Feasibility study on infilling of horizontal wells with difficult to recover reserves in Fuyu reservoir

Siqi Zheng

School of Resource Exploration Engineering, Daqing Petroluem Institute, Daqing, China

Abstract. Aiming at the inter well drive immobile remaining oil in Fuyu oil layer of block 1 due to the non densification of surface village coverage, taking into account the undeveloped reserves that can not be produced by vertical wells due to being located in the wetland protection area along the river, the feasibility study of layered densification of horizontal wells in the main oil layer with good reservoir development is carried out to explore a new densification mode of horizontal wells in Fuyu tight oil reservoir.

1 Raising questions

The development experience of block 1 shows that infill adjustment can improve the oil production speed and recovery degree of the block. In view of the inter well drive immobile remaining oil caused by the non densification of the surface village coverage, taking into account some of the undeveloped reserves that cannot be produced by vertical wells because they are located in the wetland protection area along the river, the layered design horizontal wells of the main oil layers with good reservoir development are preferred, and a new densification mode of horizontal wells in Fuyu tight oil reservoir is explored.

2 Feasibility study of horizontal well infilling

2.1 The structure of the proposed well area is gentle

Structurally, it is located in the West Wing of nose structure, showing a single slope dipping to the northwest, low in the West and high in the East in the east-west direction, and the stratum dip angle is 1-3.5 °. Based on the drilling data and seismic data, a three-dimensional fine geological model is established by well seismic combination. The structure of the proposed well area is gentle and there is no fault development in the horizontal section.

2.2 The main stratum in the proposed well area is prominent

2.2.1 The main oil reservoirs are developed stably.

Medium and small channel sand bodies are developed in main oil layers A, B and C in the proposed well area, with a width of 400 ~ 800m and a thickness of 2 ~ 5m, mostly distributary plain river deposits; The effective thickness of flattening is 3.2, 2.8 and 4.7m respectively. Small distributary channel sand body and inter river sand are mainly developed in non main oil layers.

2.2.2 High control degree of available reserves.

The continuity of planesA, B and C of the main oil layers is good. Horizontal wells are designed in layers. The average thickness of interlayer A and B is only 1.2m. The control degree of through layer fracturing reserves of horizontal wells is 56.4%. After deducting the influence of narrow channel sand body and inter river sand with an effective thickness of less than 1m, the control degree of available reserves is 73.1% (Table 1).

* Corresponding author: Zhengsq1@petrochina.com.cn

Table 1. Statistical table of effective thickness of reservoir in proposed well area.

Serial number	Well number	Effective thickness of layer A(m)	Effective thickness of layer B(m)	Effective thickness of layer C(m)	Effective thickness of the whole well (m)	Proportion of control thickness in the whole well (%)	Thickness of a and B compartments (m)	Available effective thickness (m)	Proportion of control thickness in available (%)
1	Well 1	2.8	0	4.4	12.4	58.1		11.1	64.9
2	Well 2	0	2.1	7.6	18.9	51.3		13.4	72.4
3	Well 3	2.8	4	3.6	19.4	53.6	1.8	13.6	76.5
4	Well 4	4.7	2	1.2	19.9	39.7	0.6	12.7	62.2
5	Well 5	0.6	1.4	0	5	40.0	1.2	4.4	45.5
6	Well 6	5.6	5	8.3	23.9	79.1	1.2	21.5	87.9
Total/ average average		16.5	14.5	25.1	99.5	56.4	1.2	76.7	73.1

2.2.3 The production proportion of main oil reservoirs is high.

The proportion of liquid production and water absorption of layer A + B + C accounts for about 70% of the total liquid production and water absorption.

3.1 The water flooding risk in the proposed well area is low

3.1.1 Fracture characteristics.

The maximum horizontal principal stress direction of Fuyu reservoir (near east-west direction). The fractures are relatively developed, and the fracture frequency is high, including natural fractures and micro fractures. The multidirectionality of fractures is obvious.

3.1.2 Impact of fractures on water injection development.

The proportion of water flooded oil wells in east-west direction is large. At the initial stage of block 1 development, 300m inverted nine point area well pattern is adopted. Water injection was started one year later. After water injection, the water content of East-West oil wells increased rapidly, and the casing pressure increased significantly after shut in. Four East-West oil wells were flooded five months later, and nine oil wells were flooded one year later, accounting for 81.8% of the number of East-West oil wells and 21.4% of the total number of oil wells.

3.1.3 The effective thickness and water washing ratio of infill wells are low, and the water flooding risk in the proposed well area is low.

The water flooding interpretation results of 48 infill wells in block 1are counted, of which 11 are expanded wells, and the water washing proportion of effective thickness is 12%; 37 wells are infill wells, and the water washing ratio of effective thickness is 15.9%. After being put into operation, the average water content in the initial stage is 26.1%. The risk of water flooding between old wells is low, and the risk of water flooding can be greatly reduced by arranging wells along the fracture direction (near east-west direction).

3.2 Through gradual encryption and adjustment, the development effect is gradually improved

The calibrated recovery factor of block 1 is 13.8%. According to the two algorithms of Tong Xianzhang chart and type a water drive characteristic curve, through gradual encryption and adjustment, the average recovery factor can reach 22.3%.

