Research and effect analysis on improving injection mode of weak alkali ASP flooding in poor oil layer block

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Abstract. In view of the large proportion of thin and poor layers in the weak-alkali ternary flooding block, the statistical analysis method is used to optimize the division of well groups with injection capacity, establish a strategy chart for different types of groups to maintain injection and tap potential, and optimize the well groups of different sand body connectivity types. The fracturing method strengthens the whole process of fracturing in the well area with poor injection capacity. The effective thickness water absorption ratio is over 80%, the maximum water cut reduction in the stage is 9.65%, the low water cut stable period is 16 months, and the recovery factor is increased by 8.77 percentage points. development effect.

Key words: Thin and poor oil layer, weak base ternary flooding, injection capacity, fracturing method

1. Introduction

In order to realize the orderly replacement of tertiary oil recovery output, break through the technical lower limit of traditional chemical flooding oil displacement object, expand the thin and poor oil layer with effective thickness less than 1m to chemical flooding development object, ensure the thickness of layer series combination and the control degree of chemical flooding, realize the industrial exploitation of thin and poor oil layer, and ensure the goal of enhancing oil recovery by more than 16% by weak alkali ASP flooding in thin and poor oil layer.

2. Classification of reservoir properties

The oil layers are classified according to the sand body development type, single-layer flattening thickness and drilling encounter rate characteristics.

Class I oil layer: mainly distributary channel deposition, channel sand is widely distributed, the effective thickness of a single layer is more than 3 meters, and the drilling encounter rate is more than 60%.

Class II oil layers: mainly deposited in the inner front facies, with relatively developed medium and small channels, the effective thickness of a single layer is≥1 m, and the drilling encounter rate is≥30%.

Class III oil layers: Mainly deposited in outer front facies, mainly sand bodies with effective thickness≤1 m, which are further subdivided into Type A and Type B, among which Type A single-layer rolling effective thickness≥0.2 m, drilling rate≥60%; Class B is dominated by independent outer layers.

3. The block has major problems

3.1 Arithmetic average index shows that the block is dominated by three types of oil layers, and the reservoir conditions are further deteriorated.

The sedimentary environment of the block is delta inner and outer front facies, with frequent phase transformation in plane and vertical, and further deterioration of reservoir properties. According to the classification standard of reservoir properties, the proportion of reserves of three types of reservoirs in the statistical block reaches 79.5%, which is more than 20 percentage points higher than that in other blocks. Compared with similar blocks, it is mainly reflected in the following two aspects:

First, the thickness of the oil layer is thin and the permeability is low. There are 17 target layer development units in the block, the average effective thickness of single layer is only 0.46m, the proportion of oil layers less than 1m reaches 87.1%, and the thickness proportion reaches 51%; the effective permeability is only $220\times10^{-3}\mu m^2$.

Second, the development of channel sand is small in scale and narrow in width, and the quality of oil layer connectivity is poor. The channel sand drilling rate is only 7.7%, which is about 10 percentage points lower than that of similar blocks, and the control degree of chemical flooding of oil layers with effective permeability greater than $100\times10^{-3}\mu m^2$ is reduced to below 60%.

3.2 According to the arithmetic average index, the injection ability is poor, the thin and poor layer is poor, and the development and adjustment is difficult.

The injection pressure in the blank water flooding stage is relatively high, with an average injection pressure of about 8.6MPa, which is 1.6MPa higher than other blocks in the same stage. Some wells in the later stage can basically inject polymer through measures and reconstruction, but the injection pressure is still relatively high. At the initial stage of polymer injection, the allowable injection pressure difference space is only 2.17MPa, and the proportion of wells with allowable injection pressure difference less than 2 MPa reaches 51.5%, which is 19 percentage points higher than that of similar blocks. The single well injection amount is only 28m^3, and the proportion of continuous injection thickness of oil layers less than 1 meter is less than 30%. Therefore, it is difficult to maintain the injection and production volume in the chemical flooding stage.

