Analysis of the dominant seepage in high water-cut reservoirs by oilfield dynamic analysis and optimization software

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Abstract: The advantages of seepage is in the middle and later periods of the oilfield development, long-term injection water flushing formed under the change of reservoir pore permeability structure, increase the reservoir heterogeneity of change, in order to weaken the advantage of seepage affects the development effect, this paper use of high water cut oilfield adjustment and optimization software, the dynamic analysis for modeling is used to identify the advantages of seepage of the R D oilfield blocks. The static parameters and dynamic parameters are analyzed respectively, and different discriminant indexes are used to calculate water injection well and production well. The determination index of dominant seepage layer is determined for small layer in development block. The probability classification statistics and comprehensive score of daily water injection volume of water injection well are carried out to find the well layer with dominant seepage development, which is also a research direction of fine geological research.

Key words: Dominant seepage; Probability statistics; Discriminant index; Discriminant index of dominant seepage layer.

1. Geological survey

Block R is located in pure oil area L of D field. The well pattern of the development block has changed from thin to dense, and now it is in the parallel stage of tertiary oil recovery and polymer flooding. A five-point well pattern with a spacing of 141m between injection-production Wells is adopted in the block. There are many oil zones in the development block, and each well pattern basically covers all small zones.

2. Selection of predominance seepage index of water drive

By analyzing the formation principle of dominant seepage and its performance in oilfield development, the method of combining static and dynamic parameters is selected to determine the dominant seepage in water drive.

2.1 Static parameter selection

2.1.1 Software is used to analyze the formation of dominant permeability control channels

Permeability and its parameters (permeability variation coefficient, permeability level difference and penetration coefficient) are also an important aspect to identify the existence of dominant channels. The reservoir permeability of R oilfield varies greatly, and the permeability ratio between high curved distributary channel sand and outer front reservoir is 10. Due to the long-term effect of water flooding in oilfield development, the average permeability difference of oil-bearing small layer after water flooding is large, which intensifies the development contradiction and leads to the formation of dominant seepage between well groups with high permeability.

2.1.2 Formation analysis of dominant channel using software reservoir thickness control

Generally, in oilfield development, for the reservoir with better physical properties, the effective thickness of the injection is larger, the water injection and liquid production capacity is stronger, and the formation erosion is more serious. Over time, dominant seepage is easily formed between these well groups, resulting in the decrease of development efficiency. The effective thickness of single well in each small layer in block R of oilfield D is between 0.06m and 9.64m, so it is easy to form dominant seepage in some layers, especially at the bottom of thick oil layer, resulting in single-layer inrush of injected water.

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2.1.3 Software is used to analyze the differences caused by the different single-layer inrush coefficients

Reservoir anisotropy is caused by reservoir heterogeneity, and single-layer inrush coefficient is caused by the difference between upper layer and layer in longitudinal reservoir. In the development process, the injected water is easier to drive along the high permeability belt with low resistance, but avoids the low permeability belt, thus forming the inconsistency of water injection propulsion, resulting in the abnormal intensity of single-layer water injection. This result is called single-layer burst and can be expressed by single-layer burst coefficient. The single-layer inrush coefficient of each well of the main oil layer in block R of Oilfield D is between 1.0 and 5.47, and the heterogeneity of each well is quite different. Therefore, high permeability bands are easily formed in Wells with high heterogeneity.

2.2 Software dynamic parameter selection

2.2.1 The daily injection volume increases with constant injection pressure

In stable oilfield development, after excluding the influence of engineering factors, the large increase of injection water is one of the signals of dominant seepage formation when injection pressure is constant. Therefore, the larger the water injection volume is, the greater the corresponding water injection intensity is likely to be, and the more likely there is a dominant seepage horizon. Considering the obvious thickness difference between injection-production units, the relatively reasonable water injection intensity is defined.

2.2.2 The oil pressure of injection with constant injection volume decreases

In the development process, by comparing the water injection curve, it can be known that considering formation factors, the water injection capacity of the injection well remains unchanged, but if the water injection pressure becomes low, it means that the seepage resistance between the well groups becomes smaller, and there may be dominant seepage. The lower the injection pressure, the greater the possibility of dominant seepage flow.

