A Analysis and Calculation Method for Reasonable Decline of Fluid Production in Affected Wells in Transfer Polymerization Flooding

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Abstract. When the J oilfield is switched from water flooding to polymer flooding, the fluid supply capacity of the effective well will decrease sharply, and it is often judged that the effective well is blocked. In fact, in addition to the blockage that occurs after the polymer flooding, some of the decline in the fluid production is caused by the nature of the polymer flooding. Therefore, it is necessary to analyze the characteristics of water flooding and polymer flooding, and compare the similarities and differences between water flooding and polymer flooding, so as to find the factors that will inevitably lead to the decline of production fluid after water flooding to polymer flooding. The range of decline in fluid production caused by these factors is a reasonable range of decline in the produced fluids of the affected wells, while the decline in fluid production caused by other factors is the blockage.

1. Introduction
First analyze the similarities and differences between water flooding and polymer flooding

1.1. Similarities
JX-ray diffraction analysis showed that the clay minerals in J Oilfield were mainly kaolinite and Iran / Mongolia mixed layers [1]. When the front of the water flood reaches the near-well zone of the polymer flooding affected well, water molecules enter the formation with higher clay content, which will cause the hydration and expansion of clay minerals [2], resulting in blockage of the pore throat of the formation near the well zone. The production fluid is reduced and even well is clogged.

1.2. Dissimilarities
When the water flooding is transferred to the polymer flooding, and the front of the polymer flooding reaches the polymer flooding effective well, the produced fluid has a stronger drag force to carry and wrap the formation particles due to the addition of the polymer, which intensifies the particle transport [3]. Sand production of affected wells in migration and polymer flooding.

In the polymer flooding process, similar to water flooding, light components such as small molecular oils in crude oil are first taken away, while heavy components such as colloidal asphaltenes remain and are adsorbed in the pores of the formation.

When the polymer statically adsorbs the rock surface, it is generally a single molecular layer, but in the process of fluid flow, the large molecular chains will cross-link with each other and mix with the...
clay particles, so that the polymer adsorption layer is no longer a uniform single layer. The molecular layer adsorption causes the percolation pores to become narrower, and the permeability and liquid absorption capacity are reduced.

When the injected polymer is incompatible with the Ca\(^{2+}\) and Mg\(^{2+}\) ions that are commonly present in the formation water, it will also precipitate and block the oil layer.

Sand particles or rock surface particles are transported to the near-well zone and sand control layer under the action of formation fluids and entrapment, providing a large number of crystal nuclei for flocculation and precipitation of colloidal asphaltenes, causing the organic scale formation [4].

The polymer aggregates with sand particles as the core to form a composite plug with a larger particle size. During the formation migration, the formation sand and the polymer-encapsulated sand particles block the pore throat.

2. Reasonable decline of liquid production in affected wells

According to the analysis of the similarities and differences between water flooding and polymer flooding, it is concluded that the liquid production reduction caused by the following points after water flooding to polymer flooding is within a reasonable range of fluid production in polymer flooding affected wells. At the same time, using the control variable method, analyze and calculate the drop in liquid production caused by each factor.

2.1. Increasing the viscosity of the produced liquid causes the liquid production to decrease

There are two major factors in the increase in the viscosity of the produced fluid: (1) the heavy crude oil content in the produced fluid rises; (2) the polymer content in the produced fluid rises [5].

On the one hand, after the polymer is injected into the formation, due to the small viscosity and the low flow resistance of the small molecular hydrocarbons in the crude oil, it is first taken away by the polymer, and the heavy components in oil phase gradually increase, causing the viscosity of the produced fluid to increase sharply. According to Darcy’s law, under the same production pressure difference, the viscosity of the produced liquid increases, resulting in a decrease in the amount of produced liquid.

