Research on Fracturing Effect of the Second Kind of Oil Layer Weak Alkali Ternary Composite Flooding

Shuxia Wang
Daqing Oilfield Co., Ltd. Third Oil Production Plant Test Brigade, Daqing 163000, China.

Abstract. The main reason for the low production of oil wells in the second type of oil wells is the poor development of the oil layer itself and the near-wellbore pollution caused by the scaling of the ternary composite system. By analyzing the dynamic and static factors affecting the fracturing of the production well, it is known that the fracturing effect is better when the formation pressure is higher than the saturation pressure after fracturing; the effective thickness is greater than 5 m, the first type of connectivity is greater than 30%, and the high water flooding thickness ratio is less than 40%, production liquids with a drop of more than 20%, a water cut of more than 5%, and a chemical flooding degree of less than 15% can achieve better oil and precipitation effects. For the weak alkali ternary composite flooding type II oil layer with permeability greater than 100×10^{-3} \mu m^2, the conductivity of fracturing has little effect on the fracturing effect, and the fracturing timing is the key factor to determine the fracturing effect.

Key words: Fracturing; weak base ternary composite flooding; second oil layer; conductivity.

1. Introduction
Fracturing is an important production increase measure for oil fields and has been widely used in development and production. Through fracturing, a certain amount of crude oil production can be increased in a certain period of time, so fracturing measures have played an important role in increasing oil production and stable production [1].

2. Reasons for low production in oil production wells
2.1. Characteristics of the development of the second type of oil layers
It can be seen from Table 1 that the oil layers in the Sabei Development Zone are divided into three categories. The first-grade oil layer is mainly composed of the flood plain and the diversion plain, and the braided channel sand body, the meandering point dam sand body, large High-bend split-flow river sand, sand body drilling rate \( \geq 60 \), single-layer effective thickness \( \geq 3m \), permeability \( \geq 0.3 \mu m^2 \); IIA oil layer is the focus of this paper, IIA oil layer is dominated by diversion plain facies and inner front...
facies, development of diversion channel sand, underwater distributary channel sand body, mat sand, sand body drilling rate $\geq 20$ or $<60$, single layer effective thickness $\geq 1$m, permeability $\geq 0.1\mu m^2$; IIB oil layer within the leading edge, outside front The main edge is the development of the mat sand, the underwater distributary channel sand, the sand dam sand body, the sand body drilling rate $\geq 20$ or $<60$, the single layer effective thickness $0.5$-$1$m, $1$-$3$m or $1$-$2$m, permeability $0.1$-$0.3\mu m^2$; the leading edge phase and the off-surface reservoir are mainly composed of the three types of oil layers, and the thin-layered sand body is developed. The effective thickness of the single layer is $0.2$-$0.4$m, and the permeability is $<0.1\mu m^2$. It can be seen from the classification table that the oil layer properties studied in this paper are poor. Even if the oil layer has a certain potential, due to the low permeability and thin thickness of the single layer, it is difficult to obtain rational yield by conventional completion methods; in addition, although some oil layers develop well, It also has a certain capacity, but due to the high viscosity of the underground crude oil and poor liquidity, the production capacity of the oil well has not been effectively released.

Table 1. Classification of oil layers in Sabei Development Zone.

| Oil layer type     | Main sedimentary facies | Main sand body                                                                 | Single layer effective thickness (m) | Effective permeability range ($\mu m^2$) |
|--------------------|-------------------------|-------------------------------------------------------------------------------|--------------------------------------|----------------------------------------|
| a class of oil layers | (Lasa) flood plain      | Braided channel sand body, meandering point dam sand body                     | $\geq 60$                             | $\geq 0.5$                             |
| IB                 | (apricot) diversion plain | Large high-bend diversion channel sand                                         | $\geq 60$                             | $\geq 0.3$                             |
|                    | Diversion plain         | Diversion channel sand                                                        | $30$-$60$                            | $\geq 0.3$                             |
| IIA                | Inner leading edge      | Underwater distributary channel sand, mat sand                               | $\geq 20$, $<60$                      | $\geq 0.1$                             |
| IIB                | Inner leading edge      | Underwater shunting sand, sand dam sand body                                 | $\geq 60$, $<20$                      | 0.5-$1$, 1-$3$, 1-$2$                  | 0.1-$0.3$                           |
| Three types of oil layers | Outer leading edge | Thin layer sand body                                                          | Off-balance sheet                     |                                        |                                     |

