Study on optimal combination of stratified water injection in extra high water cut period

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Abstract: After several decades of mining, the block has entered the development stage of ultra-high water cut. Although the encryption adjustment and subdivision adjustment for different mining objects have been completed, the interlayer interference is still serious and invalid cycle still exists, making it difficult to develop and adjust. The subdivision adjustment of water injection well can further improve the production degree of various oil layers, effectively improve the utilization rate of water injection, and realize the adjustment of water injection well profile and water injection structure, which is one of the measures with low investment that can effectively improve the development effect of water flooding. To satisfy the needs of the reservoir, fine reservoir, operation based on the production dynamic data and based on the analysis of monitoring data, the application of multidisciplinary reservoir description technology, quantitative analysis of thin layered segment permeability variation coefficient, monolayer onrush of small layer in the paragraph number, interval number, sandstone thickness influence on subdivision adjustment effect, analysis of well test cycle and operation costs influence on economic benefits, A series of combination parameters of subdivision water injection interval are obtained, which can guide the subdivision water injection program, effectively alleviate the range of production decline and water cut rise, and provide technical support for fine tapping potential of water flooding in ultra-high water cut period.

Key words: Extra high water cut stage; Subdivision water injection; Interval; Input-output ratio.

1. Question raising

As the oilfield enters the development stage of ultra-high water-cut stage, the water-cut difference between each set of layers becomes smaller and the water-well layer with high water content gradually increases. The injected water is easy to advance along the established dominant water-injection channel, forming the low-efficiency injection-production cycle, inhibiting the effective utilization of thin and poor layers and outer reservoirs, and aggravating the contradiction between layers and within layers. According to the data of isotope water absorption, the water absorption ratio of sandstone and effective thickness is 74.6% and 78.9% respectively. Among them, the water absorption ratio of sandstone and effective thickness greater than 2m is 95.0% and 95.3% respectively, and the water absorption ratio of outer surface is only 42.7%. The use of medium and low permeability layer is seriously disturbed. Water drive development adjustment is the basis of enough water injection, water injection well, to control water cut increase rate, slow down production decline, excavating remaining oil to the greatest extent, fine injection-production structure adjustment, and fine water injection interval, encryption layered testing, therefore, it is necessary according to the oil field reservoir characteristics, reasonable parameters of interval combination optimization, improve water flooding development effect.

2. Study on reasonable parameters in stratified water injection section

In order to quantify and subdivide the classification standard of water injection, the water injection status of stratified Wells and sections with continuous water absorption profile were investigated, geological parameters of sections with different utilization degrees were counted, and the statistical rule of utilization degree greater than 80% was obtained. The main demarcation index of the study is the proportion of sandstone working thickness, and the main parameters of the selected study include related parameters reflecting the heterogeneity between layers, the number of small layers in the section, and the thickness of sandstone in the section.

2.1 Effect of interlayer heterogeneity on reservoir production

2.1.1 The relationship between permeability difference and reservoir production ratio

Permeability level is a parameter that reflects the degree of heterogeneity within the interval, and permeability level difference = Kmax/ Kmin. The relationship between permeability difference and sandstone thickness exploitation ratio is not obvious.

2.1.2 The relationship between the interlayer variation coefficient and the production ratio of the oil layers

The coefficient of variation between layers refers to the ratio of the mean square deviation and average permeability of each reservoir in a statistical interval. The larger the permeability variation coefficient is, the stronger the interlayer heterogeneity is.
Average permeability

$$\overline{K}=(h_1k_1+h_2k_2+\cdots\cdots h_nk_n)/(h_1+h_2+\cdots\cdots h_n)$$

The standard deviation

$$\sigma=\sqrt{\left[(K_1-\overline{K})^2+(K_2-\overline{K})^2+\cdots\cdots(K_n-\overline{K})^2\right]/n}$$

Coefficient of variation between layers $K_V=\sigma/\overline{K}$

From the relationship between the coefficient of variation between layers and the proportion of sandstone thickness, the coefficient of variation decreases gradually with the increase of the proportion of sandstone thickness. The coefficient of variation between layers should be controlled below 0.72 if the oil reservoir exploitation degree reaches more than 80%.

