Design and Effect of Micro Nano Robot in Fracturing and Oil Displacement Technology of Three Types of Reservoirs

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Abstract. Aiming at the problems of many types of sand bodies, poor reservoir physical properties, low recovery degree, scattered residual oil, large adsorption capacity, and difficult chemical flooding in the development process of the third type reservoirs in Sazhong Development Zone, the "fracturing oil displacement" technology is proposed, which can form a high-speed channel by fracturing long fractures, and quickly send high-efficiency oil displacement agent to the remaining oil enrichment position through fractures, It can reduce the contact time and distance between the chemical agent and the formation, reduce the loss of chemical agent performance along the injection process, improve the utilization efficiency and enhance the oil displacement effect.

Keywords: Three kinds of reservoir · Fracturing and oil displacement · Alkali surface binary system

1 Introduction

With the growth of the world economy and the improvement of people's quality of life, the world's demand for oil is also growing. As a limited renewable resource, oil has become an important factor affecting the sustainable development of the world economy. At present, China's dependence on foreign crude oil has exceeded 55%, but the domestic old oil fields are in short supply due to the increase of exploitable burial capacity year by year. Except for the long-term diesel war, Xinjiang Oilfield and Qinghai Oilfield, other oilfields have entered the stage of production reduction year by year. The main development oilfields have entered the late stage of high or ultra-high function. In addition, the distribution of remaining oil is complex and it is difficult to develop and adjust.

According to the reservoir classification standard of Daqing Oilfield, the reservoirs in Xingbei development zone are divided into primary reservoirs and Tertiary reservoirs. The geological reserves of class I reservoirs account for 35.5% of the whole region. Some blocks have entered the subsequent water injection stage of polymer flooding, and strong alkali composite flooding has also been applied in industry. With the application of the

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tertiary oil recovery technology, the recoverable reserves of the main layer in Xingbei development zone are gradually decreasing, and the oilfield is facing the situation of insufficient recoverable reserves for continuous and stable production. However, 64.5% of the geological reserves in Xingbei development zone are located in class III oil layers, which are rich in reserves. However, the geological reserves are mainly distributed on the surface, accounting for 87.3%, with high mud content and poor physical properties. The third type of recovery is low, but the remaining oil is dispersed in each storage group. The tertiary recovery factor of the main reservoir in Shengli Oilfield is about 10%, and that of the main reservoir in Daqing Oilfield is more than 20%. It shows that the tertiary recovery of the main reservoir is good. The first part introduces the relevant background and significance of this paper, the second part is the related work of this paper, and the third part is design method of fracturing and oil displacement technology for three kinds of reservoirs. The fourth part is field effect of fracturing and oil displacement in class III reservoir. The fifth part is conclusion.

The third type of oil layer test area in Sazhong Development Zone is mainly composed of Pu I5 + 6_1−7 and Pu II formation, belonging to delta inner and outer front facies.

2 Related Work

Based on the theory and technology of combined stimulation, Su et al. presented an application of the combined stimulation technology to a low-deliverability CBM well in the Sunan Syncline, Anhui Province, China [1]. Wu et al. improved the fracturing effect of this kind of reservoir [2]. As the fracturing modeling and stimulation technology advances question: “Can use the fracturing modeling and reservoir simulation technologies to optimize well energy supplement and cluster spacing based upon Fracture Controlling Fracturing (FCF) technology, which is the latest concept for stimulation technology with successful applications in China’s unconventional oil and gas development?” [3]. Due to the limited volume of reconstruction, the production decreases rapidly, which makes it difficult to achieve the purpose of economic and effective exploitation [4]. Theoretically, the mechanical model of the intersection of HF and NF is established, and some judgment criteria are put forward [5]. Therefore Wang et al. investigated the evolution of crack initiation and propagation in a hydraulic rock mass under various stress conditions [6]. In line with the complex geological characteristics of ultra-deep oil and gas reservoirs in China, seven technical development directions are proposed: (1) To establish systematic new techniques for basic research and evaluation experiments; (2) to strengthen geological research and improve the operational mechanism of integrating geological research and engineering operation; (3) to develop high-efficiency fracturing materials for ultra-deep reservoirs; (4) to research separated layer fracturing technology for ultra-deep and hugely thick reservoirs; (5) to explore fracture-control stimulation technology for ultra-deep horizontal [7]. for the multistage for flooding, there are many ways to handle the openhole, however, there is little dangerous for worker, in the openhole completion, the fracturing technology is used, so it will reduce the dangerous, so the author research the fracturing openhole technology for flooding, it will slow the pressure and get good reservoir for production [8]. Therefore, the research on EOR and optimized combined flooding technology of three flow reservoir is carried out to provide technical support for the production of three flow reservoir. After years of development, the total water content of the three reservoirs has reached 91.3%. However, the development of water cycle is difficult and the economic benefit is low. In the combined oil displacement test of three flow reservoir, the combined oil displacement of three flow reservoir can improve the oil recovery by 5%.