2.2. Oil layer pollution

During the drilling process, the oil layer is immersed for a long time, the performance of the drilling fluid is poor, and the relative density is large, which may cause oil layer pollution; during the completion of the well, the perforation is not thorough, or after the perforation is not promptly sprayed and put into operation, and after the oil well is put into operation, Oil well pollution may occur due to the use of well killing hydraulic wells in underground operations [2]. The severity of the pollution can be expressed by the skin factor $S$:

$$ S = \frac{2\pi Kh}{Bq\mu} \Delta P_s $$  \hspace{1cm} (1)$$

Where: $K$ represents formation permeability, $m^3$; $H$ represents the thickness of the formation, $m$; $B$ represents the volume coefficient of crude oil, $\%$; $q$ represents the production of the well, $m^3/s$; $\mu$ represents the viscosity of the formation crude oil, $Pa\cdot s$; $\Delta P_s$ represents a dimensionless additional pressure drop, and the permeability of the small annular region around the wellbore is different from that of the oil layer. When crude oil flows from the reservoir into the wellbore, an additional pressure drop is created in the annular region.
In general, for homogeneous reservoirs:
S=0 indicates that the well is not contaminated (perfect well);
S<0 means that the stimulation measures are effective wells (super-well wells);
S>0 indicates that the well is contaminated (imperfect well), and the larger the S value, the more serious the pollution.

3. Analysis of factors affecting fracturing effect
The oil well fracturing effect is mainly reflected in the initial daily oil increase and the cumulative oil increase during the effective period. The commonly used oil-fracture oil increase is shown in (2):

$$\Delta Q_o = \left[ 2\pi H (1 - f_w / L\mu_1\mu_2) \right] K_2 \mu_1 (P_{e_2} - P_{w_2}) - K_1 \mu_2 (P_{e_1} - P_{w_1})$$  \hspace{1cm} (2)

When the formation pressure after fracture is not lower than the saturation pressure, the above formula can be described as (3):

$$\Delta Q_o = \left[ 2\pi H / L\mu (1 - f_w) \right] K_2 (P_{e_2} - P_{w_2}) - K_1 (P_{e_1} - P_{w_1})$$  \hspace{1cm} (3)

Where: $\Delta Q_o$ represents the fracturing oil increase, m$^3$/d; $r$ represents the wellbore radius, m; $H$ represents the oil laminate opening thickness, m; $f_w$ represents the fracture zone water content; $K_1$, $K_2$ represents the fracturing layer before and after fracturing Section oil layer permeability, $\mu m^2$; $P_{e_1}$, $P_{e_2}$ represents the formation pressure at the oil well L before and after fracturing, MPa; $P_{w_1}$, $P_{w_2}$ represents the flow pressure before and after fracturing, MPa.

It can be seen from formula (3) that the fracturing effect is related to the pressure of the formation before pressure, the degree of development of the oil layer, and the water state of the oil layer. The following is mainly to analyze the influence of formation pressure, oil layer development and dynamic characteristics of oil production wells on fracturing effect.

3.1. Formation pressure
According to the statistics of production wells with formation pressure data, the daily oil increase of single wells in 6 production wells is greater than 7t and the cumulative oil increase exceeds 1000t, the formation pressure and saturation pressure ratio is 1.22; the daily increase of single wells in 9 production wells is less than 5t and The cumulative oil increase is less than 700 tons, and the formation pressure and saturation pressure ratio is 1.08. This is because the formation pressure will decrease after the oil is laminated, the production pressure difference will be reduced, and if the formation pressure is reduced below the saturation pressure, the original degas will be degraded in the formation, the viscosity will increase, the flow coefficient will decrease, and the fracturing effect will be poor; When the pressure $P_{e_1}$ of the formation before the pressure is relatively high and the pressure $P_{e_2}$ of the formation after the pressure is higher than the saturation pressure, the fracturing effect is better. It can be seen that maintaining high formation pressure before pressure, and pre-pressurization culture is the prerequisite for ensuring the fracturing effect of the production well.