2.2.3 See water absorption index change degree is big

The apparent water absorption index of injection well refers to the average daily water absorption of oil layer per meter thickness of injection well under unit wellhead water injection pressure. It can reflect the size of water absorption capacity of water injection well. Depending on the mutation of water absorption index, it also indicates the change of reservoir properties to a certain extent. Through empirical analysis, it can be known that the apparent water absorption index changes steadily before the formation of dominant seepage, while it rises suddenly after the formation. According to the analysis of the development curve, for a specific time point, the higher the apparent water absorption index, the more likely there is to be dominant seepage.

2.2.4 The cumulative water injection per unit thickness is large

The difference of cumulative water injection per unit thickness represents the difference of water absorption capacity of reservoir, and also reflects the difference of connectivity and conductivity of reservoir. The larger the cumulative water injection per unit thickness, the stronger the water absorption capacity of the reservoir, and the greater the possibility of dominant seepage.
Evaluation indexes of influencing factors of low-efficiency circulating Wells are shown in Fig. 1.

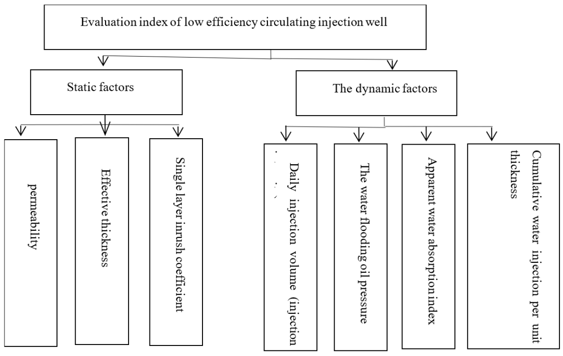

Fig. 1 Evaluation index diagram of low efficiency circulating injection well

For the oil well, three dynamic indexes of daily fluid production, water cut and cumulative fluid production per unit thickness are selected to judge the oil well with low efficiency circulation.

2.2.5 The daily liquid quantity does not increase

After dominant seepage is formed, the seepage resistance between oil and water Wells decreases, and the injected water forms low efficiency circulation between oil and water Wells. Under the condition that the difference of injection-production pressure between a production well and its corresponding injection well remains unchanged, the fluid production increases rapidly. Therefore, in the absence of measures, the greater the daily fluid flow, the more likely there is dominant seepage.

2.2.6 The water content decreased more without cause

Another prominent manifestation of dominant seepage is water content. After dominant seepage is formed, injected water will burst along the highly permeable strip, and the swept area of water will be reduced, and the displacement efficiency of remaining oil other than the dominant seepage will be reduced, resulting in abrupt change of water content. At present, the block has entered the ultra-high water cut development stage, and the water cut of all Wells in the area is generally very high, which also proves the possibility of the existence of dominant seepage. For each production well, the higher the water cut, the greater the possibility of dominant seepage.

2.2.7 The cumulative fluid yield per unit thickness is large

The difference of cumulative fluid production per unit thickness represents the difference of water absorption capacity of reservoir, and also reflects the difference of connectivity and conductivity of reservoir. The higher the cumulative fluid production per unit thickness, the higher the water absorption capacity of the reservoir, the more likely there is an inefficient cycle.
Evaluation indexes of influencing factors of low-efficiency circulating oil Wells are shown in Fig. 2.

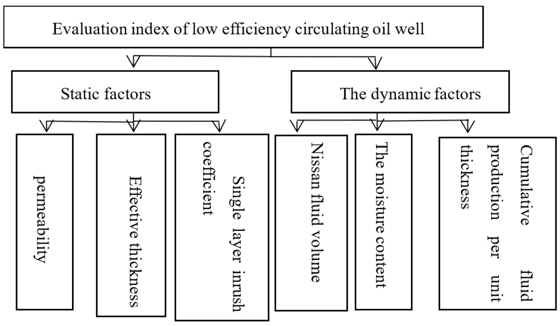

Fig. 2 Schematic diagram of evaluation index of low efficiency circulating oil well

3. The dominant seepage layer is determined by software

Some dynamic and static indexes of oil and water Wells are still needed to determine the dominant seepage horizon. From the point of view of sedimentary facies zone map, the Wells in the same layer are located in different sedimentary microfacies, and the same well also has different sedimentary characteristics in different layers. Therefore, for interconnected oil and water Wells, the connectivity depends on the sedimentary microfacies of each well. The distance between oil and water Wells also affects the formation of low-efficiency circulating bands. The smaller the distance between oil and water Wells is, the shorter the migration distance of injected water in the formation is, and the smaller the affected area is. Therefore, the more serious the erosion of reservoir structure on the mainstream line is, and the more likely dominant seepage is formed. In addition, the effective thickness and permeability of small zones are different from each other. It is obvious that the injected water will preferentially advance into the zones with large effective thickness and high permeability, forming low-efficiency circulating bands over time. The above are the static parameters that affect the formation of the dominant seepage horizon, and also the parameters selected for the determination of the dominant seepage horizon.

