Study on Class 3 reservoirs infill adjustment methods

Yu Zhang

Oil Production Plant, Petrochina Daqing Oilfield Company, Daqing, Heilongjiang 163001, China

Abstract. The exploitation object of the Class 3 reservoirs of infill adjustment well pattern is SaPu thin and poor oil reservoir and Gaotaizi oil reservoir. The remaining oil potential of thin and poor oil reservoir and untabulated reservoir is brought into full play to the maximum extent, which is the focus of this infill adjustment. Therefore, it is necessary to carry out effective research on the formulation of mining plan, the dynamic change law of new and old wells from plane connection to vertical sedimentary units, and the tracking and adjustment of surrounding wells. First, according to the change law of sand body control degree in different oil layers and different well spacing, combined with the remaining oil distribution characteristics of Class 3 reservoirs of Sapugao oil layers, the well pattern and well spacing are optimized. The second is to study the complex well pattern, well location relationship and its matching adjustment timing. Through the structural adjustment of the infill well pattern of the Class 3 reservoirs in plane and vertical combination, A set of adjustment and tapping technology of the infill well area of the Class 3 reservoirs is formed, which gives full play to the remaining oil potential. Compared with the expected single well daily oil production of the typical region increases by 1.2t, water cut decreases by 2.8 percentage points, and the natural decline is -10.22%. The research results of this innovative well pattern infill combination method and potential tapping method of matching adjustment have certain reference significance for guiding the adjustment and potential tapping of infill well area of Class 3 reservoirs in water drive.

key word: Class 3 reservoirs infill well pattern adjustment methods

1. The preface

In the ultra-high water cut stage, the remaining oil is highly dispersed, and the well spacing of the Class 3 reservoirs before infill is relatively large, with an average well spacing of 300m. It is difficult to establish an effective driving pressure gradient for exploitation of thin and poor oil layers, resulting in poor utilization degree and high remaining oil abundance. Only through infilling adjustment can the utilization degree of thin and poor reservoirs and untabulated reservoirs be improved. After infilling, according to the dynamic changes of new and old wells, the research on tracking adjustment and tapping potential technology of oil and water wells is carried out, which provides scientific basis for infilling adjustment of Class 3 reservoirs in the future.

2. Study on effective ways to improve the development effect of Class 3 reservoirs

2.1 Research on remaining oil potential of Class 3 reservoirs

2.1.1 Water drive well pattern injection production is not perfect, so infill adjustment is needed to improve the development effect

Water flooding analysis is divided into sapu and Gaotaizi two sets of layers. The thickness ratio of connected sandstone in perforated intervals of sapu II and III oil layers is 82.4% and the effective thickness ratio is 79.4%, in which the multidirectional connected sandstone and effective thickness ratio are only 23.7% and 19.9%. The connected and effective ratios of sandstone in the perforated interval of Gaotaizi reservoir are 92.8% and 90.4% respectively, in which the multidirectional connected and effective ratios are only 23.0% and 21.2% respectively.

2.1.2 The utilization degree is relatively poor and has the potential of tapping.

The profile test results show that under the condition of 90% water cut in each well pattern flooding, only 20% of the well flooding is in good condition, and about 30% of the thickness is not in use. The results of electrical interpretation of water flooded zones in new wells drilled recently show that the proportion of medium and high water flooded zones with effective thickness greater than 1.0m is more than 80% and the water flooded degree is high, while the proportion of medium and high water flooded zones with effective thickness less than 1.0m is only about 50%. It shows that the reservoir still has a certain water flooding potentia.

2.1.3 Numerical simulation shows that the recovery degree of class 3 oil layer in Sapugao is low and there is residual oil

The numerical simulation results show that the recovery degree of class 3 oil layer in Sapugao is 31.5%, which is close to the actual recovery degree of the block. The production degree of good units is more than 50%, and that of bad units is less than 20%. The production degree of of class 3 reservoirs in Sapugao is also very different under the condition of 250 ~ 300m large injection-production well spacing and general exploitation. The remaining oil mainly has the following forms:

First, it is distributed in the area of poorly formed oil layers. Due to thin oil layers, poor physical properties and large spacing between injection-production wells, effective driving pressure gradient cannot be established, resulting in the remaining oil distributed in sheets. Second, the remaining oil is uncontrollable in well pattern, which is distributed in the flat surface of the sporadic distribution of shaped or narrow strip sand body. The remaining oil is formed due to the small size of sand body, large well spacing and difficult to control well pattern. In addition, there are a few remaining oil due to pinch-out blocking well pattern injection-production is not perfect, but the distribution is scattered.

