Formation pressure prediction technology of infill point in low permeability oilfield

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Abstract. Poor reservoir physical property which leads to low rate of water injection pressure decline after the shut-in because of drilling control is the main characteristic of Daqing peripheral oilfields. To reduce reservoir energy loss, ensure the effect of infilling well, it is necessary to study the formation pressure of infill well point. However, there is no formation pressure prediction formula for infill well point in low permeability reservoir. In this article, combined with detailed reservoir description results, the effective characteristics of formation with different permeabilities are analyzed, the range of effective displacement permeability are defined, and the formation pressure of infill well point is calculated based on reservoir engineering method. Meanwhile, according to the actual injection pressure, produced liquid volume and partial static pressure data, numerical simulation pressure prediction is presented to simulate infill well point pressure. Considering to both prediction results, formation pressure at infill well point can be determined. Field test verifies that the predicted pressure is close to the actual pressure with an error rate within ±10%, wells with pressure coefficients less than 1.80mpa/100m can be drilled, and those with the pressure coefficients greater than 1.80mpa/100m, drilling should be processed after depressurization.

Key word: Low permeability, Formation pressure, Pressure prediction.

1. Introduction

Drilling control and depressurization standard of Daqing Oilfield "If the water injection pressure of the well is within 2.0MPa, and the water injection pressure of the water injection well is within 600m, the well can be drilled" Suitable for Daqing plasticine medium high permeability oilfield. But Daqing peripheral low permeability oil field, due to poor physical properties of reservoir, it is difficult to establish an effective displacement system between oil and water wells [1], slow pressure drop after drilling control and shut in of water injection well, after extended shut in time, decrease of liquid supply capacity of surrounding oil wells, formation pressure drop, seriously affect the development effect, therefore, it is necessary to explore a reasonable standard of drilling control and pressure reduction.

Taking a certain oilfield in the periphery of Daqing as an example, controlling and shutting in 79 water injection wells around the infill well, due to poor physical properties of reservoir, slow drop of water injection pressure after shut in, drilling for 14 months, water injection pressure drops from 14.4mpa...
to 9.1mpa, water injection pressure drop rate 0.35mpa/month, it is estimated that drilling conditions can be reached after 2 years and 6 months of drilling control shut in well. Affected by long shut in time, the liquid supply capacity of the surrounding oil wells decreased significantly, liquid production capacity of 86 oil wells in drilling control area decreased, daily oil production decreased from 51.1t to 39.1t; according to drilling control shut in pressure drop rate, it is estimated that 4311t oil production will be affected during drilling and shut-down period; the formation pressure level in the block continues to decline, from 10.52Mpa before shut in to 10.14Mpa, with the drilling time further extended, aggravation of formation degassing, it will seriously affect the effect of infill wells and the overall development level of the oilfield.

There are many methods to calculate the inflow performance of oil wells in low permeability reservoirs, however, these ones here is not adaptable to the prediction of infill well pressure [2]. By using reservoir engineering method and reservoir numerical simulation method, the pressure distribution in the remaining oil enrichment area of the adjustment well to be drilled and the pressure prediction value with high accuracy can be obtained [3].

2. Reservoir engineering method formation pressure prediction

Application of pressure distribution formula of plane radial flow [4]:

\[
P = P_e - \frac{P_e - P_w}{\ln \frac{R_e}{R_w}} \ln \frac{R_e}{r}
\]

(1)

The meaning of symbols in formulas: \( P \) — Pressure at any point in the formation, MPa/m;
\( P_e \) — Supply boundary pressure, MPa;
\( P_w \) — Bottom hole flow pressure of production well, MPa;
\( R_e \) — Supply radius, m;
\( R_w \) — Wellbore radius, m;
\( r \) — Distance between infill well and basic well pattern, m;

Considering whether to establish effective displacement for reasonable optimization of supply boundary pressure. Effective displacement can be established for the main layer, the point pressure of water injection well be selected for calculation; failed to establish effective displacement, the supply end pressure \( P_e \) be calculated applying the average formation pressure formula (formula 2) of seepage mechanics(formula 3).

Calculation formula of average formation pressure:

\[
\bar{P} = P_e - \frac{P_e - P_w}{2 \ln \frac{R_e}{R_w}}
\]

(2)

The meaning of symbols in formulas: \( \bar{P} \) — average formation pressure, MPa/m;

Application formula 3, the formation pressure at the supply end can be obtained:

\[
P_e = \frac{2 \ln \frac{R_e}{R_w} \bar{P} - P_w}{2 \ln \frac{R_e}{R_w} - 1}
\]

(3)
3. Numerical simulation pressure prediction

Application of fine reservoir description results, carry out numerical simulation to predict formation pressure in an oilfield [5], the grid accuracy on the plane is 60m×60m. Vertically, taking a sedimentary unit as a simulation layer, 15 simulation layers are divided. The total number of geological models established is 66×122×15 = 120780.

There are three steps in the application of numerical simulation to the pressure prediction of the block:

First, based on the historical fitting of the model, according to the actual pressure data of oil wells around infill wells, the liquid production of oil wells under the measured pressure be simulated.

Secondly, according to the difference between the simulated liquid production and the actual liquid production of the oil well around the infilling well, carry out comparative analysis, the injection pressure of water injection well under the simulated production is calculated.

Last, application of calculated injection pressure, the pressure at the infill well point be simulated.

From the results of numerical simulation, the average formation pressure of infill well point 18.72mpa be predicted, average formation pressure coefficient 1.39mpa/100m.

Comprehensive reservoir engineering method and numerical simulation prediction, there are 14 wells with pressure coefficients less than 1.6mpa/100m, there are 13 wells with pressure coefficient between 1.6mpa/100m and 1.8mpa/100m, 5 wells with pressure coefficient greater than 1.8mpa/100m.

