforation parameters on crack width and length are given under the condition of calculation, it analyze the influence of perforation parameters on crack propagation and provides fundamental basis for hydraulic crack propagation.

Key words: Perforation parameter, hydraulic fracture, extension, numerical simulation

INTRODUCTION

The implementation development of hydraulic fracture of low permeability reservoir is the effective measure to improve the oilfield production, we need to optimize perforation parameters in order to give full play to the role of hydraulic fracture. At present, people have more fully studied the influence of perforating parameters on crack initiation pressure through the means of theory analysis and experiment (Zhang *et al*., 2003; Li *et al*., 2005; Wang *et al*., 2005) but it's lack of the research of the influence on the fracture extension (Zhang *et al*., 2003).

In this study, the dynamic analysis methods are adopted under the condition of considering fluid-structure interaction, analyze the influence of stratum on crustal stress generated in the process of well drilling, well cementation and perforation. Research the influence of perforation parameters on crack initiation pressure and fracture shape.

MECHANICAL MODEL OF RESERVOIR ROCK

Take a perforation oil reservoir as the research object; the way of perforation is spiral perforation. Take a radius is 5 m and the thickness is 0.7 m considering the boundary effect, then set up the three-dimensional elastic-plastic fluid-solid coupling mechanics model of stratum-casing. The mechanical model is shown in Fig. 1.

Load constraint effect on the model: (1) The formation of the overlying rock pressure P_z, (2) The maximum and minimum horizontal stress effected on the formation of outer boundary σ_H, σ_h and vertical stress σ_v (not shown), (3) Fracturing fluid effected on the inner wall of the casing and hole P_S, (4) Stratum heavy G, (5) Model bottom does not allow a rigid displacement, applying zero displacement constraint of Z direction at the bottom surface and (6) Applying the osmotic pressure in the upper and lower surface and circumferential surface.

The stratum rock uses solid elements, casing uses membrane elements and preset crack surface uses damage element, the mechanical model is created for discretization of mechanical models, as shown in Fig. 2. Adopt the

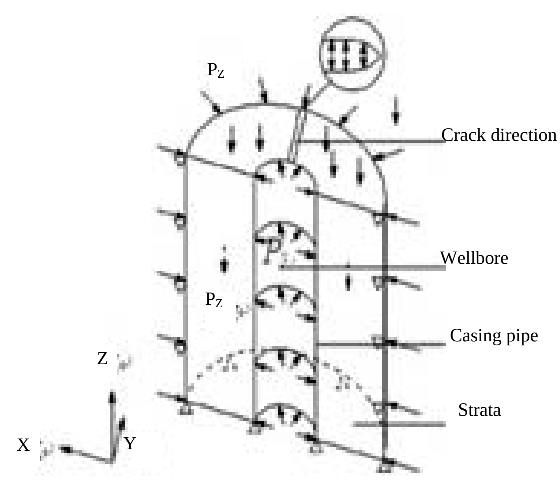

Fig. 1: Hydraulic three-dimensional fracture mechanics model

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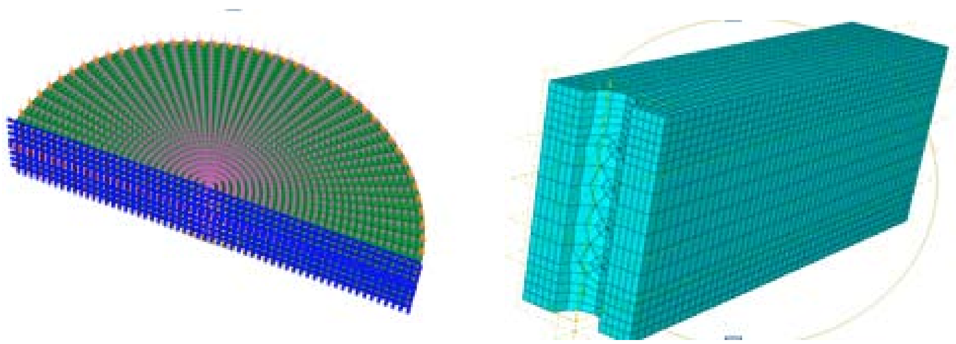

Fig. 2: Whole grid model and local model of casing-stratum

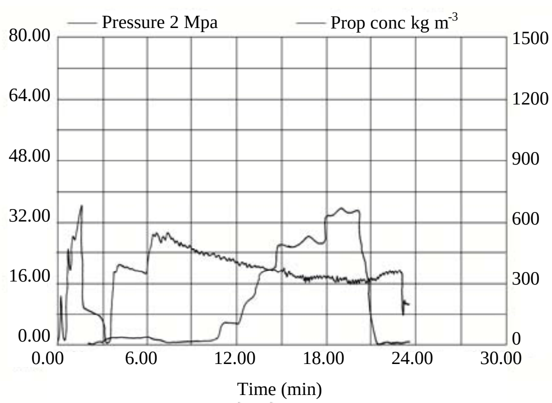

Fig. 3: Crack initiation pressure test curve

sub-model calculation in the process of calculating crack expansion process in order to enhance computational efficiency; the sub model is a finite element method obtained part of more accurate (Zhang *et al*., 2000).

