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Review

Research on injection profile of polymer flooding reservoir in Bohai Oilfield

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During polymer flooding, the behaviors of water injection profile reflect the flooding efficiency and its performance in medium and low permeable layers represents the sweep efficiency of the reservoir. In this work, the polymer flooding wells in Bohai Oilfield is analyzed and the observations on the performance are, with more polymer injected, the injection profile is characterized by: In most of the wells, vertically, the intake profile of each layers is improved efficiently and water absorption of low and medium permeable layers increase correspondingly; however, in some wells, the injection profile is not improved vertically but the water absorption of high permeable layers increases instead while low and medium permeable layers do not absorb any water; in addition, water absorption volume in high permeable layer is higher than that of the total volume of low and medium permeable layers, which is prejudicious for polymer flooding. By analyzing the field scale data, it is found that the differential of formation capacity between layers has big impact on water injection profile improvement by polymer flooding. Nevertheless, with certain formation capacity, injection profile of low and medium permeable layer, with the increase of injection volume, will increase first, then decrease and then increase again. Based on the study, it should be avoided to inject polymer to wells whose formation capacity differential is large. If it is ineluctable, injection profile should be adjusted before injecting polymer. For those wells whose intake profile is improved obviously, attention should be paid on the rules of the injection profile with the increase of injected polymer, and conduct zonal polymer injection, injection profile adjustment or increase polymer volume to enhance polymer flooding effect when its relative water absorption volume reduce.

Key word: Polymer flooding, offshore oil field, water injection profile, influences factors.

INTRODUCTION

Compared to onshore oilfields, polymer flooding in offshore oilfields is more challenging. Firstly, conventional polymer cannot meet the demand because of the lack of fresh water. Secondly, polymer injection equipment has special requirements because the production platform space is narrow and the service life is limited. Besides, there are several difference of reservoir properties and characteristics between onshore oilfields and offshore oilfields such as big well spacing, the high viscosity of the subterranean oil, the thickness of the reservoir and so on. These characteristics also make the polymer flooding in offshore oilfields more challenging (Shouwei et al.,

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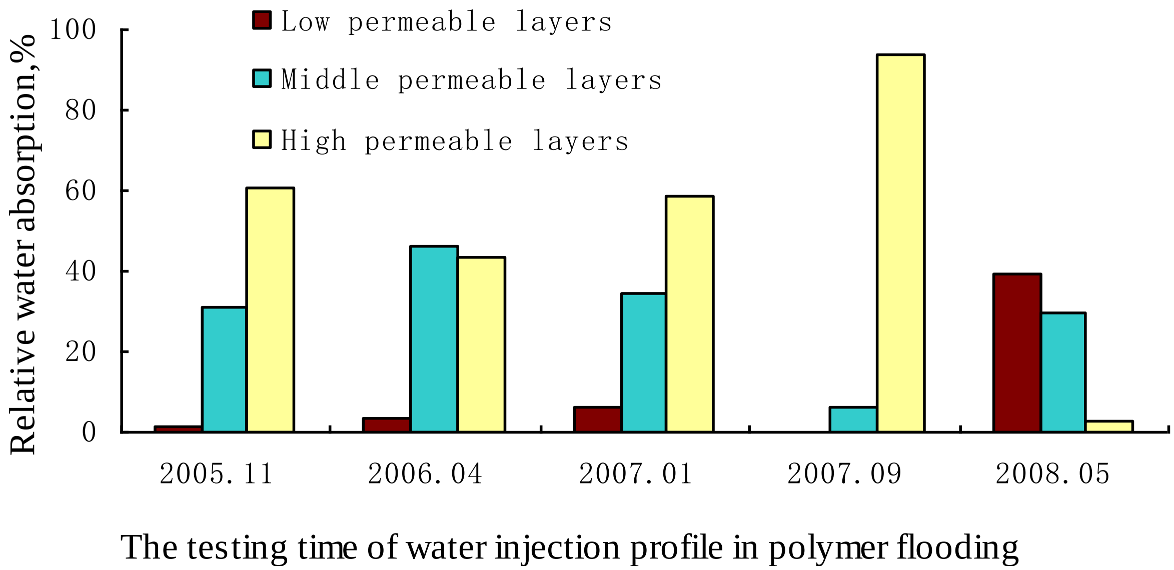

Figure 1. Histogram of P2 well water injection profile, Suizhong Plot Area.

