A Block in Daqing Saltu Oilfield Study on well network reconstruction of stratigraphic system

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Abstract: A block in Daqing Saltu Oilfield has a large span of formation systems, large permeability grade difference, prominent inter-formation conflicts, low degree of control of multi-directional water drive, large injection and extraction well spacing in thin differential layers, and low degree of utilization, etc. In this regard, based on the existing well network, a study on the reconstruction of the formation system well network is carried out in this area. Longitudinal subdivision of the layer system, narrowing the mining span, the X, Y, Z oil layer mixed mining, adjusted to X oil layer separate mining, Y + Z oil layer mixed mining; at the same time, according to the nature of the oil layer subdivision of mining objects, X oil layer and Y + Z oil layer mining objects adjusted to medium and high permeability layer and low permeability layer. On the plane of optimizing the injection and extraction well spacing, the original 250m well spacing was adjusted to 175m area well network, which eased the development contradiction.

Keywords: Inter-layer conflicts; development adjustment; well network optimization.

1. Introduction

At present, the target of water-driven exploitation is mainly three types of oil formations with many layers and thin single layer thickness. In order to solve the problems of long well sections, large span and prominent contradiction between layers on the vertical side of the water-driven well network, and large injection and extraction well spacing and low utilization of thin reservoirs on the plane; the restructuring and adjustment of the well network of layer system was carried out in a block of Sanan Development Zone to further solve the development contradiction and expand the scale of water-driven adjustment.

2. Adjustment of the basic overview of the block

Adjustment area development area of 3.13km2, mining object is X, Y, Z oil layer, belongs to the river - delta phase sediment, adjustment area water drive is divided into well network 0, well network I, well network II and well network III 4 sets of well network mining, divided into good layer, poor layer for X, Y, Z oil layer mixed mining. There are 122 oil and water wells, including 50 water injection wells and 72 oil extraction wells, with daily actual injection of 5809m3, daily liquid production of 3974t and daily oil production of 214t.

3. The main problems in the adjustment area water drive development

3.1 Large span of existing layer system and large permeability grade difference

The average single well section span in the adjustment area is 203.6 m, and the oil formation thickness is 31.4 m. The well networks cross each other. The average permeability of each well network is 116×10-3μm2, and the average permeability grade difference is 9.1. Except for Well Network III, the permeability grade difference of all other well networks are around 10, and the permeability grade difference is large.

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Table 1 Statistics of span and permeability grade difference of each well network

Well net	Mining target	Span (m)	Thickness (m)	Average penetration rate ($10^{-3}\mu m^2$)	Penetration grade difference
Well net 0	X, Y, Z thick layer	243	40.8	124	10.5
Well netI	X, Y differential layer + Z	217	43.9	101	10.1
Well netII	thin differential layer	206	25.6	108	9.9
Well netIII	thin differential layer	244	15.8	91	5.7
Average value		203.6	31.4	116	9.1

There are differences in the activation status of each formation group, among which the water absorption status of Z formation is poor with 61.2% of water absorption thickness, and the activation status of Y formation is the best with 81.9% of activation degree.

Table 2 Statistical table of the degree of activation of each oil formation group

Oil layer group	Water absorption thickness statistics		
	Statistical thickness (m)	Absorption thickness (m)	Degree of utilization (%)
X	837.2	682.4	81.5
Y	1547.7	1267.9	81.9
Z	438.3	268.2	61.2

3.2 Relatively low degree of multi-directional water drive control

The degree of control of water drive in the block is 89.7%; among them, the degree of control of multi-directional water drive is 25.7%, and the degree of control of multi-directional water drive is low.

Table 3 Statistical table of the degree of water drive control for each oil formation group

Item	One-way(%)	two-way(%)	Multi-directional(%)	Total(%)
X	36.9	30.8	19.3	87.1
Y	26.9	36.8	30.1	93.8
Z	32.4	30.8	25.7	88.9
Total	31.3	32.7	25.7	89.7

3.3 Thin differential layer injection and extraction well spacing is large and the degree of mobilization is low

The distance between well network II and well network III injection and extraction wells is 250m. A total of 83 injection wells absorb water profiles, with an average single well absorb water thickness ratio of 77.5%. Among them, 77.6% of the oil layer with thickness 0.2-0.4m was used effectively; 68.4% of the oil layer with thickness less than 0.2 was used; the degree of use was low.

Table 4 Different sandstone thickness grading dynamic status table

Effective thickness	Utilization ratio		Unexpended percentage	
Level	layers (%)	Thickness (%)	layers (%)	Thickness (%)
Thickness≥1m	89.1	90.2	10.9	9.8
Thickness 0.5-0.9m	80.3	81.4	19.7	18.6
Thickness 0.2-0.4m	75.9	77.6	24.1	22.4
Thickness <0.2	67.1	68.4	32.9	31.6
Total	73.9	77.5	26.1	22.5

4. Analysis of remaining oil potential in the adjustment area

According to the residual oil analysis based on the comprehensive analysis method, the three types of oil layers still have some adjustment potential, and this potential is mainly in the thin differential oil layer and part of the medium water-bearing thick oil layer. The analysis results show that the average single well residual oil layer thickness is 27.3 m. The residual oil is fragmented longitudinally, and each oil layer group is distributed, among which XII, XIII, YII and Z oil layers are more concentrated, and the residual oil thickness of the four oil layer groups is 23.8 m, accounting for 87.2% of the total residual oil thickness. From the residual oil type, it is mainly the residual oil of imperfect injection and extraction and inter-layer interference type.

