Prediction Methods About Development Condition of Horizontal Well Section

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Keywords: Well testing, numerical well testing, reservoir engineering method, development condition.

Abstract: With the advancement of drilling technology, in order to meet the demand of special oil reservoirs, horizontal well has become an advanced and important technology to develop oil and gas fields and improve recovery. However, in the process of the development of oil and gas fields with horizontal wells, the unbalanced development condition of horizontal wells severely restricts the exploitation results of horizontal well. At present, optical fiber testing is carried out in the field to obtain the development condition of the horizontal well section. However, this method leads to costly expense and requires prefect well statues. Therefore, this paper presents a prediction method about the horizontal well section development condition. The way of the well testing and reservoir engineering method were adopted. This method makes the most of the dynamic data and static data to ensure the correctness of the result. And this method is low-cost and high-precision, which can provides a basis for large-scale the evaluation of the potential, the next development and deployment of the oilfield.

1 INTRODUCTION

Horizontal well development technology has been widely adopted in various kinds of reservoirs. It plays an effective role in the construction of new oil fields and the adjustment of old oil fields. According to the actual data of oil field, the development condition of horizontal well section has great influence on reservoir development. At present, the analysis of the horizontal section development condition is only limited to heavy oil reservoirs, since it obtains the development condition of horizontal well section by temperature distribution along the wellbore, in the process of thermal recovery for heavy oil reservoir. Therefore, providing a set of effective methods to obtain the development condition of horizontal well section is necessary（Joshi,1991）.

First of all, well testing method is adopted in this method to obtain the effective development length, geological parameters of horizontal wells and dynamic development parameters. Subsequently, to verify the correctness of the well testing, the horizontal well productivity formula is applied to calculate the effective development length. Finally, the numerical well testing model is proposed to establish the geologic model of the well circumference which is used to simulate the development of the block where the target well is located. By combining well testing method with reservoir engineering methods, the development condition of horizontal well section of the target well is obtained.

2 ANALYSIS

A horizontal well (called well A) in edge water reservoir is studied in this paper. The development condition of this horizontal well is obtained. The basic data of the well is shown in Table 1.

Table 1 Parameters of the well A

Porosity（%）	30.0	volume factor	1.060
Thickness（m）	4.5	Viscosity（cp）	9.46
Wellbore radius（m）	0.062	Compressibility (psi-1)	$1.283*10^{-5}$

Zhao, F., Zhang, Y. and Li, D.
Prediction Methods About Development Condition of Horizontal Well Section.
In *3rd International Conference on Electromechanical Control Technology and Transportation (ICECTT 2018)*, pages 72-76
ISBN: 978-989-758-312-4

2.1 Conventional well testing

Two sets of well test data from well A in August 2008 and June 2016 are analysed by the conventional well testing methods. The results of well testing including initial formation pressure, well storage coefficient, skin coefficient, effective permeability, the ratio of vertical permeability and radial permeability, effective development length are shown in Table 2. The curve fitting of conventional well testing are shown in Fig 1,and Fig 2. By conventional well testing, the horizontal section effective development length of well A are 178 m and 180.4 m, respectively.

Table 2 Results of well test about well A

	August 2008	June 2016
initial formation pressure（MPa）	11.3621	9.4533
well storage coefficient（m^3/MPa）	11.1	2.31
skin coefficient	-6.73	-6.08
k_z/k_r	0.342	0.011
effective permeability (md)	240	56.4
effective utilization length (m)	178	180.4

Analysis of the well test data from August 2008

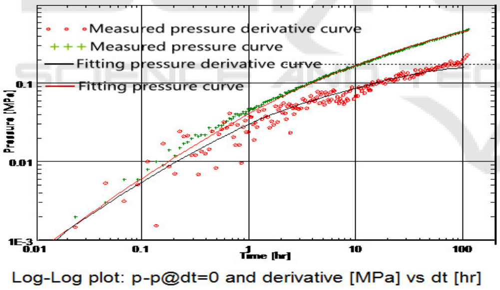

Figure 1 Log-Log plot：pressure and pressure derivative curve

Analysis of the well test data from June 2016

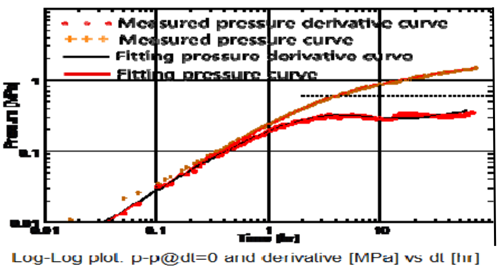

Figure 2 Log-Log plot：pressure and pressure derivative curve

2.2 Reservoir engineering method

2.2.1 Borisov

In 1964, the Soviet scholar Borisov system studied the seepage principle of horizontal well. He divides the three dimensional seepage field around the horizontal well into internal seepage field and external seepage field. Assuming that the horizontal well is located in the middle of the top-bottom closed oil layer, the fluid flow is steady-state and the fluid is incompressible in the formation. The pressure drop in the wellbore was ignored in this formula. According to the quasi-3D method obtain the horizontal well yield formula, Laid the foundation for two-dimensional steady-state analysis of horizontal well productivity（Joshi, 1988）.