3 Strong Reservoir Heterogeneity

The research shows that the heterogeneity of Pu I5 + 6_1–7 layer is mainly manifested in the large permeability difference between single wells, mainly in the medium permeability layer; the reservoir of Pu II group is mainly in the low permeability layer between single wells. In general, the heterogeneity of the three types of reservoirs is more serious than that of the first and second types of reservoirs.

3.1 The Vertical and Upward Watered Out Thickness Proportion of Pu II Formation is Large, and the Remaining Oil Distribution is Scattered

The vertical immersion thickness ratio of the two groups was 89.5%, mainly concentrated at the middle nozzle. Reservoir immersion conditions vary with thickness. The effective oil layer thickness ≥ 0.5 ~ 1 m is mainly medium jellyfish, and the effective oil layer thickness of 0.2−0.5 m is mainly oil layer. The average functional saturation of complex reservoir is 46.86%. There are two types of residual oil. The first type is incomplete residual oil, which is mainly distributed in layer 5 and 10 of Fuer 2. Secondly, the remaining oil with low water absorption is mainly distributed in fu24, fu6 and fu9 layers. The potential of the remaining oil in this reserve is difficult to develop.

3.2 Each Small Layer of the Third Type Reservoir has High Water Cut and High Production Degree

At the initial stage of production, the water cut of the third type reservoir test area is 91.8%. The test data in the second half of 2005 show that the average thickness of sandstone and the effective thickness of liquid are 82.9% and 87.9% respectively. In the range of 0.2–0.4 m, the number of non main sand producing layers accounts for 60.7%, the thickness of sandstone accounts for 83.8%, and the effective thickness accounts for 62.4%; in the range of 0.5–1.0 m, the number of small layer producing liquid layers accounts for 75.6%, the thickness of sandstone accounts for 89.8%, and the effective thickness accounts for 79.1%; and in the case of ≥1.0 m, the liquid producing condition of small layer is 100%. The test results show that each sub layer has high water content, only Pu II1 sub layer has water content lower than 90%.

$$
\begin{aligned}
||\Delta x_{k+1}(t)||e^{-\lambda t} &\le e^{-\lambda t}\int_0^t e^{(pk_f+m_2+m_3)(t-\tau)}(m_1||\Delta u_k(\tau)|| + pd)d\tau \\
&\le m_1\int_0^t e^{(pk_f+m_2+m_3-\lambda)(t-\tau)}e^{-\lambda t}||\Delta u_k(\tau)||d\tau + pd\int_0^t e^{(pk_f+m_2+m_3)(t-\tau)}d
\end{aligned}
\tag{1}
$$

4 Design Method of Fracturing and Oil Displacement Technology for Three Kinds of Reservoirs

4.1 Well and Layer Selection Design Object and Method

4.1.1 Well and Layer Selection Criteria for Production Wells

The selection of injection wells (production wells) and injection layers for fracturing flooding in three types of reservoirs is based on the construction purpose, so as to solve the prominent contradiction of three types of reservoirs. The selection of production wells mainly includes the following three types.

(1) The wells and layers whose recovery degree is lower than that of the whole area, residual oil is highly scattered, and the effect of conventional fracturing measures is not good. The physical property development of most of these wells is lower than the average level of the whole area, and there are many types of sand bodies, serious interactive distribution and other problems. At the same time, in the late stage of chemical flooding, because the recovery degree is lower than the level of the whole area, the reserves are bound to be sealed after this round of chemical flooding, resulting in a certain degree of loss of recoverable reserves in chemical flooding stage.
(2) The wells with serious formation energy deficit are usually the ones with slow recovery rate of fluid volume and low formation energy after long-term shut in or drilling down. At this time, the water cut rises rapidly. The oil gas water three-phase flow is produced near the well due to the degassing of formation crude oil, so the fracturing oil displacement method can be used to quickly supplement the formation energy. The above two types of oil wells also need to have a certain number of connected directions. Because the later stage of fracturing oil displacement needs to further supplement the formation energy through water injection (or polymer flooding/ASP flooding), the oil and water wells need to have a certain connection relationship, at least two directions of connection.