Table 5 Residual oil thickness statistics

Oil Formation Group	Thickness≥0.5m (m)	Thickness 0.2-0.4m (m)	Other reservoir thickness (m)	Total thickness (m)
XI	0.4	0.6	0.6	1.6
XII	0.8	0.8	2.9	4.5
XIII	0.9	1.1	5.6	7.6
YI	0.4	0.2	1.3	1.9
YII	0.9	1.2	5.2	7.3
ZI	0.8	1	2.6	4.4
Total	4.2	4.9	18.2	27.3

Table 6 Statistical table of different residual oil types

Category	Thickness ≥0.5m (m)	Thickness 0.2-0.4m (m)	Other reservoir thickness(m)	Total thickness(m)
Injecting and extracting imperfections	3.5	3.3	14.6	21.5
Planar Interference			0.5	0.5
Poor absorption	0.7	1.6	2.4	4.6
Inter-layer interference			0.7	0.7

5. Reconfiguration study of layer system well network

5.1 Rational injection and extraction well spacing study

According to the block stratigraphic development, a model was established to calculate the variation of recovery degree under different well spacing separately, and a relationship curve between injection and recovery degree under different permeability conditions was formed.

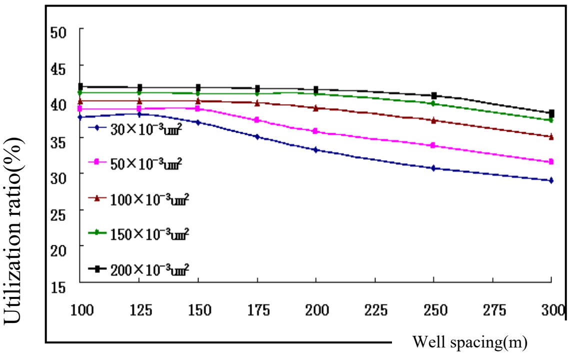

Figure 1 Relationship between well spacing and recovery rate for oil reservoirs with different permeability

It can be seen from the curve that the degree of recovery decreases accordingly with the increase of injection and recovery well distance for different permeability formations. The reasonable injection and extraction well spacing should be controlled at about 150m for oil formations with permeability of 30×10-3μm2 and 50×10-3μm2, and at about 200m for oil formations with permeability of 100×10-3μm2 and 150×10-3μm2.

The relationship between injection and extraction well spacing and reservoir mobilization status was obtained by counting the mobilization status of thin differential oil reservoirs in adjacent blocks and analyzing the mobilization status of thin differential oil reservoirs at different well spacing, and using curve linear regression, the following relationship equation was derived:

$y = -0.0006x^2 + 0.0255x+92.622$, $R^2 = 0.9441$

Where: y-absorption thickness ratio, %; x-well distance, m

Based on the above equation, we calculate the degree of oil formation utilization under different injection and extraction well spacing. It can be seen from the graph that if the percentage of oil use in the thin differential oil layer reaches about 80%, the oil injection and extraction well distance should be controlled at about 175m; if the injection and extraction well distance is further increased to 250m, the percentage of oil use in the thin differential oil layer is only 61.5%.

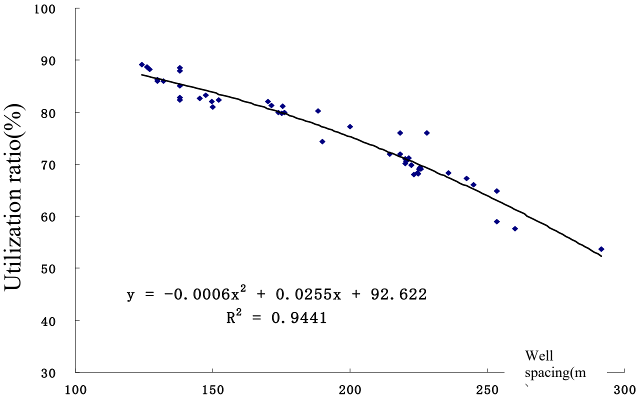

Figure 2 Diagram of oil formation utilization at different well spacing

The above research results on injection and extraction well spacing show that the reasonable injection and extraction well spacing should be controlled at about 150m for oil formations with permeability of $30\times10^{-3}\mu m^2$ and $50\times10^{-3}\mu m^2$, and at about 200m for oil formations with permeability of $100\times10^{-3}\mu m^2$ and $150\times10^{-3}\mu m^2$.

