Study on Technical Limits of Well Pattern Adjustment for the third type oil layer in middle part of Lamadian oilfield

Chunsong Xu
Geological Team of the Sixth Oil Production Plant of PetroChina Daqing Oilfield
Email: 550838722@qq.com
Tel: 18345573570

Abstract: After the Lamadian oilfield enters the development period of ultra-high water cut, the third type oil layer will be in the stage of water flooding development in the medium and long term in the future. By recombining oil layers and rebuilding the well network, it is possible to better control the difference of oil layers, slowing plane, inter-layer and intra-layer contradictions, improving the development effect of multi oil layers sandstone reservoir in extra-high water cut period. This paper uses the subdivision of water-driven oil layers, recombining oil layers, many data of field test, comprehensive analysing and studying the third type oil layer (Gao I6 and below), providing technical support for the adjustment of the well pattern network of the third type of oil layer development in the future, and forming an operational development model for the subdivision of water-driven oil layers, the reconstruction of well pattern in the development stage in ultra-high water cut.

1. GENERATION OF MIDDLE PART OF LAMADIAN OILFIELD
This block is located in the middle part of Lamadian oil field, with 40th fault in the north and 46th fault in the south, with an area of 1.1 km². The average single well developed sandstone thickness is 46.6m and the effective thickness is 18.1m. The average sandstone thickness of each sandstone group is 4.7m, the effective thickness is 1.8m, and 4.1 natural layers. There are 7 sets of development layers in the experimental area. The absolute well network density is 156.4 port/km², 172 wells of various types, 76 injection wells, and 96 production wells.

2. WELL PATTERN ADJUSTMENT IDEAS OF OIL LAYERS
In view of the actual development of oil fields, combined with geological features, stratigraphic division, well pattern status and waterflooding development situation, the oil layers developed by water is targeted in the medium and long term, at the existing development layer and well network, subdivision of oil layers and reconstruction of well network, realizing the expansion of water-driven volume, improving the unbalanced current situation of oil layers employed, and forming an operational development model for subdivision of water-driven oil layers and well network reconstruction in the development period of extra high water cut.

The experimental considerations of development and adjustment of the test area is based on the third type oil layer with Gao I6 and below oil layers as the main adjustment targets, deepening the study of the development boundary of the sequence well pattern, and clarifying the optimal thickness of the water drive layers and the well spacing of different oil layers with injection and production. In the combination of layers, centering on "subdivision and reorganization, optimizing oil-bearing series",...
reasonably combining the thickness of the oil layers, reducing the difference in permeability within the oil layers, slowing the inter-layer contradiction and improving the development effect; in the well network deployment, focusing on "reducing wellhead spacing and comprehensive utilization", using water-driven well network, comprehensive utilization of well network, new drilling and intervening well reduce injection-production well spacing, and forming a new water-driven well network matching with oil layers and reorganization At the same time, taking into account the relationship between the well network reconstruction and the third type of oil layer tertiary oil recovery well network, the operational development model of the water drive subdivision of oil layers and reconstitution of well pattern in the development period of extra high water cut is formed.

3. RESEARCH ON THE BOUNDARY OF SUBDIVISION AND REORGANIZATION

3.1 permeability variation coefficient is less than 0.8
Theoretical research and development practice have shown that the development status and nature of reservoirs are important factors affecting the development of oil layers. The coefficient of variation of oil layer permeability in each layer is an important parameter to characterize the rationality of layer combination. The results of numerical simulation of experimental area show that the smaller the coefficient of variation of the permeability of the oil layers in a set of oil layers, the higher the water flooding recovery rate, the better the development effect. As the permeability variation coefficient increases, the water flooding recovery rate decreases gradually, and the development effect becomes worse. For every 0.1 increase in the coefficient of variation of permeability, the waterflood recovery rate will decrease by about 0.7%. For the development of water flooding in multi-layer heterogeneous sandstone fields, the coefficient of variation of permeability in each layer is less than 0.8, which is more conducive to Improve water flooding recovery.

3.2 Effective thickness lower limit of the realization of reasonable production capacity conversion is 8.0m
According to the principle of reservoir engineering, based on the indoor high-pressure physical property, relative permeability curve experiment and actual production data of Lamadian oilfield, combined with economic benefit evaluation, crude oil viscosity, volume coefficient and residual oil saturation of crude oil under different formation pressures are analyzed. The results show that formation pressure in the Lamadian oil field is between the saturation pressure and the original formation pressure, which is 10.7MPa~11.3MPa.

