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Analysis of Abnormal Pressure in Fracturing Construction of Horizontal Wells and Suggestions for Measures

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Abstract

The tight sandstone reservoir in Daqing Oilfield has the characteristics of low porosity and low permeability, and the natural fractures are not developed, and the production requirements can only be met after horizontal well fracturing, but some horizontal wells have high construction pressure, low rate and large construction risk, so how to effectively reduce the pressure and improve the rate is the key to improve quality and efficiency. In this paper, the reasons for the abnormal construction pressure of the well are analyzed in detail from the aspects of geological and engineering factors. During fracturing construction, the net pressure is high, and perforation, multiple cracks, and in-situ stress are the main reasons for abnormal construction pressure. On this basis, the process methods such as optimizing perforation parameters, drilling orientation, and slug grinding are proposed, which provide valuable suggestions for the later development of the block.

Keywords

Net Pressure; Fracturing; Construction Pressure; Multi-crack.

1. Introduction

The main production layer of tight sandstone reservoir in Daqing Oilfield has a buried depth of 2000-2300m, the reservoir is relatively compact, the matrix porosity is mainly distributed in 1-8%, the permeability is 0.2-5mD, the formation temperature is 105 degrees, the formation pressure coefficient is 1.06, and the natural fractures are not developed. The fracturing process of horizontal wells uses traditional guanidine gum fracturing to create long fractures to increase the oil drainage area. The design is 500-600m long horizontal well section, perforation completion mode, each section is 70-80m, perforation length is 7-8m, construction rate is 3-4m^3/min, each section uses 20/40 mesh ceramsite as proppant, and the sand addition amount is 40-50 tons.

The maximum construction pressure on the site reaches more than 60MPa, and the construction pressure is too high to cause the displacement to be difficult to increase, the construction risk is large, and the requirements of increasing production cannot be met, and some wells even exceed the bearing capacity of the surface equipment, resulting in the failure of sand and construction. Therefore, it is necessary to analyze the causes of high construction pressure and put forward targeted technological measures to reduce construction pressure, so as to effectively improve the success rate of reservoir transformation in this area and provide technical support and guarantee for the efficient development of Daqing Oilfield.

2. Pressure Calculation

Surface pressure calculation formula:

$$P_{surf} = P_e + P_F + P_b + P_{perf} - P_H$$

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P_{surf}-surface pressur; P_e- extension pressure; P_F-wellbore friction; P_{perf}-perforation eyelet friction;P_b-crack bending friction;

P_H- liquid column pressure

The crack does not always go in one direction in the process of extension, but bends and turns. The bending friction of cracks has the greatest impact at the beginning of construction, and gradually decreases with the progress of construction [1]. The bending friction of the crack can be obtained from the step-down displacement.

The high pressure is largely due to the poor connectivity between the wellbore and the fractures, resulting in excessive pressure loss between the wellbore and the fractures. The accuracy of the hole friction calculation directly affects the prediction of fracture pressure, and the geometry of fracture propagation is a key parameter for current-limiting fracturing, which has an important impact on the smooth implementation of fracturing construction and post-fracture evaluation [2]. The traditional formula for calculating eyelet friction is as follows:

$$P_{perf} = 0.02244 \frac{q^2}{n^2 dc^2} \rho$$

q—flow rate;

ρ—density of liquid;

n—the number of eyelets;

d—eyelet diameter;

c—flow coefficient,0.6-0.9;

Net pressure means that in the process of hydraulic fracturing, the pressure of the pumped fracturing fluid overcomes the friction along the way, the friction of the blast hole, the friction resistance near the well zone and the fracture closure pressure, and finally the remaining effective pressure that directly acts on the rock to produce cracks in the rock. The net pressure is calculated as follows:

$$P_{net} = P_{ISIP} - P_{Closure}$$

P_{net}—net pressure;

P_{ISIP}—stop pump pressure;

$P_{Closure}$—crack closure pressure;

From the above formula, it can be seen that the construction pressure is closely related to the fracture elongation pressure, and the fracture elongation pressure is determined by the reservoir in-situ stress, and the greater the in-situ stress, the greater the fracture elongation pressure, and the construction pressure also increases accordingly. The fracture propagation pressure can be obtained by the instantaneous pump stop pressure at the end of fracturing, the ISIP and the liquid column pressure, as shown in Figure 1. The crack closure pressure can be calculated as a G-function.