$$q = \frac{0.543Kh}{\mu_o B_o} \frac{\Delta P}{\ln \frac{4r_{eh}}{L} + \frac{h}{L} \ln \frac{h}{2\pi r_w}} \qquad (1)$$

$$r_{eh} = \sqrt{A/\pi}$$

2.2.2 Giger

In 1984, Giger applied the equivalent radius instead of the semi-major axis of the horizontal elliptic area. And derive the production formula for homogeneous isotropic reservoir under the steady-state（Giger, 1985）（Giger， Reiss and Jourdan, 1984）.

$$q = \frac{0.543Kh}{\mu_o B_o} \frac{\Delta P}{\ln \left[\frac{1+\sqrt{1+\left(0.5L/r_{eh}\right)^2}}{0.5L/r_{eh}} \right] + \frac{h}{L} \ln \frac{h}{2\pi r_w}} \qquad (2)$$

2.2.3 Guo Baoxi

Assuming that the reservoir is a circular, closed, anisotropic and top-bottom closed formation. The horizontal well section is 2L.The reservoir thickness is h. The horizontal wellbore radius is r_w. The horizontal well section is located at the distance z_w from the bottom of the reservoir. The horizontal well is located horizontally in the center of the reservoir .Setting the amount of liquid production q, derived horizontal well productivity formula from the edge water reservoir.(Guo, Wang and Luo, 2007.)

$$q=\frac{K_h h \Delta P}{1.842\mu_o B_o F_{sse}} \quad (3)$$

The reservoir engineering method is used to calculate the effective development length of the horizontal section of well A in September 2016. The results of the three formulas are 164m, 165m and 177m respectively, as shown in Table 3. The results match conventional well testing. By comparing conventional test method and reservoir engineering method, the effective length of the well is about 170m, and the total length of the horizontal well is 279m. Therefore, the length of the undeveloped horizontal well section is about 100m. The comparison of traditional well test method and reservoir engineering method is shown in Table 3.

The reservoir engineering method is applied to verify the accuracy of well testing method. But the effective development length of the horizontal section is high sensitivity for multiple parameters in the productivity formulas. Such as, yield, permeability and reservoir thickness. Reservoir engineering method can only be used as a validation method, therefore, cannot be directly used to calculate the development condition of horizontal well section.

Table 3 Results of conventional well testing and reservoir engineering

	conventional well testing	Borisov	Giger	Guo Baoxi
June 2016	180.45m	164.38m	165.17m	176.69m

2.3 Numerical well testing

Numerical well testing method is a new well testing interpretation technique developed in recent years. The technology has absorbed the mature technology of reservoir numerical simulation to describe the properties of complex reservoir. Such as describing the change of formation fluid properties, reservoir thickness distribution, seepage condition heterogeneity and reservoir special outer boundary shape, etc. The high precision pressure gauges were adopted in the field, which provides an effective technical support for the dynamic description of well testing in heterogeneous reservoirs（Ding, Onur and Reynolds, 1989）（Al-Zayer, Mesdour, Al-Faleh, Basri and Utaibi, 2013）.

In fact, the numerical well testing is a fine numerical simulation of a well group or a flow unit of injection and production. Compared with the conventional well testing, it has the characteristics of small hypothesis, large scale and the influence of the neighboring well. Therefore this technology is more suitable for the seepage of the actual reservoir development characteristics. It can better solve problem of the multiphase flow, multi-well interference, complicated boundary and heterogeneity which can't be solved by the conventional well testing. Numerical well testing can determine formation pressure, reservoir parameters and under multi-well system, which can provide the basis for the adjustment of injection-production structure and the measures for the excavation（Frick, Brand, and Schlager, 1996）（Al-Mohannadi, Ozkan, Kazemi H, 2007）（Al-Thawad， Issaka and Aramco, 2003）.

In order to obtain the development position of the horizontal well, numerical well testing method is applied to obtain the pressure distribution and the saturation distribution in the block where the target well is located. Firstly, based on the formation parameters and fluid parameters of well A, the Saphir was applied to establish three-dimensional geological model. The geological model was loaded with production data to establish a production model. Then, the model was used to simulate the production status from the well put into production to August 2008. Adjust the model parameters by fitting the log-log curve of reservoir pressure and pressure derivative which obtained from the well test data simulated by the model and the field test well data. Pressure fitting curve is shown in Fig 2, and Log-Log fitting curve is shown in Fig 3.