As the crustal stress is related to initial state and transformation process, the calculation includes the following steps:

Step 1: Apply gravity to form the initial geostress field

Step 2: The crustal stress state surrounding the perforation can be obtained to judge the crack position and crack initiation pressure when simulate the fracturing process. The substep (2) is in the process of fracturing, it need to judge according to the cracks on the surface of the state because of the crack boundary is a changing boundary. A certain capacity of fracturing fluid will be injected to perforation unit at the beginning of fracturing, the rheological properties of fracturing fluid accord with power-law fluid flow rule, the rheological index and consistency coefficient are selected according to the laboratory experiment experimental data

NUMERICAL VERIFICATION

Take a fracturing well of an oil production plant in Daqing oilfield as an example, the perforation depth is 1479 m, porosity is 0.169, the permeability is 16.6×10^{-3} μm^2, the rock force elasticity modulus is $2.99\times10^{11}P_a$, the Poisson ratio is 0.25, the internal friction angle is 45°, the cohesion is 8.23 Mpa, initial ground stress is:

$$\sigma_v = 30 \text{ Mpa } \sigma_H = 22 \text{ Mpa}, \sigma_h = 19 \text{ Mpa}$$

The construction pressure curve of fracturing well is shown as Fig. 3, the wellhead instantaneous crack initiation pressure is 35 Mpa and the string resistance loss

