Practice and Understanding of Water Control and Tapping Potential of Small Well Spacing in Extra-high Water-cut Period

Li jia
No.1 Oil Production Company of Daqing Oilfield Company Ltd., Daqing Heilongjiang 163001, China

Abstract—In 2010, a certain Gaotai block of Daqing Oilfield adopted a 106-metre-5-point area well pattern to implement the infilling adjustment. After years of development, the water-cut has increased from 91.29% at the initial production to 96.02%, with an average annual increase rate of 1.3%. However, due to small well spacing, high speed of injection and production, and low qualified rate of water injection, the decline rate of the block has reached more than 10%, which poses a challenge to stable production. On the basis of in-depth study of the principal contradiction issues, the development effect was significantly improved after comprehensive adjustment in accordance with the working ideas of precise geological research to clarify the direction of potential excavation, precise scheme design to find the location of potential excavation, precise technological measures to improve the effect of measures, and precise management means to improve the overall efficiency. In addition, the precise understanding of the remaining oil in the ultra-high water-cut stage, the precise policy technique and the practical experience gained in the development and adjustment are of guiding and reference significance to the control of the production decline and the rise of water-cut in the ultra-high water-cut stage.

1. Background of Study
Since putting into production in the small well spacing in succession, because of the intensified exploitation, the rapid increase of water-cut, the large decrease of production, the serious low efficiency circulation of water injection, the low utilization of oil reservoir and the poor development effect, how to improve the development effect of small well spacing in water flood well network has become a real problem in front of us With the continuous exploitation of oil fields, because of the relatively high oil saturation, so it is the current development trend for thin differential reservoirs to exploit remaining oil through small well spacing. Therefore, the objective analysis of this study is of great significance to find out the influencing factors of small spacing well development\(^1\) and to formulate effective adjustment methods, which will ultimately improve the development effect of small spacing well pattern.

2. Problems Existing in Area of Small Well Spacing

2.1. Existing Problems
There are four problems: firstly, the range of the production decline is large; the second is the rapid rise of water-cut; thirdly, the qualified rate of water injection is low; fourthly, the utilization of the reservoir is poor.

2.2. Reason Analysis
Firstly, the characteristic of small well spacing pattern leads to its development contradiction which is more prominent than that in the conventional area. For example, the long perforation section and...
excessive exploitation layers lead to contradiction between layers. Small spacing and irregular patterns also make the plane contradiction prominent.

Secondly, the water injection and the recovery of liquid is at a higher level. The injection and production speed is relatively low in the early period of small well spacing. Therefore, in order to maintain stable production, intensified mining was adopted, and the injection and production speed was increased to 2.9 times that of the conventional area.

Thirdly, interlayer interference makes it difficult to adjust water injection. Through field tests, we found that a slight change of the nozzle in one segment would cause a large fluctuation of water volume in other segments. This indicates that the serious interference between layers increases the difficulty in adjusting the water injection well and leads to a low pass rate of water [2] injection in small well spacing.

3. Analysis of Countermeasures and Effects

Aiming at the main problems existing in development, based on the study of fine geology, this study [3] identified and treated the efficiency of water injection and controlled the rise of water-cut by carrying out inefficient and invalid water circulation layer. At the same time, the two ends of injection and production were adjusted comprehensively, so as to optimize the structure of injection and production and control the production decline. In addition, through the application of intelligent measurement and adjustment, the new round inspection and adjustment technology, the qualified rate of water injection can be improved, and the final production condition of oil reservoir can be improved.

3.1. the Identification Technology of Determining the Dominant Seepage Channel of the Low Efficiency and Invalid Circulation Layer

In this study, a fine numerical simulation model is established by using mathematical modeling technology. The simulated calculation of tracer flow in multi-well group and large block was carried out, and then the superior seepage channel was used to identify the system, and finally the screening of wells and layers was realized.

This method can be used to realize: firstly, the production status of wells and layers is developed from qualitative to quantitative, and the results are finally visualized; secondly, based on the evaluation method of single well benefit, the chart of industrial and water-cut economic benefit is finally established.

Results: In Sasaki water flooding, in total of 2,898 layers were identified. Among them, the central area of small well spacing has a serious inefficient and invalid circulation, accounting for 56.9% of the total inefficient and invalid circulation area.

3.2. Scheme Optimization and Adjustment Technology for Injection Wells with the Purpose of Precise Injection

Generally speaking, the matching adjustment of injection wells is mainly based on the means of recombination of layers. The adjustment method of “Four Combination” is mainly adopted to optimize the adjustment scheme of injection well, so as to finally alleviate the unbalanced contradiction of reservoir utilization.

Firstly, the recombination of layer segment is combined with the simulation of tracer flow. Combined with tracer flow simulation technology, this study simulates the advance direction and speed of water injection, which provides the basis for the control of water injection in the stratified segment. Secondly, the recombination of layer segment is combined with the results of the test section. Combined with the data of the test section, this study conducted statistical analysis on the layers with continuous water absorption of more than 30% in recent three years, so as to control the phenomenon of monolayer breakthrough. Thirdly, the recombination of layer segments is combined with regional shallow profile control. Combined with the shallow profile control technology, this study adopts the piecewise shallow profile method to control the ineffective injection in the main water absorption layer in the concentrated area of three-high well. Fourthly, the recombination of layer segments is combined with the coefficient of osmotic resistance variation. Combined with the method of interval recombination of seepage
resistance variation coefficient, this study optimizes the combination and water distribution of water injection in small well spacing.