After dominant seepage appears, injected water will flow in this layer in a way similar to pipe flow. As production time goes on, the cumulative injected pore volume multiple of Wells in this layer is much larger than that of other layers, and the oil displacement efficiency is greatly improved, and the remaining oil saturation is greatly reduced.
To sum up, the analysis and determination indexes of the selected dominant seepage layer are as follows: connectivity relationship of small layer sand body between oil and water well, distance between oil and water well and static state of injection well (effective thickness and permeability of single layer), dynamic parameters of stratified production (oil well: single layer oil displacement efficiency, water well: multiple of single layer cumulative injected pore volume).

4. Use software to analyze block application examples

Accurate geological modeling of R development block shows that the actual geological reserves of the target layer are 1322.34× 104T, and the calculated geological reserves are 1320.66× 104T, with an error of 0.127%. The actual comprehensive water cut of R oil layer in D oilfield is 92.49% by February 2019, and the historical comprehensive water cut is 92.40%. The absolute error is 0.09. The geological model of the block is used to extract and calculate the discriminant index of the dominant seepage flow, and detailed analysis is carried out.

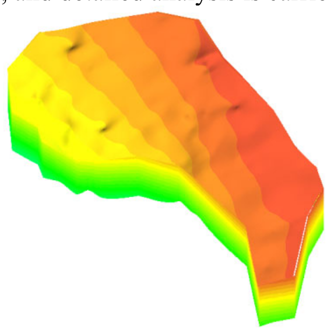

Fig. 3 Geological modeling of Block 405

4.1 The probability distribution of water flow of injection-production unit in this block is analyzed by software

Under the condition that the development block meets two basic conditions, that is, the well pattern is basically stable, and the production and injection volume is basically stable. The probability distribution of daily water injection in injection-production units during the recent period of relative stability was counted (see Fig. 4), and the composition proportion of water flow in different levels was analyzed to reasonably delimit the boundary of dominant water flow.
The blue curve as samples, the cumulative probability red curve for injection probability, occupy 90% of the amount of data curve can show sample injection of sample data points only accounts for the total injection amount of less than 40%, other 10% of the data sample of injection

accounted for more than 60%, there are advantages that 10% of the sample flow (dominant).

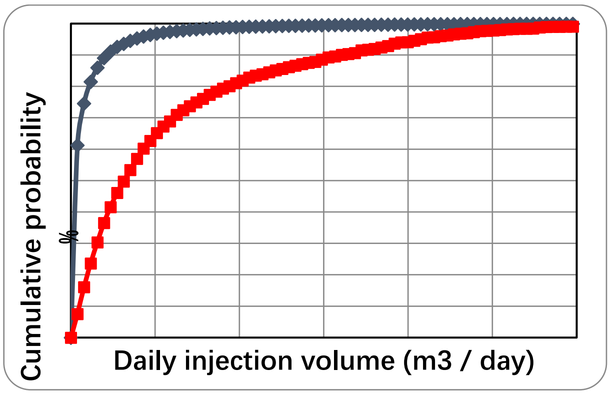

Fig. 4 Cumulative probability statistical chart of daily injection quantity

4.2 Selection of dominant seepage flow between injection-production units

The total score screening method is used to calculate the overall advantage coefficient D, as shown in the following formula:

$$D = A \times W_1 + B \times W_2 + C \times W_3$$

Among them, the dominant coefficient of water injection intensity oilfield A, the dominant coefficient of water injection intensity well group B, and the dominant coefficient of water injection capacity C;, and are the weight coefficients. In practical application, A is the most important and 0.5 can be given; B. 0.3; C Finally, you can give 0.2. According to the overall dominance coefficient, the injection-production units were sorted from large to small, and the top 30% injection-production units were initially selected as candidates for the dominant flow channels.