2006). In spite of the above difficulties, both SZ pilot and LD pilot have achieved satisfactory effect, which makes polymer flooding in Bohai bay more feasibility (Su et al., 2012). During polymer flooding, the behaviors of water injection profile in polymer injection well reflects the producing layer directly, at the same time, the improvement of medium and low permeable layers represents the sweep efficiency of the polymer flooding. According to the statistics of water injection profile of polymer flooding wells, the distribution of water absorption in some wells is uneven, and in layer and inter layer heterogeneity is aggravated by the polymer injection; on the other hand, even the water absorption of some wells are improved after polymer injection, it is characterized as a staged change with the injection of polymer (Weihong, 2007; Dongmei et al., 2007; Hong et al., 2008). Water injection profile is the most intuitively on-site data to evaluate polymer flooding effect. Therefore, it is helpful to find out contingency plan promptly so as to ensure the polymer flooding effect by studying the behaviors of water injection profile during the offshore oilfield polymer injection (BaoJing, 2008; Changjiu et al., 2005).

INJECTION PROFILE BEHAVIORS

At present, Bohai oilfield is experiencing polymer flooding on a large scale and is divided into three pilot areas. According to the polymer flooding data of Liaodong Pilot Area (five wells) and Suizhong Pilot Area (seven wells), the behaviors of water injection profile in each reservoir are completely the same, namely, water absorption decrease in high permeable layers and increase in medium or low layers while injecting. The behaviors of water injection profile after polymer flooding can be divided into two types, including:

1. Wells with low inter layer heterogeneity
2. Wells with high inter layer heterogeneity

Wells with low inter layer heterogeneity

The relative water absorption of medium and low permeable layers of eight wells are improved, according to the testing data of twelve wells, accounting for 67%. Take P2 well in Suizhong Pilot Area for example, the behaviors of water injection profile is shown in Figure 1 (Three sublayers of Lower Dongying Formation I are the main injection layers). Vertically, the permeability is arranged as compound Rhythm mode [low (<50 mD); high (>500 mD); medium (50～500 mD)]. The differential of formation capacity between layers (the formation capacity ratio of high to medium and low permeable layer) is 2.38 and 3.43, respectively. As is shown in Figure 1, with the injection of polymer, the water absorption volume of high permeable layers appears to decrease slightly and then decrease dramatically after considerable increase. Meanwhile, in medium permeable layers tend to climb firstly, then fall and rise again. In addition, in low permeable layers, the water absorption volume increased obviously with the decrease of volume in high permeable layers. By analyzing the reasons, it is found that, with the injection of polymer, flowing resistance of high permeable layers is increased and cause the polymer absorbed by medium and low permeable layers. However, in medium and low permeable layers, the injected polymer will be redistributed by stage due to the significant increase of

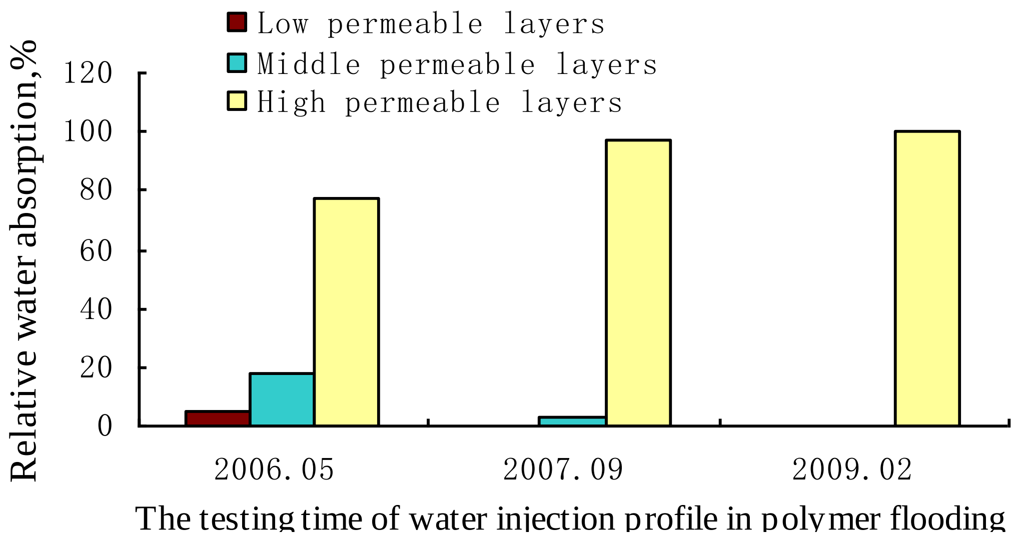

Figure 2. Histogram of P3 well water injection profile, SuiZhong Plot Area.

resistance factor by even a small amount of polymer absorption.

