Long Horizontal Section Well Application in Developing Ultra-Low Permeability Layer

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Abstract. The *F* oil layer is a typical low permeability reservoir. Conventional development cannot develop the low permeability reservoir effectively, so the long horizontal wells cooperate with volume fracturing in the way to transform the ultra-low permeability reservoirs. Well *P*1 is the first long horizontal section well drilled by our company. Based on its condition and formation characteristics, it conducts a large-scale multi-segment multi-cluster volumetric fracturing field test of horizontal wells to realize the volume utilization of the layers. The test verifies the feasibility of volume fracturing in the reconstruction of horizontal wells and the applicability of the supporting process in the application of ultra-low permeability reservoirs. At the same time, the fiber sand-adding process test for tight oil type II reservoirs was conducted. After the fracturing, tracer monitoring was performed on the flowback liquid to ascertain the produced fluid of each layer, and it was determined that the crack cutting technology had a good transformation effect. The design and development of well *P*1 is of guiding significance for the development of horizontal wells in low permeability reservoirs in the future.

Keywords: Horizontal wells · Long horizontal section · Ultra-low permeability reservoirs · Fracturing

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1 Introduction

The utilization rate of our main production reservoir has reached 94.0%. Therefore, as a replacement reservoir, the effective use of the F oil layer will affect the steady production of our crude oil. The F oil reservoir is characterized by poor geological conditions, low porosity, low permeability, small reservoir thickness, small throat radius, undeveloped natural fractures, low formation pressure, and ineffective water injection. The conventional horizontal well development can improve the contact area between wells and strata. However, the effective use of the unrecoverable reserves cannot be greatly improved. Therefore, long horizontal wells cooperate with volume fracturing in the way to realize the effective use of low permeability reservoir [1]. Since 2014, we have drilled six long horizontal wells with an average horizontal section footage of 873.8 m and an average drilling depth of 2954.2 m. Now take *P*1 well as an example to describe the detailed effect of long horizontal well cooperate with fracturing technology on the transformation of ultra-low permeability reservoirs.

2 Well Condition and Formation Conditions of Well *P*1

The target layer for well *P*1 is the F reservoir group. The designed drilling depth is 2915.0 m, the target depth is 1872.0 m, the horizontal section is 2014–2915 m, the footage is 901 m, and the sandstone is 819 m in total. The sandstone drilling rate is 90.9%. Oil immersion is 373 m, oil spot is 333 m, oil trace is 63 m, oil sandstone total is 769 m, and oil sandstone drilling rate is 85.35%.

The horizontal well path shows that the reservoir of this group is located in the F oil layer, and the lithology is dominated by siltstone, silt-bearing siltstone, and argillaceous siltstone, with good oil-bearing properties. A total of 53 layers are explained, of which eighteen I-1 tight oil layers, sixteen I-2 tight oil layers, eleven II-1 tight oil layers, six II-2 tight oil layers, and two dry layers. The construction situation and test results show that the flowback rate of fracturing fluid is low and also the reservoir yield. According to the analysis, the physical properties of the reservoir in this well are poor, and the single-slot modification model which controls the volume is small, and it is impossible to achieve a breakthrough in production capacity. An ultra-long horizontal well volume fracturing transformation mode is required. For the tight oil reservoir in this well, the concept of crack cutting and reformation is adopted. By increasing the scale of reform, improving the fracture conductivity and increasing the volume of reservoir control, the reservoir can be effectively transformed.

3 Field Test

In order to further verify the increase in the contact area between the fracture and the reservoir, the feasibility and applicability of the sand body volume design concept and supporting technology in the Fuyang oil zone are also verified. At the same time, the long-term stable production of the horizontal well and the elastic production period is improved. The fracturing construction scheme of well $P1$ was optimized from five aspects including fracture spacing, fracture length, flow conductivity, effective fracture support, and construction parameters.

3.1 Fracture Crack Spacing Optimization

The principle for the fractured section design is based on the geological reservoir division. The cracks should be arranged as far as possible in the areas with good oil and gas indications to ensure that the sweet spots are fully reformed, in order to ensure the effective extension and support of the layout cracks. The parameters such as fracture pressure, Young's modulus, and GR value, which affect the crack initiation and extension of the perforation point in the same section, must be as uniform as or close to each other. In order to reduce interlamellar strata and other issues, there must be a certain length of cementing quality between the fractures. The plug should be placed in a well cemented part; the perforation point and bridge plug location should avoid a certain distance from the coupling, at least 1 m.

According to the geology condition of the reservoir and the similarity in terms of physical properties and oil content, similar GR values, similar densities, and similar lithology, sand bodies are classified into tight layer I-1, I-2 and tight layer II-1, II-2. According to geological data, the permeability of the tight layer I-1 and I-2 is 0.3–1.37 mD, the permeability of the tight layer II-1 and II-2 is 0.01 mD, by comparing permeability and single-seam control the control width of the tight layer I-1 and I-2 is between 35 and 50 m, and that of the tight layer II-1 and II-2 is between 5 and 9 m. Considering the construction safety distance and the control range of the single joint, the perforation position was optimized according to the principle of the fracture layout of the ultra-long horizontal well and the logging interpretation results, and the fracture spacing was optimized. A total of 22 cracks in eight sections were designed in the horizontal well section of the $P1$ well (Fig. 1).