4. Well cluster type division

4.1 The data of coring wells show that the well area with poor reservoir development has small porosity and high shale content

The sedimentary types of sand bodies are generally divided into channel sand, main sand and non main sand. Among them, the main sand is subdivided into thick layer main body and thin layer main body with an effective thickness of 1m. According to the statistical data of geological characteristic parameters of classified sand bodies of coring wells, the results show that the well-developed sand body has large thickness, high permeability, large porosity, large pore radius and low shale content; The sand body with poor reservoir development has small thickness, low permeability, small porosity, small pore radius and high shale content.

Table 1 Statistical comparison of geological parameters of classified sand bodies

Sand body type	Effective thickness(m)	Permeability (mD)	Porosity (%)	Pore radius (um)	Mud content(%)
Channel sand body	1.7	338	28.1	9.67	7.5
Thick layer main body	1.3	284	28.0	7.89	8.6
Thin layer body	0.8	179	27.6	6.25	9.2
Non main sand	0.4	104	26.7	4.10	10.0

4.2 The classification standard of well group injection capability evaluation was quantified by applying the classification and screening statistical method

Aiming at the characteristic parameters such as the type, thickness, permeability and other characteristics of the sand body corresponding to the injection wells and the connected production wells, the main features are the large differences in types and the large amount of data. Therefore, by dividing the characteristic parameter types of the research object, changing the traditional method of transposing to establish VF database statistics, and applying Excel data pivot table to classify and filter statistics, the work efficiency is greatly improved.

From the water absorption profiles of different sand bodies in the block, the proportion of continuous injection thickness of oil layer below 1m is less than 30%. The distribution proportion of discontinuous injection reservoirs is counted by Excel PivotTable, which is mainly affected by poor reservoir development and poor inter well connectivity. The thickness ratio of thin injection and thin production oil layer is 32.7%, the thickness ratio of thin injection and thick production oil layer is 21.6%, and the thickness ratio of thick injection and thin production oil layer is 39.6%. Therefore, according to the four sand body deposition types of channel sand, thick layer main body, thin layer main body and non main body sand, the inter well sand body connection relationship types are determined, which are mainly divided into four types and eight injection production sand body connection relationship types. According to the eight types of sand body connection quality between wells, the well group division standard of injection capacity is quantified, and the well group is divided into three well group types: Grade I, grade II and grade III.

Table 2 Proportion of discontinuous injection reservoir types

Injection type	Low permeability at the injection end		Injection end hypertonicity	
	Thin injection and thin mining	Thin injection and thick mining	Thick injection and thin mining	Thick injection and thick mining
Thickness ratio (%)	32.7	21.6	39.6	6.1

Table 3 Types of connectivity quality of sand bodies between fine wells

Production well / Injection well	Channel sand	Thick body	Thin body	Non-subject
Channel sand (Efficient≥1.5 m)	One type	Class II	Three categories1	Four categories1
Thick body (Efficient≥1.0 m)	Class II	Class II	Three categories1	Four categories1
Thin body (1.0m>Efficient≥0.5m)	Three categories2	Three categories2	Three categories3	Four categories3
Non-subject (0.5m>Efficient≥0.2m)	Four categories2	Four categories2	Four categories3	Four categories3

Table 4 Criteria for the classification of strong and weak injection capacity

Well group type	Connected mass thickness ratio				
	Class I + class II	Class III 1 + class IV 1	Class III 2 + class IV 2	Class III 3 + class IV 3	Total
Class I	≥40		< 20		≥70
Class II	< 40		≥30		≥65
Class III	< 10		≥50		< 70

5. Mainly adjust the tapping methods.

5.1 Strengthen fracturing reform to ensure the level of injection and production fluid.

5.1.1 Establish the chart of governance countermeasures for different well groups

In the process of chemical flooding development, for the well area with poor injection condition, in order to improve the injection and control the development cost, a governance process was established in which the well was flushed first, and if the well flushing was invalid, the plugging removal was carried out, and the fracturing was carried out after the plugging removal was invalid. The characteristic curve of well flushing efficiency and polymer dosage was analyzed for well groups with different injection capacities. The larger the polymer dosage, the lower the well flushing efficiency. Therefore, a chart of well groups with different injection capacities is formulated to ensure injection control strategies, among which the wells with level III capacity are mainly fracturing.