2.1.3 The relationship between the inrush coefficient and the proportion of oil reservoir production

The inrush coefficient reflects the degree of homogenization of oil layers within the interval, and the larger the value is, the stronger the heterogeneity between layers is.

Single layer inrush coefficient $=K_{\max}/\overline{K}$.

It can be seen from the proportional relationship between the inrush coefficient and the producing thickness of oil reservoir that the producing thickness of sandstone increases with the decrease of the inrush coefficient. If the production degree of oil layer reaches more than 80%, the inrush coefficient should be controlled below 1.23.

2.2 The influence of the number of small layers in the interval on the production condition

It can be seen from the curve of the proportion between the number of small layers in the section and the working thickness of sandstone that the proportion of the working thickness of sandstone increases gradually with the decrease of the number of small layers in the section. When the number of layers is reduced to 6, the proportion of water absorption increases significantly with the further decrease of the number of layers. When the number of small layers in the interval is less than 5, the utilization ratio of sandstone thickness reaches more than 80%.

2.3 Influence of interval sandstone thickness on production condition

It can be seen from the relationship between the thickness of sandstone in the interval and the proportion of producing thickness, that the proportion of producing thickness increases gradually with the decrease of the thickness of sandstone in the interval, and when the thickness of sandstone in the interval decreases to less than 6.5m, the proportion of producing thickness of sandstone reaches 80%.

3. Determination of reasonable number of layers

Theoretically, the more subdivided sections an injection well is, the higher the eOR value will be. However, in actual single well adjustment, the number of subdivided sections of a well is limited based on the parameters in the above sections. The reasonable number of subdivided sections should consider the development requirements, technological conditions, testing technology, economic benefits and other factors. Considering the cost of subdivision operation, stratified testing and deployment within the effective period, section sealing operation and other costs, when the injection well is subdivided into 5 sections, the input-output ratio reaches the maximum value, so the reasonable number of sections from an economic perspective is 5 sections.
Subdivision waterflood matching technology
In order to ensure the effect of layered water injection, the supporting technology needs to be further improved on the premise of satisfying the parameters in layers as far as possible. For thin and poor oil reservoirs, fracturing measures should be taken before subdivision to ensure that the water injection after adjustment is strengthened in place. The application of eccentric integrated water injection technology makes the oil layer with thickness above 0.6m subdivide. Constant current plug is applied to make the injection volume in high aquifer section not affected by the change of injection pressure, and ensure the injection volume control in the control section after subdivision.

4. Subdivide the implementation effect of water injection

According to the subdivision water injection technology limit, 98 water injection Wells were subdivided and adjusted in the adjustment area, 120 layers were added, and the daily water injection volume was increased by 1320m3. The average number of water-injection zones in a single well was adjusted from 3.64 to 4.86, and the average number of small zones in a well was 4.58, which decreased by 1.68 compared with before adjustment. The average thickness of sandstone in the section is 6.29m, decreased by 1.94m. The number of oil layers and sandstone production ratio of subdivided Wells with permeability less than 0.1μm2 increased by 17.8 and 18.3 percentage points, and the average single well oil production of surrounding Wells increased by 0.3t, effectively alleviating the range of production decline and water cut increase.

5. Conclusion

(1) Subdivision water flooding can effectively alleviate the contradiction between layers, improve the production condition and control the production decline. It is one of the most economical and effective water flooding technology under the existing well pattern conditions.
(2) In the preparation of subdivision plan, considering the connectivity between subdivision well and production well, oil layer development, casing damage protection, long stop zone recovery and other factors, in order to achieve the development effect of over 80% oil layer utilization, the coefficient of variation between layers should be controlled below 0.72, and the inrush coefficient should be controlled below 1.23. The number of small layers in each interval should be controlled within 5, and the thickness of sandstone in each interval should be controlled within 6.5m. At the same time, the number of divided intervals should be controlled within 5, so the Wells below 5 intervals are mainly subdivided and adjusted, while the Wells above 5 intervals are mainly recombined and adjusted.
(3) The effective implementation of reservoir subdivision water injection depends on the simultaneous development of multi-disciplinary reservoir description technology, oil production technology and survey and adjustment technology.