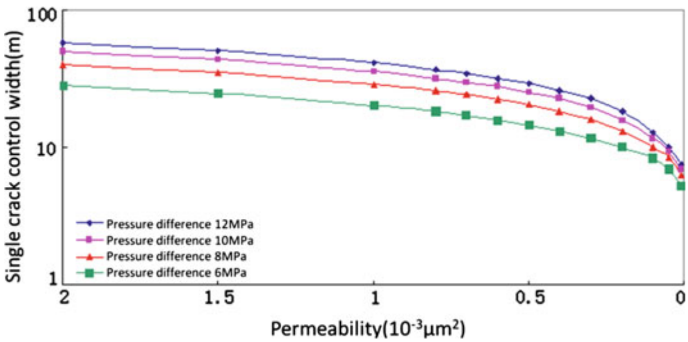

Fig. 1. Permeability and single-slit control width curves

3.2 Crack Length Optimization

According to the law of distribution of sand bodies, in order to achieve the matching of cracks and sand bodies, the length of cracks is optimized and the maximum sand body is used. The east side of *P*1 well is adjacent to the fault, and the distance between the wellbore and the fault is 190–316 m. Considering the condition of the sand body and the distance from the fault, the half-length of the fracture is designed to be 170–320 m. Considering the possibility of sand body change and gradual recognition, in the design of fracturing construction parameters, considering the fault distance around the *P*1 well and the width of the sand body of the river channel, half-length of the fracture is arranged. The impact of the construction was adjusted piece by piece in the later on-site implementation (Table 1; Fig. 2).

Table 1. Design slot length and production forecast after fracturing in well *P*1

Fractured section	Lift (m)	Right (m)	Fault distance	Design Half-length	Fracturing yield
1st	120	80	410	320	2.8
2nd	120	80	399	300	2
3rd	387	97	228	200	2.4
4th	466	103	190	170	2.2
5th	442	100	220	200	2.4
6th	422	54	240	220	2.6
7th	71	127	312	280	3.2
8th	85	108	316	280	3.1

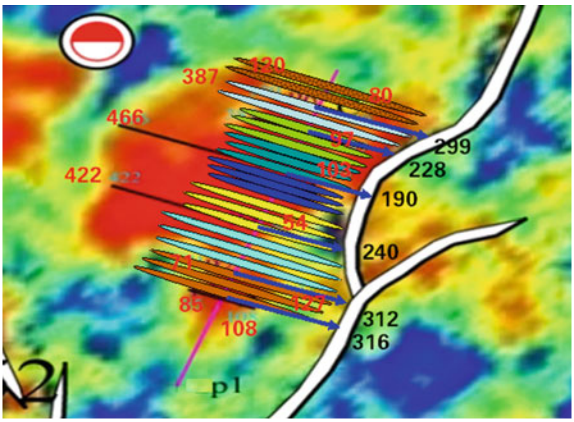

Fig. 2. *P*1 sand body distribution and slot length optimization

3.3 High-Pressure Crack Optimization

The drilling layer of well $P1$ was located at the FI6 layer of the well H3 which is the neighboring well. The target layer had a stress of about 2 MPa and the difference between the GR values of the storage layer reached 51API, and there was a certain lithology block. According to the crack stress and gap spacing and segment spacing formula:

$$F = 1 - x^3\left[x^2 + \left(\frac{h}{2}\right)^2\right]^{-3/2}$$

Substituting the optimized segment spacing and crack spacing, the crack stress interference was calculated. When crossing the fracture, if $dx/H > 2$, the flow resistance is lower, if $dx/H > 2$, the slit width is larger; when there is the longitudinal crack, if $dx/H > 2$, the slit width is larger. According to the simulation of stress disturbance and the seepage distance under different permeability, the height of the adjacent well is about 7–10 m.

3.4 Fracturing Construction Parameter Optimization

I. Fracture cracks conductivity optimization

Through simulation studies, because of the low demand for fracture conductivity in low permeability reservoirs and the permeability range of this well, the optimal flow conductivity range is 3.5–26 μm^2 cm. Considering factors such as proppant embedding, the design range is 16– 25 μm^2 cm (Table 2).