4 Horizontal well design and productivity prediction

4.1 Design 4 horizontal wells in two horizons

In view of the immovable inter well drive remaining oil caused by the non densification of the surface village coverage, taking into account some of the undeveloped reserves that cannot be produced by vertical wells because they are located in the wetland protection area along the river, the layered design of the main oil layer with good reservoir development is preferred. A total of 4 horizontal wells are deployed, with an oil-bearing area of 1.42km^2 and geological reserves 27.1×10^4t (Table 2). The orientation of the horizontal well is close to the east-west direction and parallel to the fracture direction. The main stress direction can be used to prevent water flooding and prolong the water breakthrough period; Drilling horizon A_B、C, in which A and B are completed by through layer fracturing, and both small layers can be used; Single horizontal well is selected as well type; The length of horizontal section is 800-1500m.

Table 2. Prediction of controlled reserves of horizontal wells.

Serial number	Well number	Horizon	Single storage coefficient (10^4/m.km^2)	effective thickness (m)	Control area (km^2)	Controlled reserves (10^4)
1	Horizontal well 1	A_B	4.16	4.7	0.28	5.5
2	Horizontal well 2	A_B		6.5	0.22	5.9
3	Horizontal well 3	C		4.9	0.46	9.4
4	Horizontal well 4	C		3.3	0.46	6.3
Total					1.42	27.1

4.2 Production intensity in the proposed well area in combination with the production effect of similar blocks

4.2.1 Determination of oil production intensity of layer A-B.

The physical properties of reservoir in block 2 are similar to those in block 1. The main fracturing intervals are: A and B. the thickness of fracturing sandstone is 8.1m and the effective thickness is 6.8m. Referring to the experience of no fracturing and no oil production in Fuyu reservoir: the oil production intensity of layers A and B is 0.32 t/d.m.

4.2.2 Determination of oil production intensity of layer C.

Select 7 infill wells in Fuyu class II block where the main oil layer is C, other layers are located at the edge of the main sand body or non main sand body, and layer C is all fractured. According to the statistics of the liquid production profile at the initial stage of production, the oil production intensity of layer C is 0.35t/d.m.

4.2.3 Initial oil production intensity of fracture network fracturing in adjacent developed block 3.

The reservoir properties of block 3 and block 1 are similar. In 2014, the average fracturing sandstone thickness of 5 wells put into operation by large-scale fracturing was 19.0m, the effective thickness was 15.2m, the average daily liquid production of a single well was 12.2t, the daily oil production was 6.6t, and the water content was 46.2%. The oil production intensity is 0.43t/d.m.

4.2.4 Determination of oil production intensity in the proposed well area.

Based on the initial oil production intensity of adjacent developed areas and combined with the fracture pattern pressure investment effect, the cumulative injection production ratio in the proposed well area has reached 6.0, the formation energy is sufficient, When tight oil horizontal well volume fracturing is adopted for interval A, B and C (in which A and B are through layer fracturing). The predicted initial oil production intensity of layer A-B、C is 0.3 t/d.m.

4.3 Various methods are used to predict the initial productivity of horizontal wells and improve the accuracy of productivity prediction

Through theoretical formula calculation, the average daily oil production of single well in the initial stage of horizontal well in block 1 is 6.3t/d.

$$q_o = \frac{2n\pi K_h h_o (p_e - p_{wf})}{\mu_o B_o} \left(H_1 + \frac{\beta h}{L} \ln \frac{h_o}{h_f} + \frac{K_h h_o}{K_f c} \ln \frac{h_f}{2r_w}\right)^{-1} \quad (1)$$

$$H_1 = \operatorname{arcch}\left(\frac{\operatorname{ch}\frac{\pi b}{2na}}{\sin\frac{\pi L_f}{2a}}\right) \quad (2)$$

According to the analogy method, the reservoir physical properties of Fuyu oil layer in block 4 and block 5 of Chang 1 are similar to those in block 1. The average effective thickness of the development horizon of 13 East-West horizontal wells is 3m, the average length of the horizontal section is 572m, the average oil production in the 100m horizontal section is 0.5t, and the average daily oil production of horizontal wells in block 1 is predicted to be 6.0t in the initial stage.

Combining the two methods, it is predicted that the average daily oil production of a single well in the initial stage of horizontal well is 6.0t, and the built production capacity is 0.72×10^4t, newly increased recoverable reserves of 6.04×10^4t, initially prepared the well opening plan for horizontal wells in Fuyu oil layer of block 1, and extended the evaluation period under stepped oil prices to 15 years, with an after tax internal rate of return of 6.7%, higher than the industry benchmark rate of return of 6%, which is economically feasible.

5 Conclusion

The artificial fracture is near east-west, and the orientation of horizontal well is parallel to the fracture trend. The principal stress direction can be used to prevent water flooding and prolong the water breakthrough period.

The remaining oil between wells in Fuyu reservoir due to the non densification of the surface village coverage, and the undeveloped reserves that cannot be produced by vertical wells due to being located in the wetland protection area along the river can be effectively produced by layered design of horizontal wells, so as to improve the development effect.

References

[1] Weng Ding Wei, Lei Qun, et al. Fracture network fracturing technology and its field application. Journal of petroleum. 2011,32 (2): 280-284.

[2] Wu Dixiang, Zhang Jifen, Li Hujun, et al. Reservoir physics. Beijing: Petroleum Industry Press, 1994.

[3] Zhang Jifen, Zhao Mingguo, Liu Zhongchun, et al. Fundamentals of enhanced oil recovery. Beijing: Petroleum Industry Press, 1997.