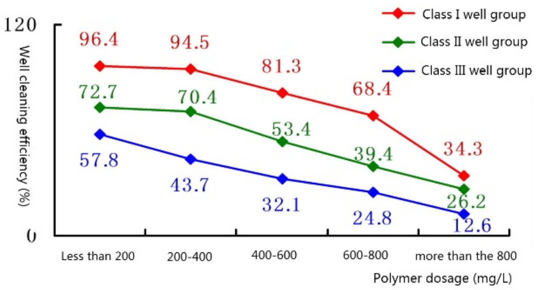
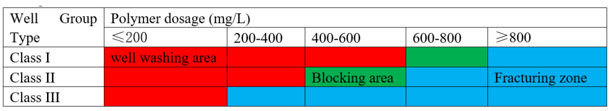


Fig. 1 Characteristic curve of well flushing effect of injection wells with different polymer dosages



Well Group Type	Polymer dosage (mg/L)				
	⩽200	200-400	400-600	600-800	⩾800
Class I	well washing area				
Class II			Blocking area		Fracturing zone
Class III					

Fig. 2 Guarantee injection of different governance strategies

5.1.2 Optimizing the fracturing method

According to the reservoir development characteristics of Class III well group with poor injection-production capacity, optimize the fracturing mode, refine the fracturing intervals, and implement the combination of multi-fractures+wide-short fractures to ensure the fracturing effect of thin and poor reservoirs:

The first is to implement injection well fracturing for well groups with thin injection and thick production;

The second is to implement fracturing of production wells in well groups with thick injection and thin production;

The third is to implement the corresponding fracturing of injection and production wells with the well spacing mainly based on thin injection and thin production;

The fourth is to develop well groups in large areas and thin layers, and implement regional overall fracturing.

Table 5 Situation table of fine fracturing intervals of different types of oil layers

Project	Class II oil layer	Class III oil layers are dominant.	Contrast difference
Effective fracturing of single well (m)	3.5	5.0	+1.5
Number of fracturing intervals (each)	4.8	7.5	+2.7
Fracturing interval with small layers (each)	4.2	2.1	-2.1
Effective fracturing of single layer (m)	1.4	0.6	-0.8
Fracturing thickness ratio of oil layer less than 1m (%)	36.2	75.0	+38.8

5.1.3 Optimization of fracturing countermeasures

The scale of outburst fracturing will be put into production to ensure the effective production of low permeability layers.

In view of the fact that the wells with a large proportion of thin and poor wells are difficult to produce, fracturing production is implemented. Fracturing operation is mainly carried out for wells with low permeability layer accounting for more than 40%, and the proportion of fracturing operation is 40.1%. After operation, the injection concentration is 2112mg / L and the injection viscosity is 26.2mpa S above, the proportion of liquid absorption thickness of low permeability reservoir is 50.2%.

highlight balance, effectively tap potential and improve injection production capacity of well groups.

Timely implement fracturing for well groups with poor injection and production capacity and large liquid production decline to ensure the injection and production capacity and oil increase multiple in the whole process.

For example, in the peak period of well a, the maximum water cut decreases by 18%, the maximum liquid production decreases by 72%, and the liquid production intensity before fracturing is 4.1T / M.D, which is lower than the average level of the block. The injection pressure of the four injection wells connected is high, the average allowable injection pressure difference of a single well is 0.3MPa, the production of thin and poor layers in the well group is poor, and the production proportion of oil layers below 1m is less than 30%. There are 1 fracturing production well and 3 injection wells in the well group. The proportion of fracturing layers in the oil layer below 1m is 65%, and the proportion of fracturing thickness is 84%. After fracturing, the injection production capacity of

the well group remains stable, the average oil pressure of a single well decreases by 2.5MPa, the daily liquid increase at the initial stage is 42t, the daily oil increase is 17.7t, the water cut decreases by 13.5 percentage points, and the cumulative oil increase is 1965 t. EOR was 8.51%, 0.56 percentage points higher than that of the whole region.
Prominent pressure equalization adjustment to ensure underground working viscosity.
For injection wells with high injection pressure, low injection viscosity, and poor well group effectiveness, implement fracturing and viscosity-raising adjustment to maintain the effect of chemical flooding in the well area. For 9 fracturing in ineffective wells and 26 fracturing in poor wells, the injection viscosity increased by 4.6 mPa.s after the measures, and the water cut further decreased by 4.0 percentage points.
Accumulatively, 260 wells were fractured in the block, of which 226 wells were fractured in wells with Class III injection-production capacity, accounting for 106%. Among them, 132 wells were fractured by injection wells, accounting for 141.9% of the number of injection wells, and the number of wells fractured less than 2 times reached 45%. Production wells were fractured 97 times, accounting for 78.9% of the number of production wells.