Under the existing development mode, the stratum pressure of the Lamadian oilfield has a good linear relationship with the well flow pressure, that is, the reasonable formation pressure range corresponds to the reasonable oil well flow pressure limit. According to the map of the flow pressure and formation pressure of the Lamadian oilfield, the reasonable flow pressure value of each water drive oil layers is determined. the reasonable flow pressure of the foundation well net is 4.6MPa~5.8MPa, the reasonable flow pressure of one encryption is 3.8MPa~5.2MPa, and the reasonable flow pressure of secondary encryption is 3.2MPa~4.5MPa. (Fig1, 2, 3).

2
According to the inflow dynamic characteristics of saturated reservoir oil wells, under the relatively stable development mode, the three-phase flow inflow dynamic equation formula is applied, which calculates the oil production amount corresponding to the reasonable flow pressure value of the Lamadian oilfield, combines with the current actual production status of the block. Furthermore, it is possible to derive a reasonable limit of the liquid production intensity for each set of oil layers (Fig4).

\[ q = 2\pi Kh(P_R - P_{WF})/\mu \ln r \]  

(1)

Where \( q \) is the production of the oil well, \( t \);
\( k \) is the effective permeability, \( \mu m^2 \);
\( P_R \) is the reservoir pressure, MPa;
\( P_{WF} \) is the flow pressure of oil well, MPa;
h is the thickness of the oil layers, m;
µ is the flow viscosity, N•s/m²;
r is the completion radius (sleeve radius), mm.

The results show that the reasonable liquid production intensity of the oilfield basic well network is between 4.4~5.9t/(d•m), first encryption is between 3.6~5.0t/(d•m), and the second encryption is 3.0~4.3t/(d•m).

The average liquid production intensity in this block is about 3.5t/(d•m). By rationally subdividing the water flooding oil layers, the oil layers potentiality can be further released and the production capacity under reasonable flow pressure can be achieved. The daily production of single well is about 30t, and the lower limit of the effective thickness of the layer is 8.0m in third types oil layers.

3.3 Calculation results of economic benefit shows that the lower limit of the effective thickness of conversion is 6.0m~14.5m

According to the principle of the relationship between economic benefit and injection-production well spacing and conversion effective thickness limit, comprehensive consideration of the original water-driven well network is encrypted to 212m, 150m and 106m five-point well spacing, when the oil price is 60, 70, 90 US dollars respectively. The third type of oil layer are divided into two sets of oil layers, and the lower limit of the effective thickness is converted.

It indicates that with the reduction of injection-production well spacing and the realization of the lower limit economic benefit, the effective thickness conversion of the 212m well pattern is 6.8m, and the 150m well pattern is 10.2m, 106m well pattern is 15.8m; when the oil price is 70 US dollars, the effective thickness of the 212m well pattern is 5.8m, 150m well pattern is 8.0m, and 106m well pattern is 14.5m; when the oil price is 90 US dollars, the 212m well pattern converted effective thickness is 4.7m, 150m well pattern is 5.8m, and the 106m well pattern is 10.0m.

According to the oil price forecast of 70 US dollars, when the three types of oil layers in the La 5-27 well area are two sets of layers and encrypted to 212m~150m~106m injection and production well spacing, the lower limit of the effective thickness is 5.8m~8.0m~14.5m.

In summary, the oilfield development practice and reservoir-related theoretical research results show that during the development of the high-water-bearing water-bearing period, when the three types of oil layers are subdivided into water flooding development, the coefficient of variation of the permeability of the oil layer in each layer should less than 0.8. When the injection distance is 212m~150m~106m, the effective thickness limit is 8.0m~14.5m.

4. RECONSTRUCTION OF WELL NETWORK LIMIT STUDY

According to the principle of reservoir engineering, comprehensive analysis this block, under the
current 300m injection-production well spacing and respectively encrypted to the 212m, 150m injection-production well spacing, the degree of water flood control. As the distance is reduced, the degree of water flooding control is getting higher and higher, especially the multi-directional connectivity ratio is increasing.