$$\lim_{k\to\infty} ||\Delta x_{k+1}(t)||_\lambda \le m_1 \frac{1-e^{(b-\lambda)t}}{b-\lambda}\frac{1}{1-\breve{\rho}} m_5 d + pd\frac{1-e^{bt}}{b}$$
$$= \left(m_1 \frac{1-e^{(b-\lambda)t}}{b-\lambda}\frac{1}{1-\breve{\rho}} m_5 + p\frac{1-e^{bt}}{b}\right) d \le \left(\frac{m_1 m_5}{b-\lambda}\frac{1}{1-\breve{\rho}} + \frac{p}{b}\right) d \qquad (2)$$

(3) The isolated well point usually has no injection production relationship or the injection production relationship is very imperfect. For example, the production well at position (1) in Fig. 1 is only supplied by one injection well and the well spacing is far away. At this time, the remaining oil in the non mainstream direction is relatively rich. The oil displacement by oil well fracturing can supplement the formation energy, release the remaining oil in some isolated well points and increase the production degree. Fault edge well is also a kind of isolated well point, which usually displaces oil by formation pressure elasticity between fault and production well, but there is no follow-up energy supplement. As shown in Fig. 1, there is no effective supply between the production well at position ② and fault, and the fault edge is still rich in residual oil. Therefore, through

reverse fracturing, the formation energy can be supplemented, and the dual effects of huff and puff and oil displacement can be exerted.

4.1.2 Injection Well Selection and Well Layer Selection Criteria

In the selection of injection wells, the wells with low injection rate and high start-up pressure should be selected. Through fracturing and oil displacement, high efficiency oil displacement agent is injected into thin and poor oil layers at one time to improve formation pressure and quickly achieve start-up pressure. At the same time, in some areas of the north, when the injection volume of the well is less than 8 m^3/D, the well must be closed in winter to prevent the freezing of the surface system. Therefore, if fracturing and oil displacement are carried out before the well is closed in winter, the normal production of the oil well in the past half a year can be guaranteed, and the effect of advanced water injection can be achieved.

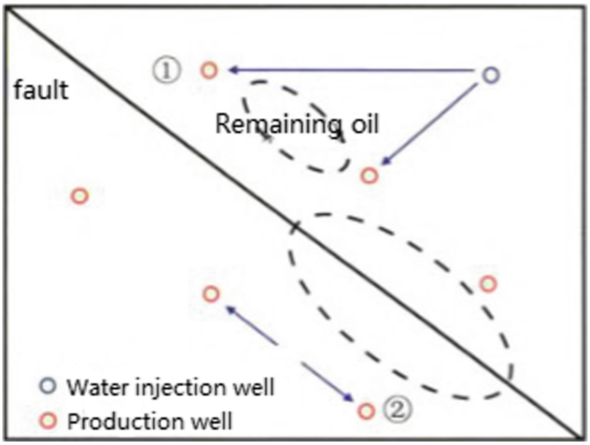

Fig. 1. Schematic diagram of well selection for fracturing oil displacement

4.2 Design of Injection Flooding Agent

4.2.1 Design Principles of Reagents

According to the above design idea of fracturing and oil displacement, the fracturing and oil displacement fluid should be filtrated up and down as far as possible to transport the fracturing fluid (oil displacement fluid) to the deep part of the reservoir, and the break-through problem caused by rapid fracture extension also needs to be reduced. Therefore, the injection agents should be selected according to the performance requirements of low viscosity system, high oil washing efficiency, good matching with three types of reservoirs, no wall building and enhanced filtration. At the same time, after the measure well is opened, some oil wells are supplemented with injection fluid, so the fracturing oil displacement fluid should be compatible with the subsequent injection fluid to avoid reservoir pollution caused by chemical incompatibility.

4.2.2 Drug Type Screening

The alkali surfactant binary system and surfactant binary system with mature technology in Sazhong Development Zone of Daqing Oilfield are optimized for evaluation. The time to achieve ultra-low interfacial tension and equilibrium interfacial tension are used to quantify the oil displacement performance index of the agent, the oil washing efficiency is used to evaluate the oil displacement performance of the agent, and the viscosity is evaluated at the same time. Finally, the injection compatibility of subsequent fluids is considered.