On the other hand, after polymer flooding, due to the addition of polymer to the injected water, its viscosity increases, and when the fluid percolates to the production end in the formation, the viscosity of the water phase increases, similar to the increase in the heavy crude oil content in oil phase. Under the same production pressure difference, the viscosity of the produced liquid increases, resulting in a decrease in the amount of produced liquid. The following specifically calculates the amount of drop in production liquid caused by the increase in viscosity of the produced liquid:

Assume that the polymer flooding affected well is a convergence point of fluid in infinite formation. The formation permeability is \(k\), the porosity is \(\phi\), and the oil layer thickness is \(h\). The borehole radius is \(R_w\) and the pressure is \(p_w\). The supply radius is \(R_e\) and the pressure is \(p_e\). The liquid production volume is \(Q\), the injection fluid density is \(\rho\), the viscosity is \(\mu\), the average formation pressure is \(\bar{p}\), and drop value of actual liquid production on site is \(\Delta Q\).

During the oil production process, the bottomhole flow pressure and formation pressure remain unchanged. According to the piston displacement theory, the production formula of plane radial flow considering oil-water viscosity difference is shown in formula (1)

\[
Q = \frac{2\pi kh(p - p_w)}{\mu_w \ln \frac{R_e}{R_w} + \mu_o \ln \frac{r_o}{R_w}} \tag{1}
\]

\[
\bar{p} = p_e - \frac{1}{2} \frac{p_e - p_w}{\ln \left( \frac{R_e}{R_w} \right)} \tag{2}
\]
Since the second term in the above formula is much smaller than the first term, it can be approximated that
\[ p \approx p_e \]  
Therefore
\[ Q = \frac{2\pi kh(p_e - p_w)}{\mu_o \ln \frac{R_e}{r_o} + \mu_o \ln \frac{R_e}{R_w}} \]

As shown in Figure 1, combining (2) organic scale analysis at point 1.2. And the smaller the distance R from the center of the wellbore, the higher the content of heavy components such as colloidal asphaltene in the fluid.

![Figure 1. Variation of colloidal asphaltene content in the different radius](image)

For the same distance from the wellbore, during the water flooding and polymer flooding, the injected water first took away the light oil components with small molecules, and the heavy components such as colloidal asphaltene remained, the content of heavy components at the same location increased.

![Figure 2. Variation of colloidal asphaltene content in the same radius](image)
With the increase of the heavy component content at the same radius $R_i$, the viscosity of the oil phase continuously changes (increasing gradually), that is:

$$\mu_0 \rightarrow \mu_1 \rightarrow \mu_2 \rightarrow \ldots \mu_n$$

Without considering other factors, according to the theory of piston flooding and Production formula of plane radial flow considering oil-water viscosity difference, that is, formula (4), it can be seen that the continuous change of oil phase viscosity leads to the continuous change of liquid production in the affected wells (gradual decrease), that is:

$$Q_0 \rightarrow Q_1 \rightarrow Q_2 \rightarrow \ldots Q_n$$

After the heavy component of the produced liquid rises, the liquid production of the oil well is as follows:

$$Q = \frac{2\pi kh(p_e - p_w)}{\mu_o \ln \frac{R_o}{r_o} + \mu_n \ln \frac{r_o}{R_w}}$$

Therefore, the decrease in the amount of liquid production caused by the increase in heavy components:

$$\Delta Q_1 = \frac{2\pi kh(p_e - p_w)}{\mu_o \ln \frac{R_o}{r_o} + \mu_n \ln \frac{r_o}{R_w}} - \frac{2\pi kh(p_e - p_w)}{\mu_p \ln \frac{R_o}{r_o} + \mu_o \ln \frac{r_o}{R_w}}$$

The increase in the polymer content of the produced liquid is similar to the increase in the heavy component of the produced liquid. The increase in the polymer content caused by the increase in polymer content is:

$$\Delta Q_2 = \frac{2\pi kh(p_e - p_w)}{\mu_o \ln \frac{R_o}{r_o} + \mu_n \ln \frac{r_o}{R_w}} - \frac{2\pi kh(p_e - p_w)}{\mu_p \ln \frac{R_o}{r_o} + \mu_o \ln \frac{r_o}{R_w}}$$

$\mu_p$ - Viscosity of the produced fluid after the polymer content of the produced fluid rises

2.2. Residual Resistance Coefficient Established by Polymer Leads to Decrease of Production liquid

The adsorption of polymers, especially at small pores and cementation points, will reduce formation permeability and cause a decrease in liquid production [6].