Fig 1. Pressure changes over time

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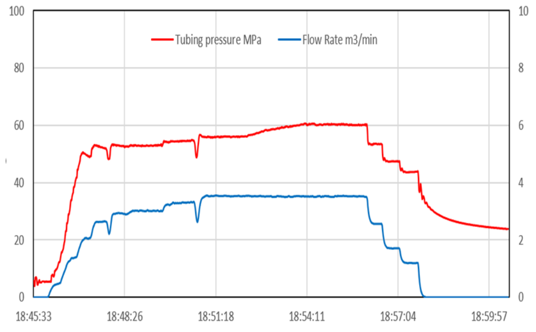
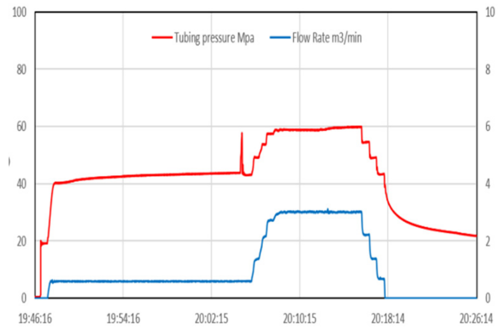
3. Test Stress Analysis

The first and second sections of XX well engineering are constructed, the flow rate is 0-3 m^3/min, the construction pressure is 60MPa, the pressure is limited to 60MPa, and there is no rupture from the analysis of the construction curve, due to the high construction pressure, the proppant can not be pumped, and the construction can not be completed in the end, and then the test fracturing is shown in Figure 2.



a. The first section of fracturing construction curve

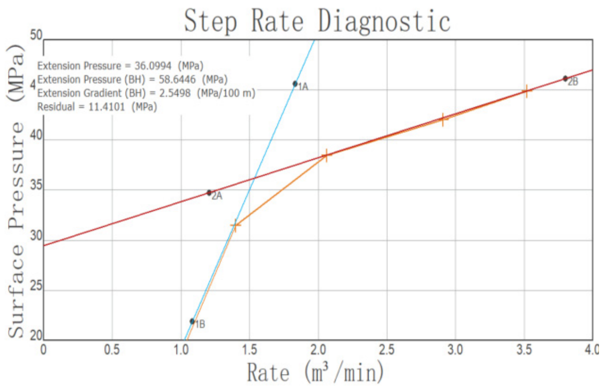


b. The second stage of fracturing construction curve

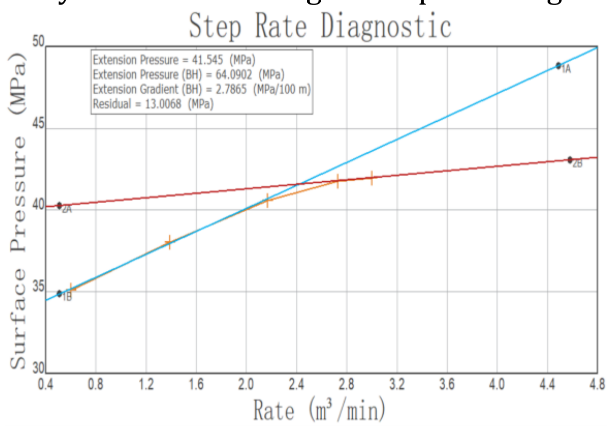
Fig 2. Fracturing curve

3.1. Step Rate Analysis

As can be seen from the following figure, the fracture elongation pressure of the first and second sections is 58.6 and 64 MPa, respectively, indicating that the fracture elongation pressure is relatively high and the formation heterogeneity is strong.