3.2. Oil layer development
In order to compare the influence of various parameters of the oil layer on the oil-increasing effect, draw a scatter plot of the daily oil increase of the single well and the effective thickness of the oil layer, the type of connectivity and the high flooding thickness ratio, and make a fitting curve, as shown in Figure 1. By analyzing the fitting curve in Fig. 1, it can be seen that the larger the effective thickness, the higher the proportion of the type of connected thickness, and the smaller the proportion of the high-water flooding thickness, the larger the daily oil increase in a single well. From the perspective of economic efficiency, the selection of fracturing technology can be established by selecting high-efficiency oil production wells with a
daily oil increase of more than 7 tons after pressing: effective thickness is greater than 5 m, type 1 connectivity is greater than 30%, and high-water flooding thickness ratio is less than 40%.

3.3. Production well dynamic characteristics
In order to compare the effects of various dynamic parameters of oil production wells on the oil-increasing effect, draw a single-well daily oil increase and production liquid reduction (compared to blank water flooding), water cut and chemical flooding degree scatter plot and fit the curve is shown in Figure 2. It can be seen from the analysis in Fig. 2 that the larger the chemical flooding liquid decreases, the larger the water content decreases, and the lower the degree of chemical flooding, the more oil is added in a single well. This is because the greater the decrease in the production fluid during the chemical flooding stage, the stronger the original production capacity of the well; the greater the water cut, the more effective the high-level section of the oil saturation; the lower the degree of chemical production, the more concentrated the remaining oil, with certain excavation potential. Through the fitting curve of single well daily oil increase and these three parameters, the area where single well daily oil increase can reach more than 7 tons can be selected, and the dynamic parameter fracturing limit can be determined: the liquid production drop is greater than 20%, and the water cut is greater than 5%, the degree of chemical flooding is less than 15%.

3.4. Fracturing timing
Based on the characteristics of water-bearing variation, the chemical flooding process is divided into three stages: water-bearing decline period, water-bearing low-value period and water-bearing recovery period, and draw the daily oil increase of single well in different periods. And make a fitting curve, as shown in Figure 3. It can be seen from the analysis in Fig. 3 that the lower the water content before the fracturing, the more...
the daily oil increase in the single well, so the fracturing effect in the low water-containing period is the best. Selecting the area where the daily oil increase can reach 7t or more, it can be seen that the fracturing effect is better in the stage of water content less than 90%.

![Daily oil increase and pre-measure water relationship](image)

**Figure 3.** Relationship between water content before fracturing and daily oil increase in single well.

In addition, in different water-bearing stages, selecting the appropriate fracturing interval is also the key to ensure the fracturing effect of the production well. In the stage of water-reducing decline, in order to promote the production well, the main fracturing of the river side; in the low-water stability stage, expand the degree of effectiveness of the production wells, mainly fracturing the main part of the river channel, fracturing and improving efficiency; the water-recovery stage, in order to control the water-recovery, the main fracturing thin layer, fracturing and efficiency.

### 4. Repeated fracturing

Most oil-fractured fractures with low permeability will have crack failure during the mining process. This is because the fracture conductivity of the fracture is low and affects the fracturing effect. In addition, since the fracturing production well in this paper is a weak alkaline ternary composite flooding test well, in addition to the low conductivity of the diversion effect, due to the high alkali concentration in the formulation, the weak alkali ternary has a large degree of dissolution to the rock, resulting in a large amount of When the scale-forming ions in the solution are larger than the solubility product constant, the scale-forming ions in the solution will scale and precipitate, forming deposits, and the new sediments cause further blockage in the near-well zone.