In the evaluation of oil washing efficiency, 5 g oil sand is weighed and put into 25 ml colorimetric tube, 2.5 ml crude oil is added to saturate for 48 h (at 45 °C), then the pressure drive fluid system is prepared respectively, and the colorimetric tube is added to 25 ml scale line, at the same time, the preparation water is also added to 25 ml scale line as blank, standing for 24 h, the upper oil washing volume is read, and the oil washing efficiency is calculated.

$$\lim_{k\to\infty} \underset{0\le t\le T}{sup} \|\Delta e_{k+1}(t)\| \le \underset{k\to\infty}{lim}\ e^{-\lambda T}\|\Delta e_{k+1}(t)\|_{\lambda} \le e^{-\lambda T}\left(\frac{m_1 m_5}{b-\lambda}\frac{1}{1-\breve{\rho}}+\frac{p}{b}\right)cd \tag{3}$$

All the indexes of the three fracturing fluid systems can meet the requirements of fracturing and oil displacement, and the indexes are relatively similar. Therefore, considering the adaptability of alkali surface binary and injection reservoir and injection system, the method of alkali plus surfactant is adopted in this test, in which the mass fraction of alkali is 1.2%, and the mass fraction of surfactant (heavy alkylbenzene sulfonate) is 0.3%. The viscosity of the binary system is 2.1−4.8 mpa-s, and the fluidity is strong, which can meet the performance requirements of fracturing oil displacement fluid with low viscosity and easy filtration. The strong alkali surfactant has good compatibility with crude oil, wide range of interfacial activity and strong oil washing ability, which can meet the demand of high oil displacement efficiency.

5 Field Effect of Fracturing and Oil Displacement in Class III Reservoir

5.1 Field Test of Pressure Drive

Taking two fracturing oil wells in Daqing Oilfield as an example, in the selection of production well A1, according to the subdivision of injection wells, the conditions of production wells and the requirements of stratification technology, the fracturing oil displacement layers are divided into six sections. Table 1 shows the design of fracturing oil displacement, in which the physical properties of the 1st to 3rd sections are slightly poor, the interlayer difference is improved and the formation energy is recovered by fracturing oil displacement, and the physical properties of the 4th to 6th sections are better, and the remaining oil in the unswept parts is exploited by fracturing oil displacement. According to the binary liquid property of alkali surface, according to the relation chart of injection system construction displacement and friction, combined with the calculation of horizontal fracture reservoir filtration rate, when the construction displacement is 4.5 m^3/min, the formation filtration is large, and the fracture can be effectively extended. In the actual construction process, it is strictly in accordance with the design, and the amount of pressure drive fluid is 555 m^3, which is close to the design amount (5949 m^3).

In the selection of injection well A2 horizon, according to the requirements of the current layering technology, the fractured oil displacement horizon is divided into five sections, and the first and second sections are drilled by fracturing to drive the remaining oil in the affected area. In the third to fifth sections, the interlayer difference is improved and the formation energy is recovered by fracturing. The actual stratification design is shown in Table 2. In the actual construction process, the consumption of pressure drive fluid is 6 297 m^3.

Table 1. The design of fracture-flooding of the oil Well A1

Fracturing interval number	Horizon	Effective thickness/m	Permeability/d	Actual injection volume/m^3
1	SII14	1.0	0.148	927
2	SII12	0.2	0.038	940
		0.3	0.061	
	SII11	0.8	0.125	
3	SIII2	0.4	0.113	829
	SIII3_1	0.4	0.072	
	SIII3_2	0.5	0.122	

Table 2. The design of fracture-flooding of the injection Well A2

Fracturing interval number	Horizon	Effective thickness/m	Permeability/d	Actual injection volume/m^3
1	SII10	1.9	0.522	1290
2	SIII3_1	0.9	0.126	1027
3	SIII5 + 6	0.7	0.112	1520

5.2 Oil Displacement Effect of Oil Well Fracturing

After fracturing and oil displacement in production well A1, the effect of increasing fluid and oil and reducing water cut is obvious, and the production curve is shown in Fig. 2.