5.2 Research on subdivided adjustment objects

The effective thickness of the three types of oil layers in the block is 81.8 m. From the development situation, there are 40.5 oil layers in the X formation group with a thickness of 36.7 m, accounting for 44.9% of the total drilling encounters in the three types of oil layers, and 49.7 oil layers in the Y+Z formation group with a thickness of 45.0 m, accounting for 55.1% of the total drilling encounters in the three types of oil layers respectively, and the thickness of drilling encounters in the X and Y+Z formation groups each account for about 50%. Therefore, the mixed mining of X, Y and Z oil formations is adjusted to X alone and Y+Z oil formations mixed mining to reduce the mining span vertically.

From the thickness classification drilling encounter, the average single well drilling encounter thickness of oil layers with permeability greater than $100\times10^{-3}\mu m^2$ and thickness ≥0.5m is 33.7m, accounting for 41.2% of the total drilling encounter thickness of the three types of oil layers. Therefore, the adjustment objects are subdivided into oil layers with thickness ≥ 0.5m and permeability ≥ $100\times10^{-3}\mu m^2$.

5.3 Design of layer system combination

According to the above research results, the X, Y and Z oil formations are subdivided into two sets of formations, X and Y+Z oil formations, and the exploitation span is reduced vertically; meanwhile, the exploitation objects are subdivided according to the nature of oil formations, and the exploitation objects of X and Y+Z oil formations are adjusted to medium and high permeability formations and low permeability formations.

X oil layer: it's subdivided into medium-high permeability layer and low-permeability layer, the span of drilling encounter stratum was reduced to 129.86m, and the permeability grade difference was reduced to 5.6 and 4.9 respectively.

Y and Z oil layers: it's subdivided into medium and high permeability layers and low permeability layers, the stratigraphic span of the drilling encounter was reduced to 98.63m, and the permeability grade difference was reduced to 4.6 and 6.8 respectively.

Table 7 Reconfiguration design table of layer system combination in adjustment area

Layer system	Well section length(m)	Effective thickness(m)	Penetration rate(μm^2)	Penetration grade difference
X good layer	129.86	9.4	0.219	5.6
Y bad layer		3.3	0.048	4.9
Y、Z good layer	98.63	10.1	0.223	4.6
Y、Z bad layer		3.5	0.043	6.8

5.4 Design optimization of well network

There are currently four sets of well networks in the adjustment area, namely, well network 0, well network I, well network II and well network III, and the statistics of each set of well network shot holes, in which well network 0 and well network I mainly shot open X, Y and Z oil layers with thickness greater than 0.5m, and well network II and well network III mainly shot open X, Y and Z oil layers with thickness less than 0.5m. The extraction objects of well network 0 and well network I are adjusted to the middle and high permeability layers of X, Y and Z, and the extraction objects of well network II and well network III are adjusted to the low permeability layers of X, Y and Z. The specific adjustment results are shown in the following table:

Table 8 Adjustment design table for well network reconfiguration in the adjustment area

Layer system	Well Layout Method	Well spacing (m)
X good layer	Well net 0 and well net I form the inverse nine-point method	250
Y、Z good layer	Well net 0 and well net I form the inverse nine-point method	250
X poor layer	Well Network II and Newly Drilled Wells Form an Anti-Nine Point Approach	175
Y、Z poor layer	Well Network III and Complementary Drilling Well Formation Five Point Method	175

After adjustment, the high permeability oil layers in X, Y and Z oil formations are explored by using well network 0 and well network I to form two sets of well network with 250m well spacing. X, Y and Z differential layers are adjusted to two sets of well network with 175m well spacing.

Table 9 Statistical table of the degree of water drive control before and after the adjustment of well network reconfiguration

Classification	One-way(%)		two-way(%)		Multi-directional(%)		Total(%)	
	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment	Before adjustment	After adjustment
X bad layer	36.75	24.94	31.43	34.52	24.65	33.64	92.83	93.1
X good layer	51.07	30.74	25.36	32.85	8.14	27.99	84.57	91.58
X Subtotal oil layer	40.65	25.13	28.33	33.88	19.64	31.48	88.61	90.5
Y、Z bad layer	29.62	19.45	31.65	32.87	30.64	41.17	91.91	93.49
Y、Z good layer	24.28	8.72	32.43	29.12	36.02	57.12	92.73	94.96
Y、Z Subtotal oil layer	26.48	15.65	32.11	31.55	33.8	46.81	92.39	94.01

6. Conclusion and Awareness

1. Through residual oil analysis, the three types of oil layers have certain adjustment potential, mainly thin differential oil layers and some medium water-bearing thick oil layers, which are more fragmented in the longitudinal direction and distributed in each oil layer group, and can be tapped through layer system adjustment.
2. Through layer segment redivision, the vertical span has been narrowed from more than 200m to about 100m; combined with the nature of the oil layer, the middle and high permeability layers and low permeability layers have been divided, and the permeability grade difference has been controlled.
3. Through the study of well spacing for injection and extraction of oil layers with different properties, the well spacing for good and poor layers was reasonably adjusted by combining the existing well network conditions, and the degree of control for all types of oil layers was increased after the adjustment, which is more conducive to fully exploiting the remaining oil potential of all types of oil layers.

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