Study on Reasonable Injection-production Well Spacing and Well Pattern Deployment in Low Permeability Oilfield

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Abstract: Aiming at reservoir conditions and geological characteristics of low permeability oilfield, this paper elaborates on factors influencing rational injection-production well pattern, determination principle of well pattern spacing, selection principle of reasonable well pattern, how to optimize well pattern and well layout, and finally optimizes reasonable injection-production well spacing and well pattern deployment method. Good results have been obtained by experiments.

1. Introduction

For exploitation of low permeability oilfield water injection way, reasonable injection-production well spacing and well pattern deployment method is vital for mining effect. until the 1990s, the United States Russia and other countries studying of common conclusion of low permeability oil and gas field development for many years is, must adopt dense well pattern, effective displacement of reservoir oil. and since then, horizontal open hole fracturing has been successfully implemented in the United States in the development of low permeability oil and gas resources. The thin well pattern and strong oil displacement are realized. Infill well pattern tests have been carried out in low permeability oilfields in China, and reasonable infill patterns for different types of reservoirs and combinations of well patterns with different fracture orientations and well row directions have been proposed.

2. Pattern Spacing for Low Permeability Oilfield Development

2.1 Factors Influencing Rational Injection-production Well Pattern

Reasonable well pattern should not only meet the requirements of small reserve loss, high final recovery rate, high oil recovery rate and better development effect, but also achieve better economic benefits. Based on the specific analysis of the actual situation of oil fields in China, the factors influencing the reasonable well pattern of low permeability oil fields mainly include the following aspects [1].

2.1.1 The Water Driving Control Degree

Generally, low permeability reservoir sand body has a small distribution range and poor connectivity, so it is necessary to use a small well spacing and a large well pattern density to improve the connectivity between Wells. The degree of water flooding control directly affects the degree of water flooding control of reservoir water flooding recovery well pattern depends on the size of well spacing of injection-production system and the distribution range of sand body.

2.1.2 Rate of Oil Production

Oil field should be produced during facilities intact recoverable reserves of main parts, well pattern type must meet the requirements of the basic oil production rate. Generally, low permeability oil fields have many times of operation and great strength, and the damage rate of oil and well is also large. The development time of main recoverable reserves is not too long, and the

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natural productivity is low. The oil recovery speed of oil reservoirs is easily restricted by the well pattern. The main factor that affects the oil recovery rate of well pattern is the injection and production intensity of well pattern. With the increase of well pattern density and injection-production well ratio, the oil recovery rate increases correspondingly.

2.1.3 Injection-production Strength

Area water injection is often used to develop low permeability oil fields [1][5]. Area water injection refers to the water injection well and oil well according to a certain geometric shape and density evenly arranged in the entire development zone for water injection and oil, the essence is to divide the field into many smaller units.

2.2 Determination Principles of Well Spacing and Well Pattern

According to the actual situation of X reservoir test area [2], the following design principles of well spacing are formulated:

The adjusted well pattern should be regular and uniform as far as possible, which is easy for oil and well production and injection distribution, and easy to control injection-production relationship.

The adjusted well pattern should be conducive to maintaining the reasonable pressure system in the test area and the uniform effect of each well group.

The adjusted well pattern should ensure as many central production Wells as possible，Single well controlled reserves are easy to calculate，It is helpful to evaluate the effect of field test.

Compared with the whole oilfield, the test results of the adjusted well pattern are relatively representative, and the well pattern has a good connection with adjacent wells in the expansion of the well pattern, which is conducive to further popularization and application.

2.3 Selection Principles of Reasonable Pattern

Whether a well pattern is suitable for oilfield development depends on three aspects:

(1) Taking full advantage of the high oil recovery rate in the early development stage of area well pattern, the water-free oil recovery period can be extended as far as possible to improve the oil recovery rate in the early development stage.

(2) Higher final recovery was obtained.

(3) Well pattern system has greater flexibility for later adjustment.

For low permeability reservoirs, it is necessary to consider the economic [2] rationality of single well control reserves and the development of the whole oilfield, the well pattern should not be too dense, the pressure transfer relationship between injection well and production well should not be taken into account, the injection and production well spacing should not be too large, and the directional water channeling and water flooding time should be delayed to the greatest extent.

3. Well Pattern Optimized Design

3.1 Reasonable Well Pattern

Area well pattern is widely used in low permeability oilfields at present [5], and it is determined whether square triangle or rectangular well pattern is used according to the degree of fracture development. From the experience of developing low permeability oil reservoirs in China in recent years, rectangular injection well pattern is the most widely used well pattern. Rectangular well pattern development can enlarge well spacing, reduce row spacing, reduce starting pressure gradient, and establish effective driving system. It is an effective well pattern for the development of ultra-low permeability reservoirs.