a. Analysis of the first stage of step rate diagnostic



b. Analysis of the second stage of step rate diagnostic

Fig 3. step rate diagnostic

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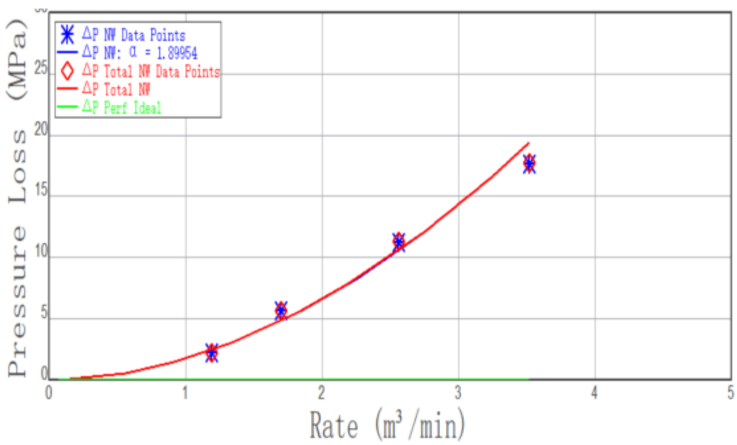
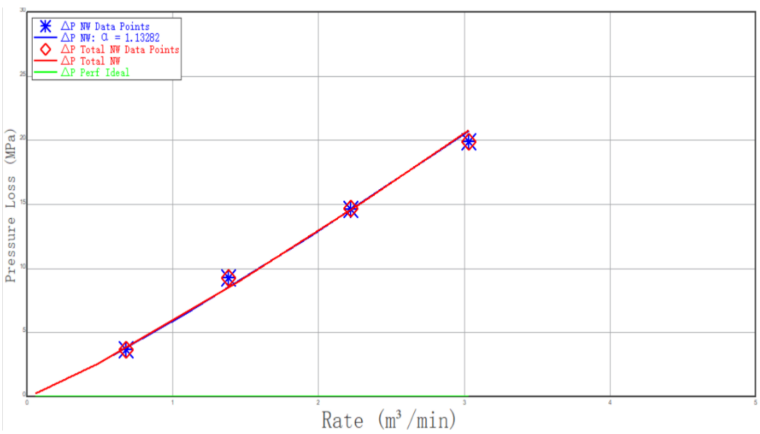
3.2. The Step-Down Displacement Analysis

The step-down displacement is used for the analysis of friction, and it can be seen from Figure 4 that the friction mainly comes from the near-well friction, and the eyelet friction is negligible. According to the problem of near-wellbore, the main reasons for the friction of fracturing are as follows: (1) The phase of the perforation hole is inconsistent. Because hydraulic fractures are often not formed in the direction of perforation, fracturing fluids usually pass through one or more tortuous passages from the hole to the fracture. The main reason is that the phase and spacing of the holes are relatively different, resulting in the perforation being inconsistent with the expected crack direction;(2) Poor perforation connectivity. The quality of perforation will directly affect the rupture pressure and construction power consumption, if the perforation is improper, the poor communication between the perforating hole and the fracture body will lead to premature sand removal of the sand-carrying fracturing fluid; (3) Crack bending. Because of the problems of distortion and turning with the stress distribution of the formation rock, irregular extension will occur during the fracture extension process; (4) The fracturing process produces multiple fractures [3-6]. A large number of micro-cracks will consume the pumping pressure, which will make the crack width narrower and make it difficult to add sand.