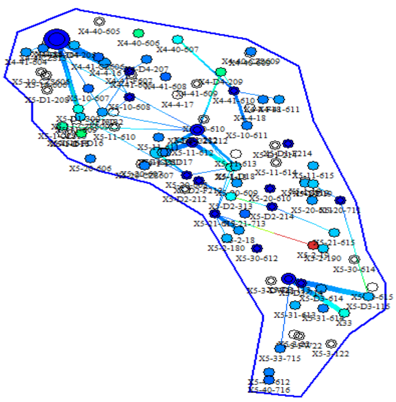

Fig. 5 Flow pipe diagram of dominant seepage flow in S28 layer

The total pore volume of the development well layer in block R of oilfield D is 2,4024,260 m³, and a total of 2,345 oil-water well connectivity relations are obtained through statistics. The dominant seepage score is calculated by software, ranging from 0 to 10 points, and the dominant seepage pore volume is summed up to 372,735 m³ if the score exceeds 6.0. The data samples of the top 1% of the score (16) are the dominant seepage we seek, as shown in the table below.

Table 1. Statistical Table of dominant Seepage well layers in BLOCK R of oilfield (score >6.0)

Wells	horizon	oil well	Final score /10 points	Average daily note /day	Sweep fraction	oil wellmoisture content/%	Well spacing / meter	Interwell permeability /mD	Remaining reserves / ton	Movable remaining reserves / ton
W1	B17	Z1	8.63	46.597	0.197	96.4	553.7	171.6	11575	3030
W2	B17-1	Z2	6.67	18.444	0.888	91.4	284.9	35.3	5685	1768
W3	B21	Z3	9.3	48.383	1	87.8	341.7	216	5689	1886
W4	K33-1	Z4	6.56	18.94	0.731	75.9	203.1	46.1	5124	1937
W5	K29	Z5	6.82	17.593	0.945	95.1	215.7	167	2391	669
W6	K311	Z6	6.11	9.692	0.412	89.2	296.4	89	1173	380
W7	K32-1	Z7	6.64	18.369	0.786	89.4	271.9	235	4651	1504
W8	K37-1	Z8	6.5	17.614	1	96.6	235.1	668	532	137
W9	K39-1	Z9	6.8	18.582	0.887	92	304.6	12.6	2406	739
W10	B1332	Z10	6.22	14.797	0.121	94.1	218.5	569	105012	30421
W11	B23	Z11	6.45	15.01	1	87.2	370	128	3287	1100
W12	B23	Z12	6.11	14.267	1	86.9	319.6	100.2	11022	3712
W13	K214	Z13	7.9	30.055	1	96.2	250.9	263	1099	291
W14	K211-2	Z14	7.92	30.505	1	91.2	298.9	352	3959	1239
W15	K21-2	Z15	6.41	16.179	0.877	93.2	147.9	141.8	3737	1114
W16	B1212	Z16	6.64	19.237	0.12	97.8	418.4	924.3	35439	8251

4.3 Classification determination of dominant seepage horizon

The discriminant index of dominant seepage layer is applied to make statistics on the dominant score of the exploitation layer in block R of D oilfield, and certain grades are given according to the development of dominant seepage. As the main oil layer is well developed in physical properties, it is regarded as a key layer of concern, so it is classified as a higher development level (8). Other formations with lower comprehensive dominant seepage score are not classified as grades. The specific classification of development blocks is shown in the following table:

Table 2. The specific classification of development blocks is shown in the following table:

Development level	horizon	Dominant seepage score
Higher development	B142-1	2.40
	B17	2.19
	B111	0.62
	B112	1.48
	B1212	3.49
	B122	1.14
	B132	3.07
	B1332	4.29
Secondary development	K25-1	1.88
	B21	1.82
	K211-2	1.80
	K25	1.66
	B17-1	1.57
	K34	1.51
Lower development	B211	1.42
	K215-1	1.27
	K21-2	1.24
	K28	1.19
	U13-1	1.12
	U1102	1.11
	U12-1	1.11
	U18	1.09
	K210-1	1.09
	B23	1.07
	B22-1	1.03
	K29	1.03

5. Conclusion

1. For dominant seepage flow, we should start with geological static factors and development dynamic factors, and make a comprehensive analysis combined with production data, which is conducive to the accuracy of discrimination and identification.
2. Oilfield dynamic analysis software can be used to better classify and calculate the development of dominant seepage flow, which has a good auxiliary role in fine geological research.
3. For the identified seepage channels, relevant governance measures should be formulated to improve the development effect from the Angle of interlayer contradiction and plane contradiction.
4. In the analysis of development blocks, we should not only pay attention to the development of dominant seepage in a single well, but also start from the single layer, classify the dominant seepage, and make personalized attention and adjustment, so as to reduce the occurrence of interlayer contradictions.

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