4. Field test results

MDT test results show that the predicted pressure is close to the actual pressure, the average formation pressure of 5 wells tested is 20.79mpa, the error rates of reservoir engineering predicted pressure and numerical simulation predicted pressure are -5.13% and -5.14% respectively.

| Classification of pressure coefficient | Infill well number | Formation pressure (Mpa) | Pressure difference (Mpa) | Error rate (%) |
|----------------------------------------|--------------------|--------------------------|--------------------------|---------------|
|                                        | Measured           | Reservoir engineering prediction | numerical simulation | Reservoir engineering prediction | numerical simulation | Reservoir engineering prediction | numerical simulation |
| < 1.60                                 | Well No.1          | 20.22                    | 18.46                    | 21.7          | -1.76          | 1.48           | -8.70          | 7.32          |
|                                        | Well No.2          | 18.62                    | 16.48                    | 18.6          | -2.14          | -0.02         | -11.49         | -0.11         |
| 1.60-1.80                              | Well No.3          | 21.10                    | 21.17                    | 16.3          | 0.07           | -4.8          | 0.33           | -22.75        |
| 1.60-1.80                              | Well No.4          | 21.90                    | 19.45                    | 23.4          | -2.45          | 1.5           | -11.19         | 6.85          |
| 1.60-1.80                              | Well No.5          | 22.10                    | 23.05                    | 18.6          | 0.95           | -3.5          | 4.30           | -15.84        |
| Average                                |                    | 20.79                    | 19.72                    | 19.72         | -1.07          | -1.07         | -5.13          | -5.14         |

The converted maximum pressure of drilling fluid density is equivalent to the predicted pressure. Preliminary test, the drilling fluid density of the three wells tested in advance is 1.45-1.50g/cm³, no spraying and leakage during construction, the highest converted formation pressure is 20.22MPa, 20.38MPa and 20.17MPa, close to the predicted pressure.
Table 2. Comparison between converted pressure and measured pressure of drilling fluid

| Infill well number | Formation pressure (Mpa) | Pressure difference (Mpa) | Error rate (%) |
|--------------------|--------------------------|--------------------------|----------------|
|                    | Measured                 | Reservoir engineering prediction | numerical simulation | Measured | Reservoir engineering prediction | numerical simulation | Measured |
| Well No.1          | 20.22                    | 18.46                    | 21.7            | -1.76    | 1.48                          | -8.70                  | 7.32     |
| Well No.6          | 20.38                    | 18.39                    | 19.5            | -1.99    | -0.88                        | -9.76                  | -4.32    |
| Well No.7          | 20.17                    | 18.42                    | 23.3            | -1.75    | 3.13                          | -8.68                  | 15.52    |
| Average            | 20.26                    | 18.42                    | 21.50           | -1.83    | 1.24                          | -9.05                  | 6.14     |

30 wells have been drilled and put into production by using this pressure prediction technology in a certain oilfield outside Daqing. The time of drilling ahead 13 months, less overflow 1833700m³; The time of Drilling control shut in well cut down, production affected by drilling control and shut in decreased by 21.6 million tons; Meanwhile, infill well be put into production one year ahead of schedule, good development effect and economic benefit have been achieved.

5. Conclusion

There are several characteristics of Daqing peripheral oilfields which affect the development, poor reservoir physical properties, low permeabilities, low decline rate of water injection pressure after shut-in because of drilling control and long period of shunt-in.

Integration of reservoir engineering method with numerical simulation pressure prediction is able to make prediction error rate of formation pressure at infill well point less than 10% which is effective to guide drilling.

For the application of pressure prediction technology, as long as the formation pressure coefficient of infill well in a certain peripheral oilfield of Daqing is less than 1.80mpa/100m, drilling can be done; those with pressure coefficients greater than 1.80 mpa/100m, drilling should be processed after depressurization of surrounding water wells.

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References

[1] Yang Zhao, Jianjun Xu, Jingchun Wu. A New Method for Bad Data Identification of Oilfield Power System Based on Enhanced Gravitational Search-Fuzzy C-Means Algorithm. IEEE Transactions on Industrial Informatics, 15(11), NOV. 2019: 5963-5970.

[2] Yang Fan, Yan Limei, Xu Jianjun, Li Hongyu. Analysis of optimal PMU configuration method based on incomplete observation. Concurrency and Computation-Practice & Experience. JUN, 2019, 31(12): e4835.

[3] Xu, J., Huang, L., Yin, S. et al. All-fiber self-mixing interferometer for displacement measurement based on the quadrature demodulation technique. Opt. Rev. 2018, 25(1): 40-45.

[4] Zhu Longchao, Xu Jianjun, Yan Limei. Research on congestion elimination method of circuit overload and transmission congestion in the internet of things. Multimedia Tools and Applications, September 2017, 76(17), pp 18047–18066.

[5] Xu Jianjun, Wang Bao’e, Yan Limei, Li Zhanping. The Strategy of the Smart Home Energy Optimization Control of the Hybrid Energy Coordinated Control. Transactions of China Electrotechnical Society, 2017, 32(12) 214-223.

[6] Nai-bo Zhang, Jian-jun Xu, Chen-guang Xue. Core-shell structured mesoporous silica nanoparticles equipped with pyrene-based chemosensor: Synthesis, characterization, and sensing activity towards Hg (II). Journal of Luminescence, 2011, 131 (9): 2021-2025.

[7] Jing Han, Xi Wang, Limei Yan, Aida Dahalak. Modelling the performance of an SOEC by optimization of neural network with MPSO algorithm. International journal of hydrogen energy 2019, 44 (9):27947-27957.