a. The first stage of friction

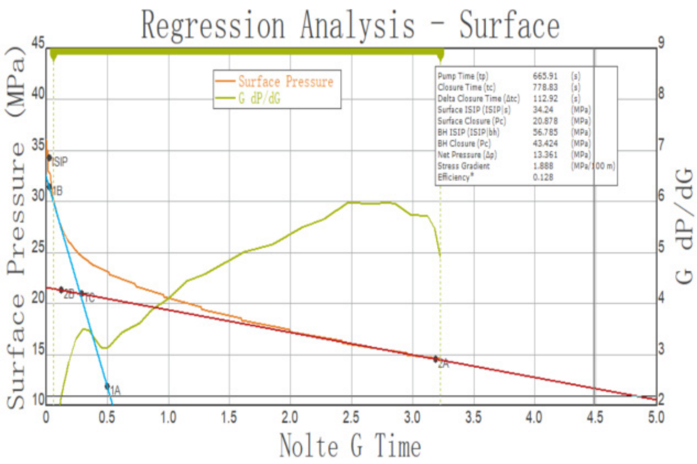


b. The second stage of friction

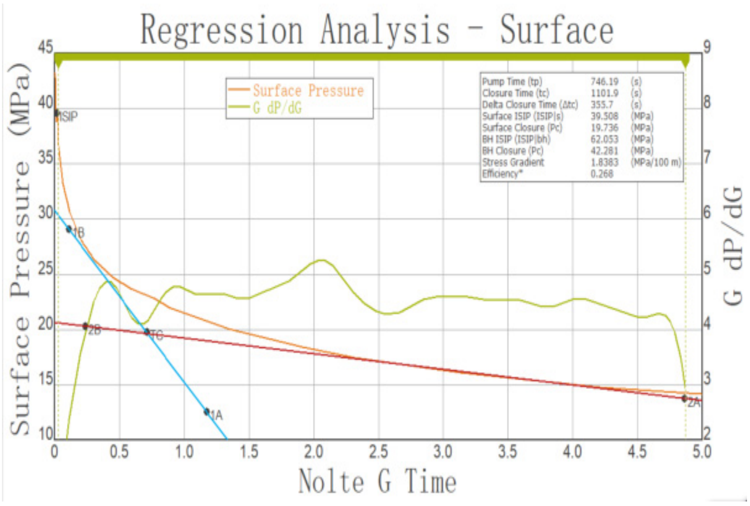
Fig 4. Friction analysis

3.3. G Function Analysis

The G-function curve of fracturing can reflect the filtration of the formation, the extension of fractures, and the development of multiple fractures. As can be seen from Figure 5, multiple fractures were produced during fracturing. The net pressure is 13.3 and 19.8MPa, respectively, and the net pressure is higher. It may be that the creation of multiple cracks has led to the higher net pressure.



a.The first segment of the G function



b.The second segment of the G function

Fig 5. G-function analysis

3.4. Net Pressure Fitting

Net pressure fitting refers to fitting the net pressure of the bottom hole fracture monitored during hydraulic fracturing construction with the net pressure of the fracture simulated by the design software. As can be seen from Table 1, the physical properties of the formation are poor, and it can be seen from the fitting parameters volume factor and fracture factor that multiple fractures were generated during fracturing, which is consistent with the results of G-function analysis.

Table 1. Fitting parameters

Segments	Permeability/mD	Stresses/MPa	Volume Factor	Leakoff Factor	Opening Factor
First paragraph	0.86	41.8	2	1	4
Second paragraph	0.72	41.5	2	1	5