In the case that the well pattern density is the same, the rectangular well pattern reverses the nine-point water injection method, and according to the characteristics of faster seepage velocity of reservoir along the fracture direction, the well spacing along the fracture direction is enlarged and the row spacing is correspondingly reduced, in order to avoid the square area of well pattern by nine issues during development process [4]. water injection well spacing widened at development time

can be appropriately increase after fracturing scale and delayed after waterflood Wells well water breakthrough time, row spacing, the reduced oil and water Wells can reduce filtrational resistance, improve the ability of oil well row of Wells for liquid, but as a result of oil and water Wells in fracture azimuth at the same time, there is still a directional see along the fissures, water issues timely fill the linear transformation based on water status, the linear turns at the same time can implement. Therefore, the rectangular linear well pattern is adopted in the test area for the development of the ultra-low permeability reservoir [6].

3.2 Well drainage direction

Due to the directional fracture reservoir, increased the heterogeneity of reservoir, Thus, the non-uniformity of reservoir oil and water movement is increased in waterflood development. The coexistence of artificial and natural fractures in ultra-low permeability reservoirs results in the heterogeneity of reservoir plane. Natural fractures have low permeability because they are closed under stratigraphic [6] conditions. However, the permeability of artificially supported fractures can reach several darcys, and it is mainly artificial fractures that play a controlling role in reservoir seepage capacity. Therefore, the configuration and optimization of low permeability reservoir well pattern is mainly the configuration and optimization of artificial fracturing well pattern.

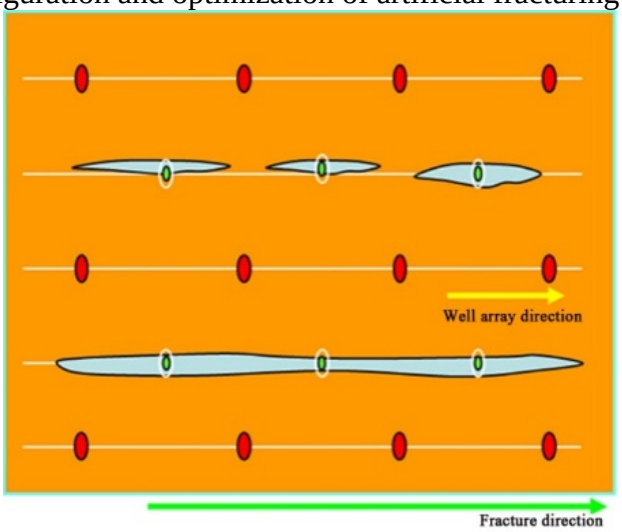

Fig.1.Schematic diagram of well pattern and fracture system

3.3 Well Array and Well Pattern

3.3.1 Well Pattern

In order to ensure that the economic benefits of reservoir development, single well control area and spacing is as large as possible. But the spacing is too large, on the one hand can't meet the requirements of the construction of a productivity, on the other hand, ultimate recovery would also be affected. if the spacing is too small, will increase the cost of development on one hand, on the other hand, will cause the inter well interference, cause short production plateau. In order to control the sand body effectively, the maximum well spacing should be controlled within the horizontal development scale of the sand body [3].

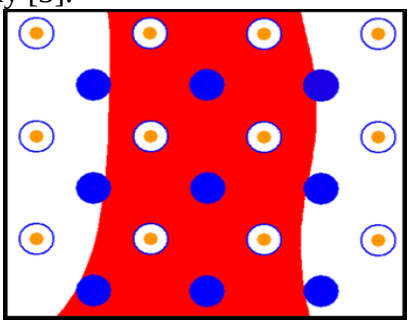

Fig.2.Schematic diagram of well pattern and sand body

3.3.2 Well array

Due to the low permeability reservoir, if the row spacing is too large, it can't afford to build effective drive system, water injection development characterized by low single-well production, decreasing amplitude is large. To improve the development effect, we must first solve the problem of effective driving system. The starting pressure gradient should be taken into account when calculating the reasonable spacing of well pattern deployment. The following test algorithm can be used to calculate the limit spacing of injection-production under the condition of given injection-production pressure difference and reservoir permeability [5].

$$\frac{P_H - P_w}{\ln \frac{R}{r_w}} \cdot \frac{2}{R} = \lambda \tag{1}$$

4. Formation Pressure under Different Injection-production Ratios

Other conditions being the same, the pressure maintenance level under different injection-production ratios was compared by changing injection-production ratio. In this scheme, 7 schemes with injection-production ratio of 1.0~1.6 were simulated.

Scheme 1: injection-production ratio 1.0; Scheme 5: injection-production ratio of 1.1; Scheme 6: injection-production ratio of 1.2; Scheme 7: injection-production ratio of 1.3; Scheme 8: injection-production ratio of 1.4; Scheme 9: injection-production ratio 1.5; Scheme 10: injection-production ratio 1.6. Simulation results are shown in Fig. 3 to Fig. 4.