Results: By adjusting 90 injection wells, the proportion of water-absorbing layers increased by 2.7 percent points, the proportion of water-absorbing sandstone thickness increased by 4.4 percent points, and the proportion of water-absorbing effective thickness increased by 4.7 percent points.

3.3. Integrated Control Technology of Oil Wells for the Purpose of Controlling Water and Tapping Potential

3.3.1. Regulation Technology of Periodic Thinning Well Layer

This study applies the advance seepage channel to identify results, combining with the dynamic data and the simulation results of well group, in height III6 units of 126-345 well group pumping and thinning well layer to carry out the cycle test.

Results: Four production wells in the first line achieved the goal of controlling water-cut by controlling fluid. Among them, the daily production fluid dropped by 82 tons and the water-cut by 0.54 percent points. The 8 production wells in the second line achieved the goal of increasing oil and controlling water-cut. Among them, the daily production of oil increased by 6.2 tons, and the water-cut decreased by 0.59 percent points.

Figure 1 G126-345 well simulated section
3.3.2. Technology of Regional Individualized Perforations Adding and Tapping Potential of the Remaining Oil

In order to improve the injection-production relationship of single sand body, combined with dynamic and static data, numerical simulation results, etc., this study took targeted measures to patch holes and tap potential with rich remaining oil in different regions.

Conventional areas: the main objects are mat sand body controlled by controlling fluid and water to avoid radiation and narrow channel sand body with relatively rich remaining oil. Fault areas: The targets are mainly old well pattern areas with poor injection-production perfection and infill wells with complementary conditions and reasonable spacing.

Results: A total of 12 wells were executed. In the initial stage, the average value of per oil increase was 7.6 tons, and the water-cut decreased by 21.7 percent.

3.4. New Technology for the Purpose of Improving the Fine Management Level

3.4.1. New Method of Optimizing Test Cycle by “Round Robin”
This study adopts the method of rotation-inspection-adjustment test. In other words, it takes 2 months as a cycle to carry out inspection and adjustment, and adjust and optimize the single well with the adjustment cycle according to the condition of pass rate with the continuous inspection.

Effect: Compared with before and after round cycle, the pass rate of inspection increased by 26 percent points, and the pass rate of test increased by 4.9 percent points.

3.4.2. Apply the New technology of Intelligent Measurement and Adjustment
In this study, 54 wells were tested and intelligent measurement and adjustment techniques were applied. Generally speaking, technical personnel are for the real-time monitoring on the computer, real-time adjusting the flow, pressure and other parameters of each layer.

Results: The pass rate in the area of intelligent measurement and adjustment is 13.8 percent points higher than that of conventional area. In addition, through the comprehensive adjustment, the oil production in the block is basically stable, the water-cut is basically unchanged, and the development effect is significantly improved.
4. Practice and Understanding

A. Based on an in-depth understanding of the development contradictions in the block, this study applies tracer flow simulation technology to realize the development from qualitative to quantitative of dominant seepage channel identification, which is ultimately of great significance for guiding the optimal design of measures to improve the water control efficiency in small well spacing.

B. After the development of small well spacing enters the period of extra-high water-cut, this study adopts to extract thin mining in well pattern and well layer, which can improve the utilization rate of water injection, and excavate the remaining oil of the diverging line, and finally achieve better effect of increasing oil and reducing water.

C. Exploration, promotion and application of round-trip inspection and adjustment test method can effectively improve the qualified rate of water injection in small well spacing, and finally provide referential basis for the realization of “enough water injection and good water injection”.

References

[1] CUI Bo, WANG Hongbin, FENG Puyong. Reason Analysis for Injection Well Clogging and the Measures to Breaking down Plugging in SZ36-1 Oil Field[J], Offshore Oil, 2012,32(2): 71-75.DOI: 10.3969/j.issn.1008-2336.2012.02.064.

[2] Li Weiping, Xiang Xingjin, Hu Mojie. Research on Water Injection Well Plugging Mechanism at Oilfield Bohai A[J]. Advances in Fine Petrochemicals. 2015,16(6):10-12.

[3] CHEN Jun, HU Haibin, GUO Jun. The characteristic of injection well plugging and research of broken down technology in Shanshan oilfield[J]. Petrochemical Industry Application. 2015,34(4):59-61 DOI: 10.3969/j.issn.1673-5285.2015.04.016.

[4] Qu Xuefeng, Sun Wei, Wei Hongmei, et Al.. Geological characteristics and development countermeasures of Chang 8 reservoir in Baima area, Xifeng District Oilfield [j], Journal of Northwest University, 2006,36(2); 301-302.

[5] Hao Fei, Cheng Linsong, Li Chunlan, etc., [J], Journal of Southwest Petroleum Institute, 2006, 28(6); 30-32.

[6] Wang Yupu, Ji Bingyu, Guo Wankui, et Al., development technology of ultra-low permeability and ultra-low abundance reservoirs outside Daqing, [j], Journal of Southwest Petroleum Institute, 2006, (06); 72-74.

[7] Liu Ziliang, Wei Zhaosheng, Chen Wenlong, et Al.. Reasonable injection-production pattern in fractured low permeability sandstone oilfield [J], oil exploration and development, 2003, (04); 86-89.

[8] Sun ye-kuang, Shi fu-geng, Wang cheng-feng-long, et al., [J], Petroleum Exploration and development, 2004, (04); 80-82.