References

1. Huang Fusheng, ZHAO Yongsheng. Petroleum geology & oilfield development in daqing, 1998,7 (2) : 30-31
2. ZHOU Lei. Re-determination of water flooding injection-production adjustment technical indexes in Lamadian Oilfield [J]. Petroleum geology & oilfield development in daqing, 2016,35 (4) : 82-87
3. Fang Lingyun, WAN Xinde. Dynamic Analysis of water injection development in sandstone reservoir [M]. Beijing: Petroleum Industry Press, 1998.
4. Niu Weimin, XU Shao, Lu Mingjun. Stratified flow measurement technology of integrated subdivision water injection well [J]. Petroleum geology & oilfield development in daqing, 2010,19 (3) : 38-41.
5. Li Haifang. Effective improvement of oilfield development effect by subdivision water injection adjustment method [J]. Inner Mongolia petrochemical industry, 2010,12 (2) : 153-158
6. Shen Zhongshan, He Xin, Mei Mei, Li Ping. Geological characteristics of the fracture zone in the northern Xingshugang oil field in the Songliao Basin[J]. Daqing Petroleum Geology and Development, 2016,35(03):22-25.
7. Zhang Dong, Shen Zongshan, Li Xin. Fine interpretation of faults and lateral stacking model in Xingbei Development Zone, Songliao Basin[J]. Daqing Petroleum Geology and Development, 2015,34(05):7-11.
8. Fu Xiaofei, Guo Xue, Zhu Lixu et al. Evolution of mudstone smear formation and oil and gas transport and closure[J]. Journal of China University of Mining and Technology,2012,41(1): 52-63.
9. Wang Haixue, LI Minghui, Shen Zhongshan, et al. Establishment of quantitative criteria for fault segmentation growth and its geological significance: an example of the Saltu oil formation in Xingbei Development Zone, Songliao Basin[J]. Geological Review,2014,60(6):1260-1263.
10. Li Xin. Fine interpretation of lateral stacked faults and its development application[C]. Proceedings of the 2017 International Conference on Oil and Gas Field Exploration and Development (IFEDC 2017),2017:9.
11. Qin Jishun, Li Aifen. Reservoir physics [M], Shandong: China University of Petroleum Press, 2006: 66-80
12. Li Bo, Luo xianbo, Liu Ying et al. A new method for determining interlayer heterogeneity [J]. Offshore oil and gas, China, 2007,19 (2) 93-95
13. J.Tingas, M.Greaves, T.J.Young, Field Scale Simulation Study of In-situ Combustion in High Pressure Light Oil Reservoirs.Presented at the SPE/DOE Improved oil Recovery Symposium, Tulsa, Oklahoma,21-24 April,1996,SPE-35395-MS.
14. Ji Bingyu,Li Yan xing. Main Technical Countermeasures of Enhanced Oil Recovery during High Water Cut Stagein La-Sa-Xing Reservoirs [J]. Petroleum Geology&Oil field Development In Daqing,2004,23(5):94~95
15. B.F.DemblaDhiraj,Simulating Enhanced Oil Recovery (EOR)by High-pressure Air Injection (HPAI)in West Texas Light Oil Reservoir, Msc. Thesis,The University of Texas at Austin,2004.
16. Li J, Zhang Shan Yan. Classification of oil reservoirs in the Lasa Xing oilfield during the ultra-high water-bearing period[J]. Daqing Petroleum Geology and Development, 2007, No. 6.

17. Zhang Shanping. Exploration of problems related to the process of stratified injection and gathering in the Sazhong Development Zone of Daqing Oilfield[J]. Petroleum Geology and Engineering, 2008, (01):156-158.
18. Liu Yikun, Liu Yunlong, Chen Huiping. Washing characteristics of the Gaotaizi oil formation in the Sa Zhong Development Zone[J]. Daqing Petroleum Geology and Development,2005, (01):87-89.
19. Liu Xiaoqing. Study on improving the degree of utilization of non-major sand reserves in the North Zone[J]. Inner Mongolia Petrochemicals, 2008, (10):112-114.