In view of the remaining oil distribution of Class 3 oil reservoirs in Sapugao, it is necessary to further reduce well spacing by infill-adjustment to increase the control degree of Class 3 oil reservoirs, so as to improve the final recovery factor of t class 3 oil reservoirs.

2.2 Research on optimization design of well pattern

The targets of the infill adjustment well pattern exploitation are Class 3 oil reservoirs, namely, the Sa-1, Sa-2, Sa-3 and Pu-2 oil reservoirs with effective thickness less than 1.0m, and all the gaotaizi oil reservoirs developed in this area.

3. Research on matching adjustment technology of infill well area of Class 3 oil reservoirs

3.1 Study on timing adjustment of new well production and injection

3.1.1 New well injection is carried out synchronously with subdivision adjustment

In order to ensure balanced water injection in Sapugao oil reservoir, subdivision water injection is carried out according to the subdivision water injection boundary developed by research. The 156 newly injected water injection wells in typical blocks were injected in all fine stratified sections, and the average number of water-injected sections in a single well reached 4.76. All geological parameters in these sections were basically controlled near the reasonable water-injected limit (Table 1).

Table 1. Investigation statistics of injection well intervals.

Item	Total sublayers (n.)	Total Sand stone thickness (m)	Total effective thickness (m)	Total intervals (n.)	Average sublayers in interval (n.)	Average sandstone thickness in interval (m)	Permeability variation coefficient
Reasonable value					7.00	8.00	0.7
Actual value	5731	5384.6	1431.7	4.76	7.72	7.26	0.72

3.1.2 The production of new wells shall be carried out simultaneously with fracturing reconstruction.

As the class 3 reservoirs are mainly exploited by thin and poor reservoirs and untabulated reservoirs, the reservoir properties are poor and the natural productivity is low. Fracturing completion is helpful to improve the conductivity of thin and poor reservoirs and improve the development effect. The 73 Sapugao class 3 oil wells in typical blocks were fractured and completed, mainly transforming the lower oil layer of GII, accounting for 44.2% of the total number of wells put into production. The initial production capacity of fractured and completed oil wells was higher, and the comprehensive water cut was lower, and the effect was significantly better than other production methods (Table 2).

Table 2. Production status of oil wells with different completion methods in class 3 Sapugao oil reservoirs in typical blocks.

Well completion system	Wells	Sandstone thickness (m)	Effective thickness (m)	Daily fluid production (t/d)	Daily oil production (t/d)	Water cut (%)	Fluid production intensity (t/m·d)	Oil production intensity (t/m·d)
Compound	86	40.3	7.9	42.8	4	90.7	2.491	0.233
Common	6	34.5	9.2	35.7	3.2	90.9	2.169	0.197
Fracture	73	41.9	9.6	35.9	5.1	85.8	1.901	0.269
Average	165	40.8	8.7	39.5	4.5	88.7	2.205	0.249

3.1.3 The production of new wells shall be carried out simultaneously with the plugging of old wells

The connection thickness of PII oil layer of old and new wells in typical blocks is large, and the interlayer interference is serious. Therefore, 41 old Sapu injection wells are plugged synchronously, accounting for 67.2% of old Sapu wells, which not only ensures the demand of polymer flooding back, but also reduces the interlayer interference to new wells. The plugging thickness of sandstone is 468.9m, and the effective thickness is 208.5m. The plugging thickness accounts for 30.5% and 30.9% of the whole well, and 90.6% and 95.2% of the PII thickness. The water intake per unit thickness before plugging is $3.3m^3$/d.m, and the intensity of water injection interval after plugging is increased to $3.9m^3$/d.m.

3.2 Research on matching adjustment technology of new and old wells

3.2.1 Match and adjust the plugging of old well and periodic water injection of new well in Sapu.

In order to ensure the development effect of new wells and give full play to the potential remaining oil potential of the Class 3 reservoirs, the adjustment technology of new and old wells should be matched and adjusted. The new well is connected with the SIII , PII and Gaotaizi oil layers. The thickness of the connection between the new well and the old well is 15.1%. Second, the new well perforated across Sapugao oil formation, and the perforation top boundary of each oil layer was far apart. The average burial depth difference between SIII and PII was 159m, and the overburden pressure difference was 2MPa. The adjustment strategy is that the old Sapu well is blocked for the common injection zone to avoid interference to the new well. The new well implements periodic water injection for the large span of the formation combination to ensure effective production of the bottom reservoir.

