Analysis of well and layer selection method for fracturing displacement in thin-and-poor layers in the transition zone of A Oilfield

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Abstract: This paper mainly provides the well and layer selection method of fracturing displacement. It mainly solves the problem of insufficient formation energy and lack of forming effective communication between oil and water wells, resulting in poor water injection capacity in thin-and-poor layers, poor oil well production capacity, formation deficit and poor seepage capacity. The research includes the following two parts. (1) Target wells were optimized by selecting those with relatively perfect injection production relationship, poor oil-water well connectivity and long-term formation deficit. The water injection wells should be those with porosity, low air permeability and some development potential. They are required to meet the construction requirements of large capability of fracturing fluid injection into water wells. (2) Target layers were optimized based on the selection of the injection-production relationship of the target well, reservoir development thickness, interlayer thickness, liquid production, liquid production intensity, formation pressure, production situation and other parameters. Then, the sedimentary unit with poor production and high potential is selected as the target layer. This method improves the effect of stimulation and development in thin-and-poor layers.

Key words: Transition zone; fracturing oil displacement; well and layer selection.

1. Background

At present, the conventional selection for well and layer fracturing mainly focuses on the well layers with pollution whose reservoir seepage requires improvement. It improves oil production by changing the seepage conditions of the formation within a small domain, removing reservoir pollution and improving reservoir seepage capacity. However, the fracturing oil displacement technology mainly selects thin-and-poor layers, energy deficit layers and poor seepage layers. Large-scale oil displacement fluid was injected into the water injection well to supplement the formation energy. The seepage capacity was improved between the oil production well and the water injection well within a large domain. Then, the water injection well and the oil production well with a spacing of 200m or more can be effectively connected. Therefore, the conventional fracturing well and layer selection method is not suitable for fracturing oil displacement technology.

2. Technical methods

2.1 Optimization of target wells

We select the wells of relatively complete injection-production relationship, poor oil-water well connectivity and long-term formation deficit. The water injection wells of the selected well group shall be those with low porosity, low air permeability, an average porosity range of 17-25% and air permeability of 20-30md, poor or no water absorption for a long time, and the injection production well spacing range of 150-300m. In addition, they should be with large spacing between injection production wells, poor production of the well group, enrichment of remaining oil and certain potential for tapping. The operational requirements of pressure fracturing for water injection wells should be met considering the ground condition, cementing quality and casing damage.

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2.2 Optimization the target layer of the target well

Parameters were optimized on the selected wells including injection production relationship, reservoir development thickness, interlayer thickness, liquid production, liquid production intensity, formation pressure, production situation, geological reserves of single sand layer, water cut level, recovery degree. The target layers are those sedimentary units with poor production and high potential. The calculation of formation deficit was completed by the balanced injection-production ratio method. The five-point water injection method is taken as an example, as shown in Figure 1.

$$Q_1 = Q_a h_2 / (h_1 + h_2 + h_3 + h_4)$$

$$Q_2 = Q_b h_5 / (h_5 + h_6 + h_7 + h_8)$$

$$Q_3 = Q_c h_9 / (h_9 + h_{10} + h_{11} + h_{12})$$

$$Q_4 = Q_d h_{13} / (h_{13} + h_{14} + h_{15} + h_{16})$$

Where H1, H2, H3,... and H16 are the connecting thickness between oil and water well; a, b, c and d are the four oil wells; Q_a , Q_b , Q_c and Q_d are the cumulative liquid production of corresponding oil wells; Q_1 , Q_2 , Q_3 and Q_4 are the amount of liquid provided by well a to corresponding oil wells. The cumulative injection liquid is calculated as follows.

$$Q = Q_1 + Q_2 + Q_3 + Q_4$$

The cumulative injection volume of well a is P . If $Q > P$, the formation is in deficit.