At present, the principle of fracturing stimulation is based on the theory of bilinear flow in formation fluids, which can be summarized as the radial flow mode before fracturing and the bilinear flow mode after fracturing. Theoretical studies have shown that to achieve bilinear flow conditions, the conductivity of the fracture must far exceed the natural flow capacity of the fluid in the pore medium of the formation. The dimensionless fracture conductivity is often used as the primary measure of bilinear flow patterns. This parameter is as in (4):

$$C_{fd} = K_f W_f / KL_f$$  \hspace{1cm} (4)

Where: $C_{fd}$ represents the dimensionless fracture conductivity; $K$ and $K_f$ represent the formation permeability and fracture permeability, respectively, $10^{-3} \mu m^2$; $L_f$ represents the crack length, m; $W_f$ represents the crack width, mm.
The results of digital-analog studies show that [3], when the non-cavity fracture conductivity is less than or equal to 0.1, the actual flow of the formation fluid after fracturing is a relatively standard "radial flow mode", that is, fracturing in this case. The guiding effect of the crack is very small; under the condition that the conductivity of the dimensionless crack is greater than or equal to 10, a relatively standard bilinear flow pattern can be realized in the stratum near the crack, and the conductivity of the dimensionless crack is larger. The more standard the bilinear flow pattern is, as shown in Figure 4. In this paper, the permeability of fractured production wells is between $217 \times 10^{-3}$ and $471 \times 10^{-3}$ $\mu m^2$. According to the statistical results of 10 fractured production wells, the single-wing pressure crack is 21~23m long and the support joint width is generally 3~5mm. The agent is made of 0.425-0.85mm (20 mesh - 40 mesh) quartz sand. If the stable permeability of the sand-filled crack is $10000 \times 10^{-3}$ $\mu m^2$, the slit width is 4mm, the slit length is 22m, and the dimensionless conductivity is less than 0.01, thus the dimensionless crack obtained under normal fracturing condition is observed. The conductivity is usually small, and it is unable to exert the guiding effect of the crack. It also shows that the flow of the formation fluid into the bottom of the well through the crack is very small. Most of the fluid flows directly into the bottom of the well through the perforating blasthole other than the crack. By repeating the fracturing by optimizing the construction parameters, the sanding amount of the single layer is increased from 7$m^3$ to 15$m^3$, and the length of the single wing after fracturing is extended from 22m to 34m, and the penetration ratio is increased from 18.6% to 25.6%. Repeated fracturing by increasing the amount of sand added is not ideal. After a fracturing, the daily oil increase was 11.4t, the water content decreased by 10.59%, and the unit thickness increased by 141t, and the effective period was 282 days. After secondary fracturing, the daily oil increase is 6t, the water content increases by 0.13%, the unit thickness increases by 60t, and the effective period is 150 days. Through single-well analysis, it is found that the primary fracturing is in the low-water phase, and the effect of oil-increasing and precipitation is obvious after fracturing. The secondary fracturing is in the initial stage of water-recovery. After the optimization, the liquid-producing ability is improved, and the water content is not changed much.

5. Conclusion

1. The main reason for the low production of oil wells in the second type of oil wells is the physical development of the oil layer itself and the near-wellbore pollution caused by the scaling of the ternary composite system;

2. By analyzing the dynamic and static factors affecting the fracturing of the production well, it is known that the fracturing effect is better when the formation pressure is higher than the saturation pressure after fracturing; the effective thickness is greater than 5 m, the first type of connectivity is greater than 30%, and the high flooding thickness is If the proportion is less than 40%, the production liquid decreases by more than 20%, the water cut is more than 5%, and the chemical flooding production degree is less than 15%, the oil production well can obtain better oil and precipitation effects;

For the weak alkali ternary composite flooding type II oil layer with permeability greater than $100 \times 10^{-3}$ $\mu m^2$, the conductivity of the fracturing has little effect on the fracturing effect, and the fracturing timing is the key factor to determine the fracturing effect.
Acknowledgments
Wang Shuxia was born in 1983, female, who is an engineer and majors in reservoir geology dynamic analysis.

References
[1] Chu Congyan. Influencing factors and improvement measures of fracturing effect. Daqing Oilfield Sabei Development Zone “Eleventh Five-Year” oil production engineering technology practice and understanding collection. 2011, pp. 34-39.
[2] Wang Yanqiu. “Study on economic analysis methods of acidification and fracturing measures”. Ph.D. thesis, Daqing Petroleum Institute, 2003.
[3] Kou Yongqiang, Xie Guixue, Le Xiaoming, et al. Study on optimization of fracture conductivity. Petroleum Geology and Recovery Efficiency, (39 May 2002) pp. 40-41.