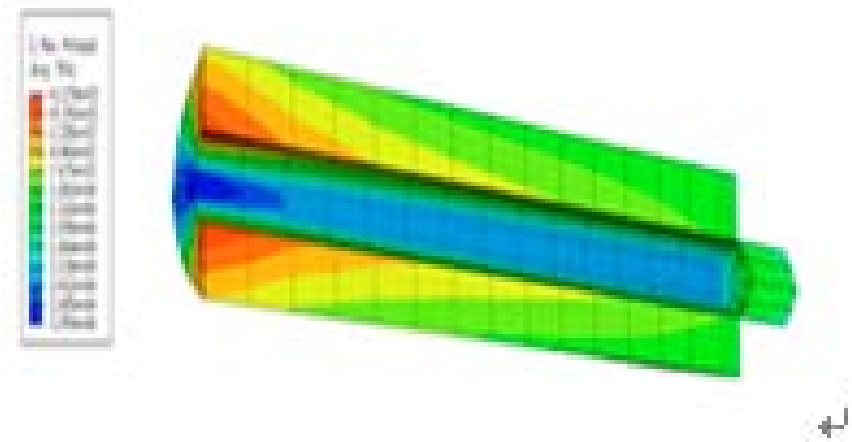

Fig. 4: Numerical simulation of the maximum main stress around the perforation

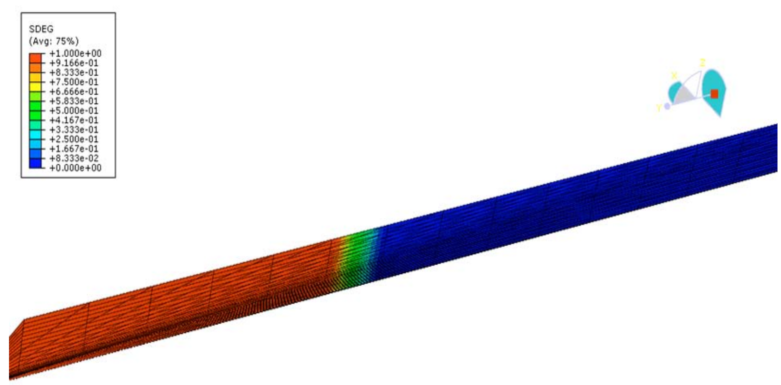

Fig. 5: Crack length of azimuth angle is 90°

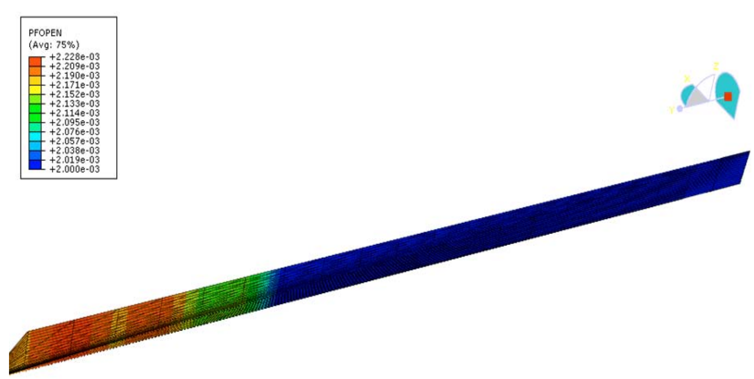

Fig. 6: Crack width of azimuth angle is 90°

is considered, the perforation location pressure is about 43.87 Mpa. Then calculate the maximum principal stress amplitude of the hole is 3.27 Mpa, achieved the tensile strength of rock, the rock occurred tensile fracture, the numerical analysis is proved to its correctness (Fig. 4).

Fig. 7: Crack length of azimuth angle is 0°

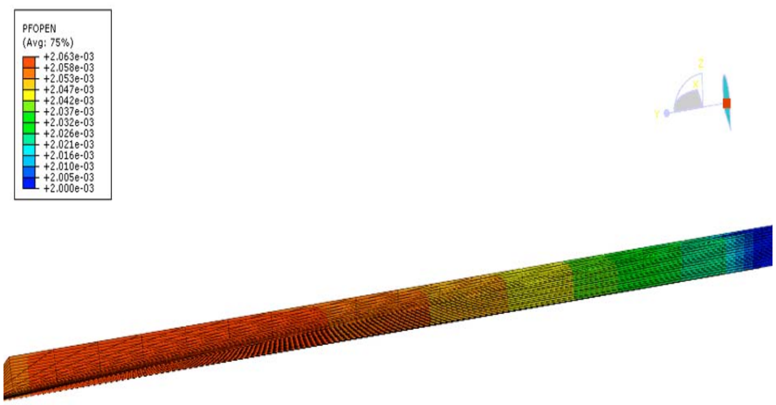

Fig. 8: Crack width of azimuth angle is 0°

INFLUENCE OF PERFORATION PARAMETERS ON CRACK PROPAGATION

The influence of perforation orientation on crack propagation, perforation azimuth angle is the angle hole axis and the maximum horizontal in-situ stress direction (Xu, 2004). Change the perforation azimuth in the calculation to analysis the effect of pressure on crack, select the 0, 30, 60 and 90°, respectively.

Figure 5-8 is the cloud picture of crack length and width which the azimuth angle is 90 and 0° at 10 sec moment, it can be known from the analysis of fracture morphology data: The crack length is 4.28 m when the perforation azimuth angle is 0, the crack width is 2.063 mm when the perforation azimuth angle is 90°, the crack length is 1.4 m, the crack width is 2.228 mm, it illustrates that it's easy to form longer crack when the perforation azimuth angle is smaller. Therefore, the perforation azimuth angle is more serious to crack shape, it should reduce the perforation azimuth as far as possible when perforation fracturing.

Table 1:Comparison of fracture width and length under different aperture

Perforation diameter (mm)	Crack length (m)	Crack width (mm)
10	1.40	2.228
16	3.56	2.117
20	4.85	2.066

Influence of perforation diameter on crack propagation: Perforation diameter is an important parameter to perforation design, select the diameter is 10, 16 and 20 mm in the process of calculation. The comparison of fracture shape under different aperture is shown as Table 1.

It can be seen from Table 1, the crack length increases and width reduces with the increase of perforation diameter, so perforation diameter is one of the important factors that influence the formation of cracks, the perforation diameter can be improved appropriately in order to improve the fracturing effect.

Influence of perforating depth on crack propagation: Perforating depth is related to the spring type, select the

Table 2: Comparison of fracture width and length under different perforation depth

Deep hole (mm)	Crack length (m)	Crack width (mm)
0.5	4.14	2.073
0.8	4.62	2.017
1.2	4.85	2.066

0.5, 0.8 and 1.2 m to analyze in the process of counting process. The contrast of crack morphology under different perforation depth is shown as Table 2.

It can be seen from Table 2. The morphology of fracture following the change of perforation depth has a little change.

CONCLUSION

- The hydraulic fracture extension mechanical model of low permeability reservoir perforation layer is established according to the rock mechanics, percolation mechanics and elastic-plastic mechanics, adopt the transient analysis method on the basis of considering fluid-structure interaction and dynamic effect, the distribution state and fracture shape of formation stress can be acquired for applying finite element method
- Perforating depth has smaller influence on the crack propagation and the perforation diameter and azimuth have larger influence on fracture morphology. When the perforation diameter is larger, the perforation azimuth is smaller, then it will more easier to form long narrow crack

ACKNOWLEDGEMENT

Project supported jointly by the National Natural Science Foundation of China Grant No. 51004023 and No. 51374074.

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