The following specifically calculates the amount of decline in liquid production caused by the residual resistance coefficient of the polymer:

In the process of oil production, it is assumed that the bottomhole flow pressure and formation pressure are unchanged. The water production rate of the oil well during water flooding is as follows:

$$Q_w = \frac{2\pi k_w h(p_e - p_w)}{\mu_o \ln \frac{R_o}{r_o} + \mu_o \ln \frac{r_o}{R_w}}$$

After the polymer flooding, the polymer has adsorbed and retained in the formation the formation permeability changes, which is $k_2$. It is assumed that the viscosity does not change, and the additional
resistance caused by the viscosity increase is not considered. The liquid production during polymer flooding is as follows:

\[
Q_p = \frac{2\pi k_p h(p_e - p_w)}{\mu_p \ln \frac{R_e}{R_o} + \mu_o \ln \frac{r_o}{R_w}} \tag{9}
\]

Decrease in liquid production caused by polymer adsorption and retention is as follows:

\[
\Delta Q_3 = \frac{2\pi h(p_e - p_w)(k_w - k_p)}{\mu_w \ln \frac{R_e}{R_o} + \mu_o \ln \frac{r_o}{R_w}} \tag{10}
\]

2.3. Increase in spread volume leads to decreased production fluid

When injecting a polymer solution into the formation, a high-viscosity injection solution preferentially enters the high-permeability layer, which increases the injection resistance of the high-permeability layer, forcing the injected water into the low-permeability layer, thereby increasing the volume and increasing the fluid flow space. The overall viscosity of the fluid increases, resulting in a decrease in liquid production at the same production pressure.

D Oilfield has implemented large-scale block profiling projects in the North-North West East District and North-North West West District of the Sabei Development Zone. The number of wells injected with profile control agents reached 26, which affected 63 surrounding oil production wells and controlled the area of the profile control area. 4.45 km², which involves geological reserves of 827.26 × 10⁴ m³ and pore volume of 1428.78 × 10⁴ m³. After profile adjustment, the production fluid volume of production wells decreased sharply. Yongtai Li believed that the significant decrease in water content of production wells resulted in a decrease in fluid production volume, and the result was a significant decrease in water production and ineffective water injection [7]. Therefore, it can be considered that the increase of the spread volume leads to a decrease in the water content of the production well, which in turn leads to a decrease in the fluid production.

Due to the increase in the spread volume, the decrease in the production fluid cannot be calculated, and it is directly is represented by \( \Delta Q_4 \.

In summary, the reasonable fluid production decline value of the polymer flooding affected well Theoretically(\( \Delta Q_r \)) is as follows:

\[
\Delta Q_r = \Delta Q_1 + \Delta Q_2 + \Delta Q_3 + \Delta Q_4 \tag{11}
\]

Since the above analysis of the impact of a certain factor on the decline in liquid production, it is assumed that other conditions do not change, but in the actual production process, various factors are intertwined with each other and affect each other. The above factors causes the drop in liquid production volume to be much larger than the sum of the calculated drop in the various factors in the form of "1 +1>2". Therefore, the decrease in the reasonable production volume of the polymer flooding affected wells obtained above represents the minimum value of the actual decrease value(\( \Delta Q_4 \)) in the reasonable production volume of the polymer flooding affected wells. The actual reasonable production volume drop \( \Delta Q_4 \) is actually greater than this value.

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