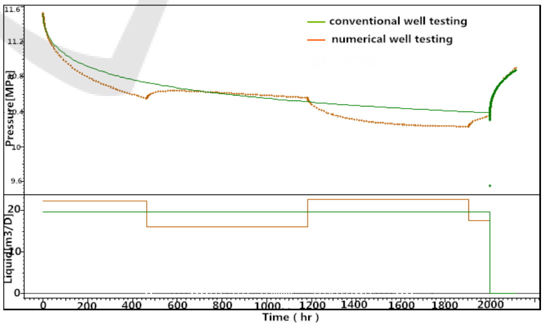

Figure 2 Pressure fitting curve

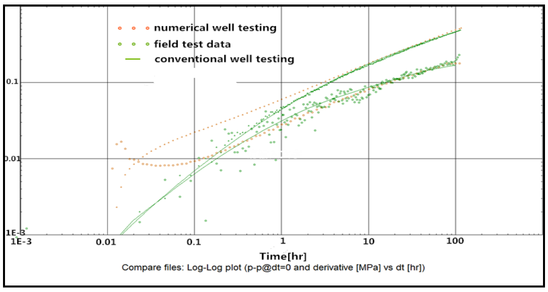

Figure 3 Log-Log fitting curve：pressure and pressure derivative curve

The adjusted model was used to simulate reservoir development performance from the well put into production to June 2016. The pressure distribution and the saturation distribution obtained by numerical well testing method were shown in Fig 4 and Fig 5, respectively. The water saturation distribution is shown in Fig 6. The water saturation across well A section is shown in Fig 7.

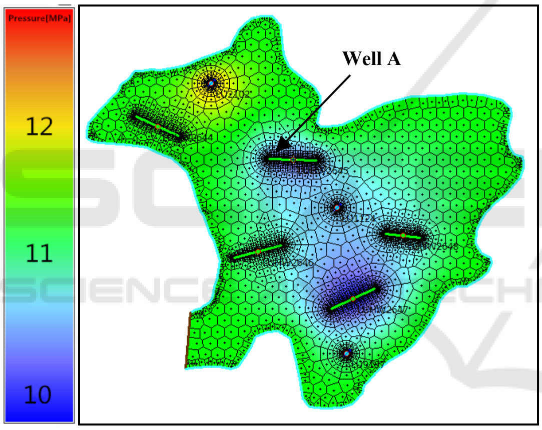

Figure 4 Pressure distribution

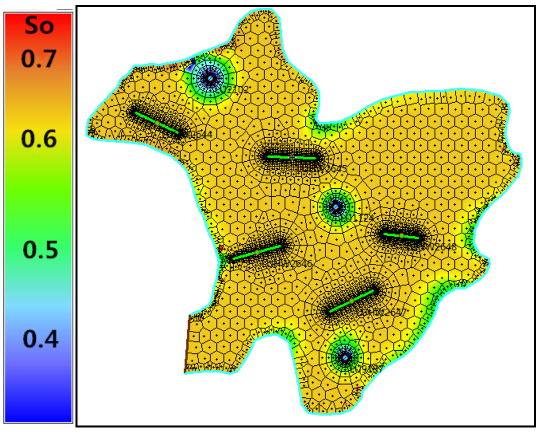

Figure 5 Oil saturation distribution

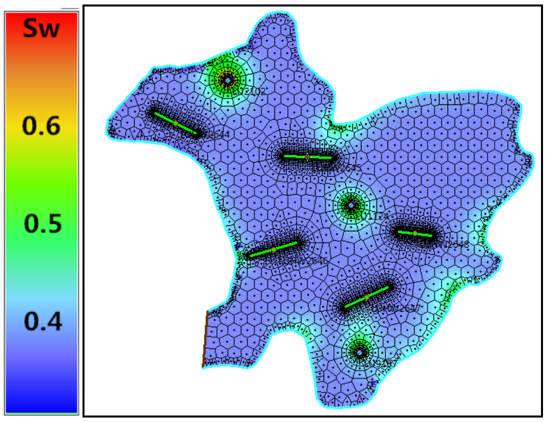

Figure 6 Water saturation distribution

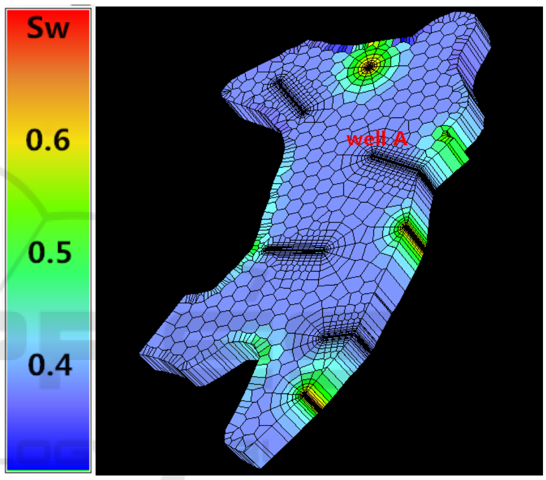

Figure 7 Water saturation across well A section

The simulation results of the numerical well testing show that the energy supplements of well A is mainly from the water injection on the right and the edge water. Water breakthrough has happened in the finger tip of horizontal section.

3 CONCLUSIONS

(1) Compared with the results of conventional well testing and reservoir engineering method, the effective use length of the well is about 170m. The total length of horizontal well is 279 m. Therefore, the horizontal section of the well about 100m has not been utilized.

(2) Numerical well testing simulation shows that the water breakthrough in the finger tip of horizontal section. It is the main segment of producing.

(3) Combining the two methods, it can be seen that the heel of the horizontal well section is poorly developed.

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