3.2.2 Make matching adjustment between early-stage production bet and late-stage tracking

After the infill adjustment of the Class 3 reservoirs in typical blocks, the injection-production well spacing is shortened to 106m. According to the injection tracer test results, the fastest agent seeing time of the main line is 14 days, and the agent seeing time of the diverging line is 45 days. The shortening of injection-production well spacing requires the implementation of tracking adjustment according to the dynamic changes by grasping the opportunity. For example, in the five well groups of the new injection well and the old production well in the same well site, the one of the new injection well without adjustment showed an increase in production and a decrease in water cut within 7 months of the effective stage, which also confirmed the existence of untapped remaining oil potential in typical blocks. In this way, water cut increases sharply and production decreases sharply from the eighth month. According to the changes of the injection status of the new infill injection well, we timely made four well groups with various adjustment measures, such as periodic water injection, fracturing of low permeability oil layer, stopping of high permeability oil layer, shallow profile control etc, which ensured the production increase and water cut decrease.

3.2.3 Oil well measures and water well adjustment should be matched and adjusted

For the oil well measures to do a good job of adjusting water injection is the key to insure the effect of measures, with new and old production well field, the well implementation measures, for example, the location relationship exists the contradiction of the old and new production for total water.The 14 Sapu old wells annual growing of daily oil production is 1.4 t, water cut down 0.2%.The 11 new infill wells daily oil production annual contrast decreases by 17.9 t, water cut increases by 1.9 percentage points, and the effect of old wells is obvious, while the effect of new wells without measures is poor. We adjusted our strategy to not only exploit the benefits of the old wells, but also exploit the benefits of the new infill wells. While the measures of new production wells were reformed, the combination of timely adjustment of new injection wells and plugging of old injection wells improved the development effect of new and old wells. The fracturing of typical infill new wells increased oil by up to 9.7t per day.

4. Effect analysis

4.1 The production effect is better than expected

The research results of remaining oil distribution characteristics, well pattern and well spacing optimization design prove that the typical block is suitable for infill development. The daily oil production increased by 1.2t and water cut decreased by 2.8 percentage points (Table 3).

Table 3. Comparison of new well production and scheme prediction in Sapugao class 3 oil reservoirs in typical blocks.

Comparison	Shoot thickness		0il wells			Water wells	
	Sandstone (m)	Effective (m)	Daily fluid production (t/d)	Daily oil production (t/d)	Water cut (%)	Injection proration (m^3/d)	Injection reality (m^3/d)
Scheme prediction	27.6	6.2	39.1	3.3	91.5	52	52
Production situation	37.1	8.2	39.5	4.5	88.7	59.4	55
Difference	9.5	2	0.4	1.2	-2.8	7.4	3

4.2 Matching and adjusting water injection structure of new and old wells solves the complex water injection situation between planes and layers

According to the analysis of the utilization degree of each sedimentary unit of periodic water injection in infill new well, the water absorption status of the original sapu oil layer with good water absorption is improved obviously through periodic injection stopping, and the proportion of water absorption thickness of sandstone increases from 2.9% to 26.5%.

The analysis of the production status of each sedimentary unit before and after the plugging of sapu old well in typical block shows that the proportion of water absorption thickness of sandstone in PII oil formation decreases from 44.2% to 11.8% through the fine plugging of PII oil formation. The water injection of this part of oil formation is mainly supplied by the new well. Finally, the comprehensive matching adjustment of water injection structure of new and old wells is achieved.

4.3 The annual oil production of new and old wells increases and the development effect is good

Through the matching adjustment of new and old wells, the remaining oil potential of Class 3 reservoirs in typical blocks is brought into full play, the annual oil production of new and old wells increases, and the development effect is good. In typical blocks, the annual oil increase of Gaotaizi is 13.95×104t, and the annual oil increase of Sapu is 9096t, and the natural decline is -10.22%.

Through the in-depth study and application of the three types of oil layer encryption adjustment method in typical blocks, it has a certain reference significance to guide the adjustment of the whole water drive three types of oil layer encryption well area, and has a broad application prospect.

5. Conclusion

Typical block belongs to GII exterior well area with poor oil layer development, which is suitable for Class 3 reservoirs encryption development.

Master the timing of adjusting potential tapping, from three synchronous at the initial stage of production to four matching after production, comprehensively analyze the relationship between flow lines and well location of new and old wells, implement matching adjustment and potential tapping, effectively improve the plane and vertical water injection structure, and achieve good oilfield development effect.

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