Specifically, the well group is comprised of an oil well which is connected to four water wells. The number ratio of oil and water wells is 1:1. The water well A provides water to surrounding oil wells a, b, c and d. The oil well a is supplied with water from the well A and its liquid production becomes $Q_1 = Q_a h_2 / (h_1 + h_2 + h_3 + h_4)$ where the proportion of liquid production equals the connection thickness between wells a and A divided by the thickness between the well a and its surrounding connected water wells. Similarly, the water supply of oil well b from well A becomes $Q_2 = Q_b h_5 / (h_5 + h_6 + h_7 + h_8)$, where the proportion of liquid production equals the connection thickness between wells b and A divided by the thickness between the well b and its surrounding connected water wells. For the oil well c, its water supply from well A becomes $Q_3 = Q_c h_9 / (h_9 + h_{10} + h_{11} + h_{12})$, where the proportion of liquid production equals the connection thickness between wells c and A divided by the thickness between the well c and its surrounding connected water wells. For the oil well d, its water supply from well A becomes $Q_4 = Q_d h_{13} / (h_{13} + h_{14} + h_{15} + h_{16})$, where the proportion of liquid production equals the connection thickness between wells d and A divided by the thickness between the well d and its surrounding connected water wells. For the water injection well A, the sum of the cumulative liquid production of its four surrounding oil wells is $Q = Q_1 + Q_2 + Q_3 + Q_4$. If the cumulative water injection from the water well A is less than the liquid production from its four surrounding oil wells due to water injection, it confirms that the formation is in deficit. This method of calculating the formation deficit is referred to be as the balanced injection-production ratio method.

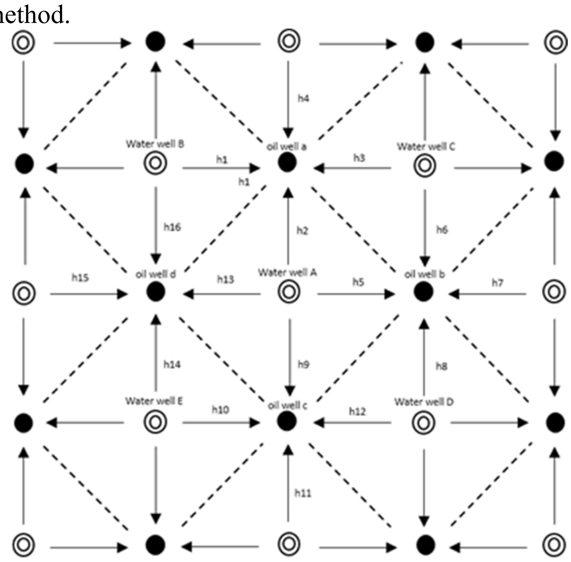

Fig. 1 Schematic of water injection by the five-point method

It guarantees the requirements for improving the overall development effect of the well group. Because the connectivity of thin-and-poor layers of selected wells are improved, the recovery degree of thin layers of connected wells are increased. For the water wells, the injection capacity is greatly improved following the field operations. This improves the water absorption in thin-and-poor layers and the degree of water drive control is improved.

3. Field Cases

Within the selected wells, parameters were considered for optimization which included injection production relationship, reservoir development thickness, interlayer thickness, liquid production, liquid production intensity, formation pressure, production situation, geological reserves of single sand layer, water cut level, recovery degree. The results are that 13 sedimentary units with poor production and high potential are selected as the target layers, such as CII11, CII12, CII13, CII41, CII42, CII50, CII92, CII100, CII111, CII112, CII114, CII115 and CII120.

The geological reserves of single sand-layer of well A-10-XIE 117 are calculated as follows. The well c-10- XIE 117 was injected in July 2012, where 29 sedimentary units were shot. The sandstone of CII formation was shot with 17.5m length and the effective thickness is 3.9m and geological reserves reaches 13298 tons. The geological reserves of single sand-layer are calculated according to the geological reserves, sand body characteristics, single sand-layer thickness, reservoir physical properties and other parameters. Table 1 shows the geological reserve of each interval of the well.

Finally, according to the parameters such as interlayer thickness, production situation and reservoir physical properties, the target layers are divided to specific intervals according to the principle of similar production situation and reservoir physical properties. It is divided into 4 fracturing intervals. The thickness of fractured sandstone is 11.8m and the effective thickness is 3.3m. Table 2 shows the division of each interval of the well.