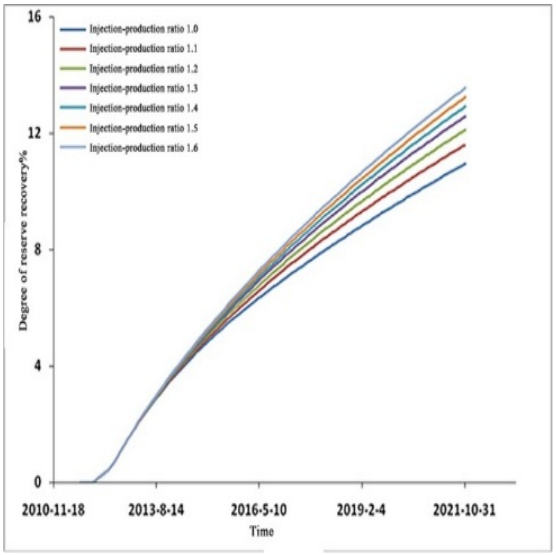

Fig.3. The comparison curve of different injection-production ratio and the degree of reserve recovery

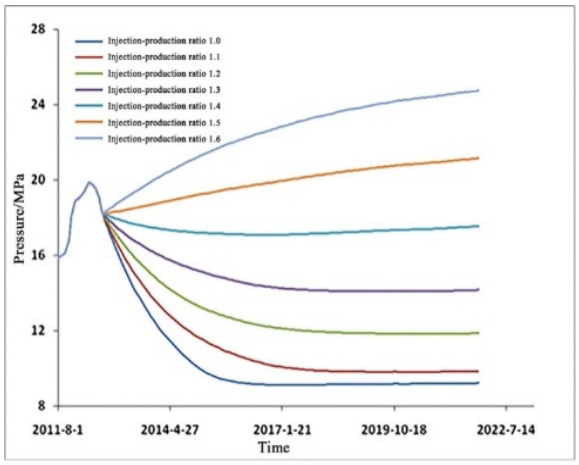

Fig.4. The pressure comparison curve of different injection-production ratio

According to the simulation results of the above 7 schemes, the final recovery degree in ten years and the pressure value at the relative maintenance level of the final pressure under different injection-production ratios were respectively calculated, as shown in Table 1.

Table.1. The recovery degree and pressure value corresponding to different injection-production ratios

Injection-production ratios	Degree of reserve recovery /%	Pressure value /MPa
1.0	11.06	9.22
1.1	11.72	9.85
1.2	12.23	11.87
1.3	12.70	14.17
1.4	13.04	17.54
1.5	13.38	21.16
1.6	13.69	24.76

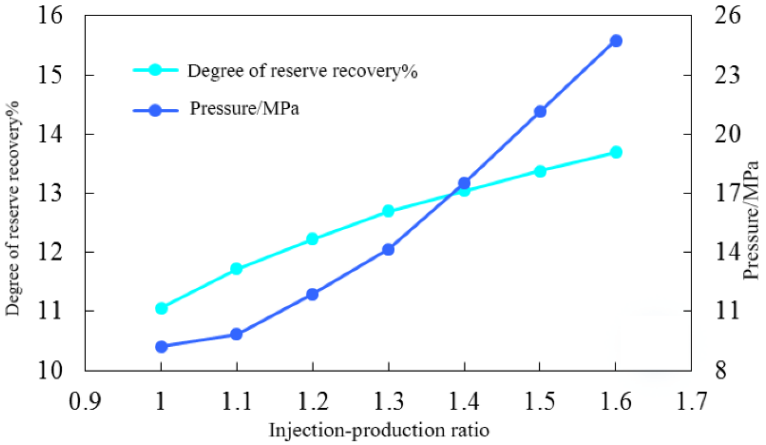

Fig.5. The relationship curve between different injection-production ratios and recovery degree and the pressure

Figure.4-5 and table 1 show that, with the increase of injection-production ratio, the degree of reserve recovery has increased at the same time, stress level has also grown, the pressure rises quickly when injection-production ratio greater than 1.4, pressure drops quickly when injection-production ratio is less than 1.4, and the degree of reserve recovery changes slowly when the injection-production ratio greater than 1.4.Finally,it follows that the injection-production ratio of 1.4 is the best choice, corresponding to the formation pressure of 17.54 MPa which is 1.10 times of the original formation pressure.

5.Conclusion

Rectangular linear injection well network has the highest degree of production and low water content in the past decade. Therefore, the rectangular linear water injection scheme is more conducive to long-term exploitation of oil fields.

The degree of water drive control, oil recovery speed and injection-production intensity are the factors influencing the reasonable injection-production well pattern. The configuration and optimization of low permeability reservoir well pattern is mainly the configuration and optimization of artificial fracturing well pattern.

The numerical simulation results of formation pressure under different injection-production ratios show that when the injection-production ratio is 1.4, the corresponding formation pressure is 17.54 MPa, which is 1.10 times of the original formation pressure. This can greatly avoid or reduce the formation damage caused by the decrease of formation pressure, which is more beneficial to the long-term efficient and stable production of oil field.

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