Table 2. Matching matrix permeability and optimum fracture inducing capability

Permeability ×10^{-3} μm^2	Fracture conductivity μm^2 cm
0.3	3.5
0.5	6.5
1.0	22.0
1.5	26.0
2.0	35.0
2.5	40.0
3.0	50.0

II. Fracturing fluid optimization

According to the surrounding construction conditions of neighboring wells, it is determined that the conventional fracturing fluid formulation system is adopted for well $P1$. According to the prediction of adjacent wells, the formation temperature of well $P1$ is predicted to be 86.3 °C. Considering the safety of construction, a fracturing fluid system of 90 °C is recommended for the pre-flush stage. Using Fracpt software simulation and previous well temperature measurement data, the temperature of the reservoir can be reduced to below 60 °C after injection of the pre-liquid. In order to reduce the cost of fracturing fluid, it is recommended to use a 60 °C fracturing fluid system for the sand-carrying fluid, which requires the fracturing fluid to adhere to more than 50 cp. Considering the difference between on-site liquid quality and laboratory experiments, the ratio of pre-liquid tannin glue was initially set at 0.36%, and the ratio of sand-carrying liquid tannin glue was initially set at 0.32% (Fig. 3).

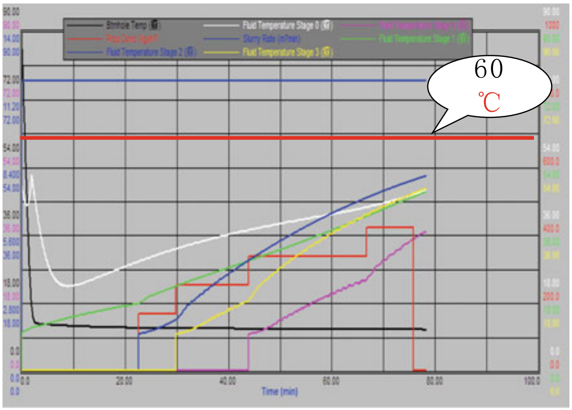

Fig. 3. Temperature simulation curve

The actual ratio of field fracturing fluid was determined based on the on-site test results. Considering that the temperature in spring and autumn and winter is low, the fracturing fluid has a long shelf life. Considering the cost reduction requirement, no stabilizer is added to the fracturing fluid in spring and autumn.

Based on the optimization of the above parameters, according to the different conditions of the Stratosphere, the reasonable scale of the safety reconstruction of the fracturing construction, the maximum sand ratio, and the construction time are given through the project risk assessment. The stimplan fracturing geological model was used to determine the sanding scale, construction displacement, construction sand ratio, and pre-liquid ratio. Through the combination of design and on-site construction, *P*1 well fracturing accumulatively adds 527 m^3 of sand, 6720 m^3 of construction liquid, 46m^3 of acid, and includes 4 m^3 of 40–70 mesh ceramsite, slick water 600 m^3, fracturing fluid 6120 m^3, predicted output about 20.7 t/d.

4 Tracking Evaluation of Fracturing Effect

In the staged fracturing process, different types of indicators are selected for different reservoirs to follow the fluids in and out of the reservoir and carry fluid information [2]. The indicators are classified, purified, analyzed, and processed [3] to obtain relevant information. By analyzing the fluid production of each reservoir, it is possible to evaluate the flowback of each stage. The fluid production profile at the initial stage of production can be evaluated by analyzing the fluid produced during the stationary period of each reservoir. Through the contribution rate of each reservoir, that is, the regular solution of each section of liquid, the engineering problem must be solved. Combine the geological conditions, the contribution rate of the reservoir, and the indicator recovery rate to comprehensively evaluate the effect of fracturing.

In order to realize the follow-up evaluation of the fracturing effect, the indicator is introduced into the well and the type, model, amount, and dosing method of the indicator are designed according to the characteristics of the fracturing interval.

Analyze the sampled samples to evaluate the effect of fracturing (Table 3).

Table 3. Fracture transformation effect of well *P*1

No.	Perforation	Log	Indicator evaluation			
			Recovery	Contribution	Indicator	Effect
1st	22	I-2	28	6.4	minor	medium
2nd	22	II-2	39.3	8.3	minor	medium
3rd	24	I-1	53.2	12.4	minor	medium
4th	24	I-2	57.4	14	major	good
5th	24	I-1	61.9	16.1	major	good
6th	24	I-1	58.7	16.5	major	good
7th	24	I-2	49.2	15.2	major	good
8th	24	II-1	33.2	11.1	minor	medium

5 Understanding and Suggestions

The field test of well *P*1 further validates the concept of increasing the contact area between the fracture and the reservoir, and the feasibility of using the design concept of the volume of the sand body and the supporting process in the F oil layer. It is of great significance to the effective utilization of the F layer.

References

1. Dong J, Guo N, Sun B, et al. Application of segmental fracturing technology in horizontal wells in the development of low-permeability oilfields. Petrol Drilling Technol. 2013, 41, pp. 115–9.

2. Jin ZJ. Application of tracer detection yield evaluation technique and application in horizontal wells. Well Testing, Aug 2015, pp. 15–8.
3. Zhang HJ. Using LWD and tracer techniques to analyze the characteristics of fractured sections in horizontal wells of tight reservoirs. J Yangtze Univ, Nov. 2016, pp. 21–3.