Table 1 The geological reserves of each interval of the well A-10-XIE 117

Layer #	Thickness (m)			Formation pressure (MPa)	Geological reserves (t)	Recovery degree (%)
	Interlayer thickness	Sandstone thickness	Effective thickness			
$CII1_1$	1.6	0.6		8.46	178	22.4
$CII1_2$	0.6	0.6		8.34	178	21.4
$CII1_3$	4.8	0.5	0.3	8.33	409	50.5
$CII2_0$	2.2	0.8		8.12	238	22.7
$CII3_1$	0.6	0.4		8.34	162	25
$CII3_2$	0.8	0.6	0.6	8.39	315	8.1
$CII3_3$	4.4	0.6		8.9	242	6.7
$CII4_1$	1.5	1.1		8.65	1096	9
$CII4_2$	3.2	0.6		8.5	178	10.3
$CII5_0$	4.2	2.3	1.4	8.57	3251	20.6
$CII7_1$	0.4	0.4		8.53	197	10.3
$CII7_2$	1.1	0.5		8.79	149	8.7
$CII8_1$	1.4	1.1		8.77	327	6.3
$CII8_2$	0.6	0.8		8.98	238	12.8
$CII9_1$	2	0.5		9.02	175	10
$CII9_2$	4.8	0.8	0.4	8.61	1606	24
$CII10_0$	1.5	0.5		8.94	149	2.7
$CII11_1$	3.3	1.1		8.98	1105	22.8
$CII11_2$	1.7	1.1	1.2	9.48	1606	4.2
$CII11_4$	0.7	1.5		9.93	1172	24
$CII11_5$	1.3	0.5		9.64	149	5.6
$CII12_0$	60.1	0.6		9.91	178	4.8
合计		17.5	3.9	8.83	13298	15.1

Table 2 The division of each interval of the well A-10-XIE 117

Sub-layer #	Perforated interval (m)		Thickness (m)			Fracturing stuck section
	from	to	interlayer	Shoot	Effective	
$CII1_1$	1059.1	1058.5	1.6	0.6		一
$CII1_2$	1061.3	1060.7	0.6	0.6		
$CII1_3$	1062.4	1061.9	4.8	0.5	0.3	
$CII2_0$	1068	1067.2	2.2	0.8		
$CII3_1$	1070.6	1070.2	0.6	0.4		
$CII3_2$	1071.8	1071.2	0.8	0.6	0.6	
$CII3_3$	1073.2	1072.6	4.4	0.6		
$CII4_1$	1078.7	1077.6	1.5	1.1		二
$CII4_2$	1080.8	1080.2	3.2	0.6		
$CII5_0$	1086.3	1084	4.2	2.3	1.4	
$CII7_1$	1090.9	1090.5	0.4	0.4		
$CII7_2$	1091.8	1091.3	1.1	0.5		
$CII8_1$	1094	1092.9	1.4	1.1		
$CII8_2$	1096.2	1095.4	0.6	0.8		
$CII9_1$	1097.3	1096.8	2	0.5		
$CII9_2$	1100.1	1099.3	4.8	0.8	0.4	三
$CII10_0$	1105.4	1104.9	1.5	0.5		
$CII11_1$	1108	1106.9	3.3	1.1		
$CII11_2$	1112.4	1111.3	1.7	1.1	1.2	四
$CII11_4$	1115.6	1114.1	0.7	1.5		
$CII11_5$	1116.8	1116.3	1.3	0.5		
$CII12_0$	1118.7	1118.1	60.1	0.6		

The technical operations were completed for the well A-10-XIE 117 on November 17, 2017. A total of 10320 631m3 of oil displacement fluid was injected. After that, the pipe string could not be pulled out and required overhaul. This well was re-opened after the overhaul on March 15, 2018. The injection capacity was greatly improved. Up to now, the cumulative water increase is 43881m3.

Four effective oil wells are connected to the well A-10-XIE 117.The injection allocation was increased from 50m3 to 65m3 on May 3, 2018. On May 7, 2018, the water injection was temporarily increased to 80m3.

After the implement of the selection of well and layer, large-scale oil displacement fluids were injected. The connection relationship was improved for the thin-and-poor layers between water-injection and production wells. The current connection distance is 3.5 times that of the original one. The water injection volume of the injection well is 79m3 compared to zero. The injection pressure is reduced from 13Mpa to 10MPa, and the average liquid production intensity of the oil well is increased from 1t / D.M to 6t / D.M. The utilization degree of thin-and-poor layers was increased from 31% to 55%. Up to October 31, 2019, the functional period reached 922 days, with a cumulative increase of 1041t.

4. Conclusions

This method can effectively select the well layers with long-term formation deficit and poor connection between production and water-injection wells. The connecting distance between the production and water-injection wells is more than 3 times of the original connecting distance, which greatly improves the seepage capacity of the fluid. This improves the production capacity, and the purpose of increasing production and oil was met. It also provides a necessary guarantee for improving the overall development of the well group. The connectivity of thin-and-poor layers of selected wells is improved, which increases the recovery degree of small layers of connected wells. For the water injection well, the injection capacity is greatly improved. The water absorption of thin-and-poor layers is improved, and the degree of water drive control is also improved.

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