For the third type oil layer, when the injection-production well spacing is encrypted to 212m, the control degree of sandstone and effective thickness water flooding is 98.0% and 97.1%; however, and the multi-directional control degree is 58.5% and 57.9%, compared with the 300m injection-production well. The degree of control is increased by 4.5 percent, and the degree of multi-directional control is increased by about 25 percent. When the injection-production well is encrypted to 150 m, the control degree of sandstone and effective thickness water drive is 99.3% and 98.2%. It is 59.7% and 59.0% respectively. Compared with the 212m injection-production well spacing, the degree of control is increased by 1.0%, and the degree of multi-directional control is increased by 1.0%. Which increase range is small.

For the third type oil layer, under the 212m injection-production well spacing, from the sand-soil deposition type, the control degree of the four different sedimentary types of sand bodies in the test area is higher than 94%. Among them, channel sand, the river sand, there degree of multi-directional control of sand bodies is higher than 62.0%, and the degree of multi-directional control of the worst-developed off-balance reservoirs is about 50%. From the grade of different thickness levels, the degree of water flooding control of four different effective thickness classes are higher than 90%, of which the multi-directional control degree of the sand body with the converted effective thickness greater than 0.5m is higher than 50%, and the multi-directional control degree of the sand body with the effective thickness less than 0.5m is also higher than 40.0%. Therefore, the extra high in the water-bearing development period, when the water-flooding well network is reconstructed, when the injection-production well spacing is about 212m, the water flooding control degree is higher, especially the multi-directional control degree is higher. It can effectively expand the water flooding volume.

The field test of the well pattern reconstruction of this block was put into operation in December 2015. According to the results of this research, the third type of oil layer was subdivided into two sets of layers: GAOI6~GAOII3 and GAO II4 and below. The new drilling data shows that the average single well development sandstone thickness of the GAOI6~GAOII3 layer is 20.5m, the effective thickness is 7.9m; the GAOII4~GAOII28 layer system, the average single well development sandstone thickness is 22.9m, effective thickness is 8.6m. After the reconstruction, the permeability of the two sets of layers is very poor, 4.75 and 2.06, respectively, which effectively alleviates the inter-layer contradiction. On the plane, the "8" font is used once and the "1" font is re-encrypted. The wells are individually encrypted, and the existing injection wells are used as injection wells to supplement the new drilling and production wells. The two sets of 212m five-point area well nets are encrypted, and the distance between the injection wells and the production wells is 300m. The injection well spacing is 212m. The control degree of the well pattern in the target interval is improved with the reduction of the injection well spacing. The injection well spacing is encrypted from 300m to 212m, and the degree of waterflood control is increased from 90.0% to 94.3%, it increases 4.3 percentage point, in which the multi-directional connectivity rate increased from 58.4% to 64.5% (above three directions), increases 6.1 percentage points.

5. A FEW POINTS OF UNDERSTANDINGS
(1) Through theoretical research and development practice, permeability variation coefficient of in-layer is lower than 0.8, the effective thickness is not less than 8.0m, and the injection-production well spacing is 212m, which is the technical limit for the adjustment of the third type oil layer.

(2) Through the subdivision well network reconstruction of Field test verification of this block, this proves that the technical limit of this research is feasible and has achieved certain practical results.

(3) Reconstructing the pilot test through the subdivision well pattern of the water drive strata in this block. Based on summarizing the experimental experience and lessons learned, it is suggested that the
middle and south blocks of the oilfield can be divided into multiple blocks for promotion. It is estimated that will increase 1.15 million tons in recoverable reserves, and the oil recovery stage will increase oil recovery by 2.0 percentage points.

Author Introduction: Xu Chunsong, 1983.01, female, Geological Team of the Sixth Oil Production Plant of PetroChina Daqing Oilfield, Engineer.

References
[1] Wang Wei, Zhao Xiujuan, etc. The field test reservoir engineering plan for the subversion well network reconstruction of the water drive strata in the La 5-27 well area of Lamadian Oilfield, 2015.2.
[2] Sun Baojing, Zhou Wensheng et al. Adaptability analysis of well pattern in extra high water cut period. Oil and gas field ground engineering [j], 2013, 23(7): 31-33.
[3] Mu Longxin. (2000) Fine Research Method of Reservoir, Petroleum Industry Press. pp. 20-45.
[4] Hong Youmi. (2008) Principles and Comprehensive Interpretation of Well Logging. China University of Petroleum press. pp. 222-233.