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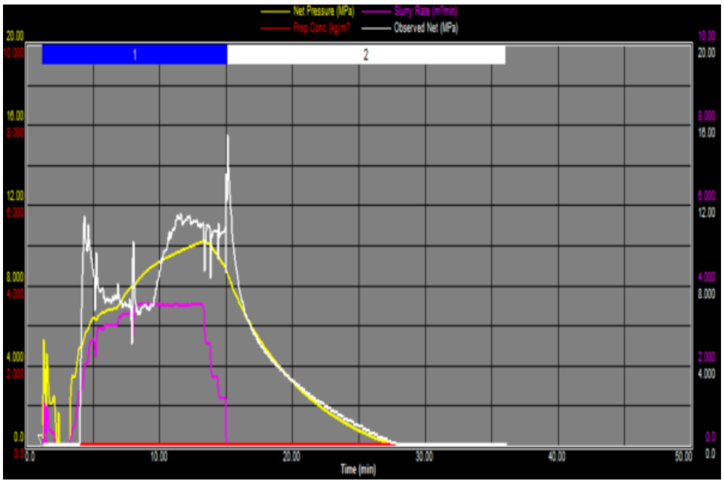
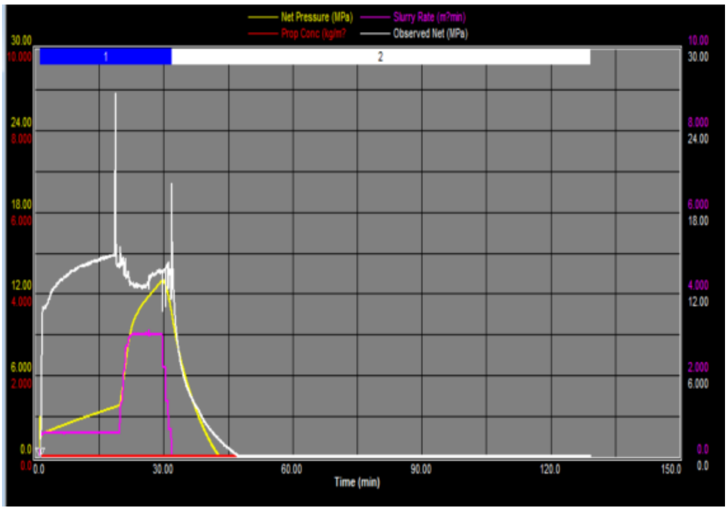


a. First segmennet pressure fitting



b. Second segment net pressure fitting

Fig 6. Net pressure fitting analysis

4. Suggestions for Measures

From the analysis, it can be seen that the cause of construction pressure is mainly caused by multiple cracks. At the beginning of fracturing, there will be a number of micro-cracks in the wellbore, which are extended and expanded in different directions, some can be connected together to form large artificial cracks, and some may expand independently, and the cracks interfere with each other, the fractures bend and extend, the friction increases, the construction pressure is high, and the crack width is small, resulting in the failure of sanding.

Fig 7. Crack formation process

The causes of multiple fractures are long perforation sections, unreasonable perforation phases, natural fractures, cementing quality and other reasons. Combined with the actual situation of the well, the perforation section of the well is 7m long, the perforation length is long, and many cracks are formed during construction, and large artificial cracks cannot be formed during the expansion process, resulting in high construction pressure. Therefore, it is recommended to reduce the perforation length in the future development process. At the same time, the perforation density is increased, which is conducive to the interconnection of cracks.

In the pre-liquid, slug grinding can be carried out with small particle size proppant to reduce the filtration loss of liquid and friction in the joint, and can seal the micro-cracks, which is conducive to the formation of the main cracks. This technique has also been widely used with good results [7-8].

In addition, it can increase the viscosity of the liquid, increase the turning radius of the crack, make the crack trajectory transition smooth, reduce the construction pressure and the chance of cracking of multiple cracks, and also increase the crack width, which is conducive to the entry of proppant into the crack in the later stage [9].

In the later stage, the drilling orientation can be carried out along the direction of minimum principal stress to form a cross-cutting vertical fracture to reduce the resistance caused by fracture bending, and this layout method can transform the reservoir to the greatest extent.

5. Conclusion

(1) The analysis of the construction curve shows that the reservoir is compact, and the fracture extension pressure and multiple fractures are the main reasons for the high construction pressure.

(2) The long perforation length is not conducive to the interconnection of cracks, which is the main reason for multiple cracks.

(3) Reducing the perforation length, slug grinding, and increasing the liquid viscosity can reduce multiple cracks and reduce the construction pressure.

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