5.2 Optimize parameter matching and adjustment to ensure the injection quality pass rate

5.2.1 Formation of injection concentration adjustment limits for well groups with different capacities

According to the injection profile data, the characteristic curve of the relationship between injection concentration and absorbed effective thickness is analyzed, and the injection concentration range in well areas with different injection capacity is determined with the target of 80% production ratio of effective thickness. Guide the block injection concentration scheme to adjust 156 wells in three batches, including 183 wells with concentration reduction and volume reduction, with the proportion of more than 85%. The pressure difference in well areas with different injection capacity is reduced from 1.23mpa to 0.46mpa.

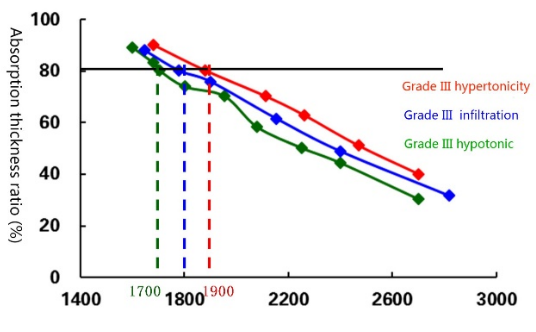


Fig. 3 The relationship between injection concentration and production thickness

Table 6 Concentration optimization table of wells with different injection capacities

Categorized well groups	Category	Permeability classification (ml)	Main slug concentration range (mg/L)
Class I	Hypotonic	less than 200	1800-2300
	Medium penetration	200-300	1900-2400
	Hypertonic	more than the 300	2100-2500
Class II	Hypotonic	less than 200	1600-2000
	Medium penetration	200-300	1800-2100
	Hypertonic	more than the 300	1800-2200
Class III	Hypotonic	less than 200	1400-1700
	Medium penetration	200-300	1600-1800
	Hypertonic	more than the 300	1600-1900

6. Stage effect analysis

6.1 Block maintains good injection production capacity.

By strengthening the fracturing transformation of well groups with class III capacity, the injection rate of the block is maintained at 0.15PV/a, and the apparent water absorption index and liquid production of classified wells are maintained at a high level. The apparent water absorption index in the main slug stage of class III well cluster is 0.33m^3/m. MPa, 0.04 m higher than other well groups m^3/m. Above MPa, the decline of liquid production is equivalent to that of other well groups.

6.2 The proportion of thickness used has improved significantly.

The water absorption ratio of the effective thickness of the block reached 80.8%, the effective thickness of the oil layer below 1 m was 72.1%, and the unproduced thickness ratio of the third-level well group decreased by 13.7 percentage points.

6.3 The third-level well group achieved good stage effect.

When the fracturing ratio of producing wells is 78.9%, the maximum water cut decreases by 10.88%, the low water cut is stable for 20 months, and the staged recovery rate is 13.43%, which is 0.42 percentage points higher than that of Class I capacity wells.

6.4 The overall development effect of the block is good.

The maximum water cut in the block decreased by 9.65%. At present, the stable period of low water cut has reached 16 months, and the enhanced oil recovery is 8.77%, 2.88 percentage points higher than the numerical model.

7. Conclusion

Chart and curve comparison method is a common method of dynamic analysis. In the case of large amount of data analysis, changing ideas and applying new and convenient classification and screening statistical methods can greatly improve the daily work efficiency.

In view of the chemical flooding blocks with three types of reservoirs as the main types, it is necessary to strengthen the fracturing reform efforts in the development process, and establish the development concept of fracturing with poor well groups, fracturing with poor well groups and fracturing with poor injection-production capacity, which can ensure that the development effect of the blocks is better than expected.

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