Production well A1 has a daily fluid production of 15t, oil production of 0.5T and water cut of 96.6% before well pressure, and a maximum daily fluid production of 65t,

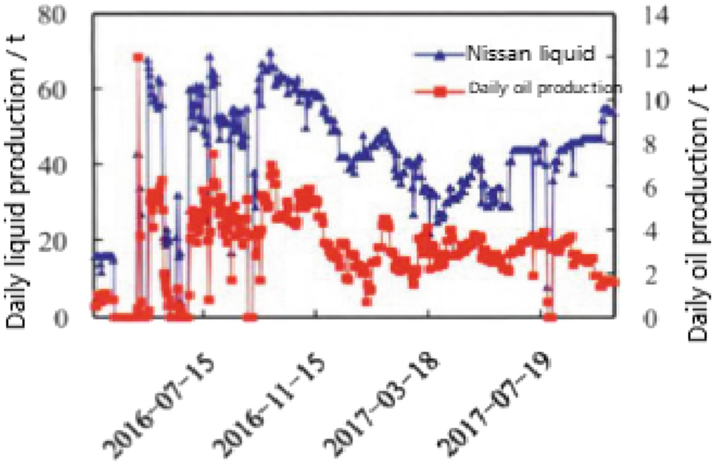

Fig. 2. Oil well production curve

oil production of 8.5t and water cut of 88.9% after well pressure. Up to now, the period of validity has reached 429d, the daily fluid production is 54t, the daily oil production is 1.6T, and the water cut is 96.0%. Due to the improvement effect of fracturing on the reservoir, the current fluid production is 3.6 times higher than that before fracturing, and the cumulative oil increase is 910t.

$$\begin{cases} E(t)\dot{x}_k(t) = f(t, x_k(t)) + B(t)u_k(t) + d_k(t) \\ y_k(t) = C(t)x_k(t) \end{cases} \tag{4}$$

Figure 3 shows the produced fluid curve. The polymer concentration in the produced fluid reaches a peak value of 499 mg/L at 126 days after fracturing, indicating that even if large-scale fracturing and oil displacement are carried out, rapid breakthrough of the reservoir is not caused.

The injection rate of conventional chemical flooding in the test area is about 50 m^3/d. according to the current fracturing oil displacement operation speed, it can reach 6480 m^3/d, and the agent transportation through fractures can reach about 100 times of the normal injection. At the same time, one-time injection of 0.05 PV plays a decisive role in the rapid recovery of formation pressure in the low permeability layer, and the purpose of further starting the reservoir is achieved by increasing the formation pressure. Because of the use of fracture direct transportation, the upper and lower filtration on the fracture surface can reduce the loss of agent performance caused by shear, adsorption and retention.

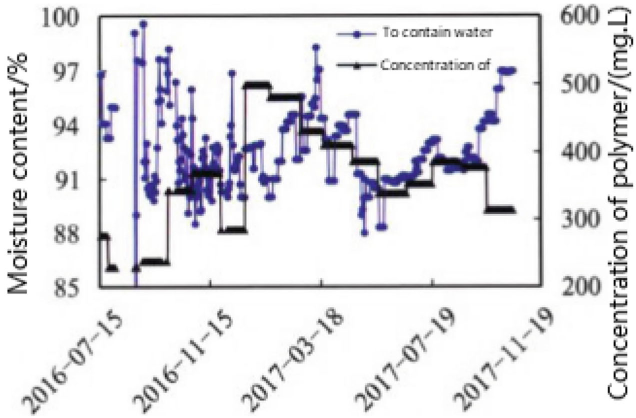

Fig. 3. The injection curve of water well

6 Conclusion

The three oil layers in the development zone of the company are mainly buried physical properties, poor reservoir physical properties, many main types and low recovery during development. The development characteristics of dispersed remaining oil are formed. At the same time, chemical oil displacement is difficult due to the large amount of reactants and adsorption. "Fracturing oil displacement" is to form a high-speed channel by fracturing long fractures, quickly send the high-efficiency oil displacement agent to the remaining oil enrichment position through fractures, use the oil displacement agent as fracturing fluid, and quickly fill the oil displacement agent into the pores while fracturing fractures, so as to reduce the contact time and distance between the chemical agent and the formation, In order to solve the problems of chemical agent performance loss along the way, low utilization efficiency and influence on oil displacement effect in the process of injection.The field test results show that the three oil products can realize autoclave and oil injection. The remaining oil potential determined by dispersion can be rapidly developed by using stimulation and water injection technology in three reservoirs in Central China IV development zone.

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