Wells with high inter layer heterogeneity

There are four wells of this type, accounting for 33% according to the statistics data. Take P3 well for example, the behaviors of water injection profile is shown in Figure 2: 1, 2, 3 sublayers of Dongying Formation II are the main injection layers of this well. Vertically, the permeability is arranged by compound Rhythm mode (low-high-low). The differential of formation capacity between layers is 15.3 and 29.15, respectively. As is shown in Figure 2, with the injection of polymer, the water absorption volume of high permeable layers appear to increase, while that of the medium and low permeable layers appear to decrease until reach non-absorbent. Basically, it is due to the severe inter layer heterogeneity that caused most of the injected polymer flow into high permeable layers and low resistance which can divert the polymer to medium and low permeable layers. As a result, the water absorption volume of medium and low permeable layers decreased.

FACTORS AFFECTING INJECTION PROFILE

Differential formation capacity

Reservoir properties affect the polymer flooding testing results directly in polymer flooding. By ensuring the same total injection volume multiples, it was mainly focused on the effect of reservoir permeability and thickness on water injection profile in the polymer flooding process, differential productivity factor is used as specific characterization parameter. In this study, the changes of injection profile in the polymer injection process are mainly statisticed in low-permeability layer of six polymer injection wells in Suizhong Pilot Area.

In Figure 3, the changes of water injection profile is indicated by the relative increment of water absorption, this value is calculated by subtracting the relatively water absorption when there is no polymer flooding been used from the peak value of the improved relative water absorption in medium and low permeability layers of polymer flooding. If this value is positive, it means that the relative water absorption volume is obviously increased in low permeable layer after polymer flooding; if it is negative, it indicates that the relative water absorption volume is significantly reduced.

A curve is used to represent formation conductivity difference of each well and is marked accordingly to each well name. As can be seen, the relative water absorption volume increase by 25 to 38% when the differential formation conductivity is between 2.8 and 3.45 in P2, P4 and P5 wells; the relative water absorption volume only increased by 7% when the differential formation conductivity is 1.27 in the low permeability layer; compared with no polymer flooding the relative water absorption of polymer flooding decrease when the differential formation conductivity is between 25 and 29.15 in the low permeability layer, which intensify reservoir heterogeneity.

Therefore, from the effect of the differential formation conductivity on injection profile after polymer flooding, conclusions can be drawn: First of all, in the selection of layers for polymer flooding, the smaller differential formation conductivity is preferred. As for the layers with bigger differential formation conductivity, deep adjustment profile and other methods should be applied to improve the reservoir heterogeneity first, so as to ensure the

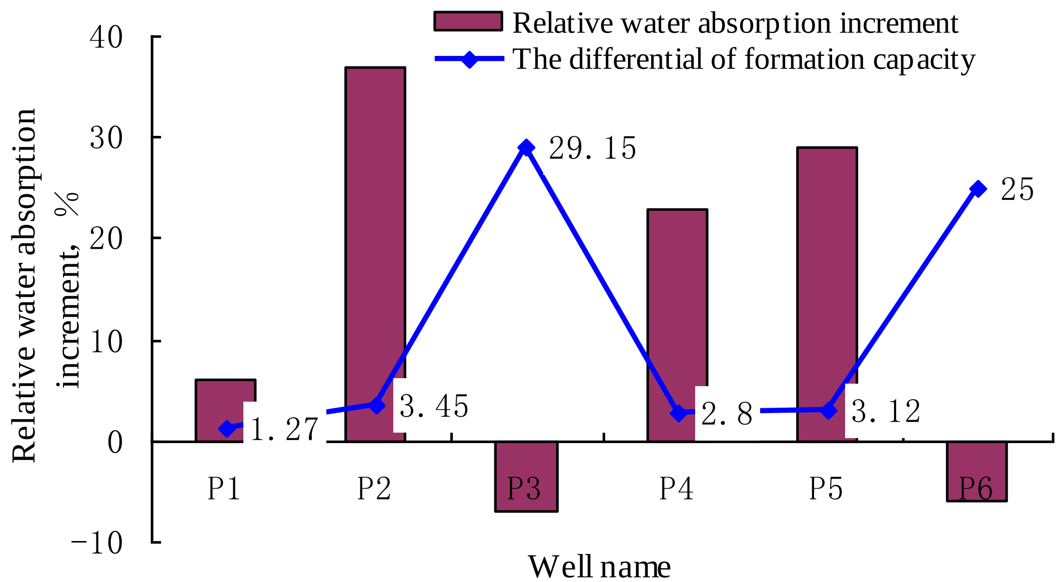

Figure 3. The effects of differential productivity capacity on injection profile in polymer flooding well of Suizhong Pilot Area.

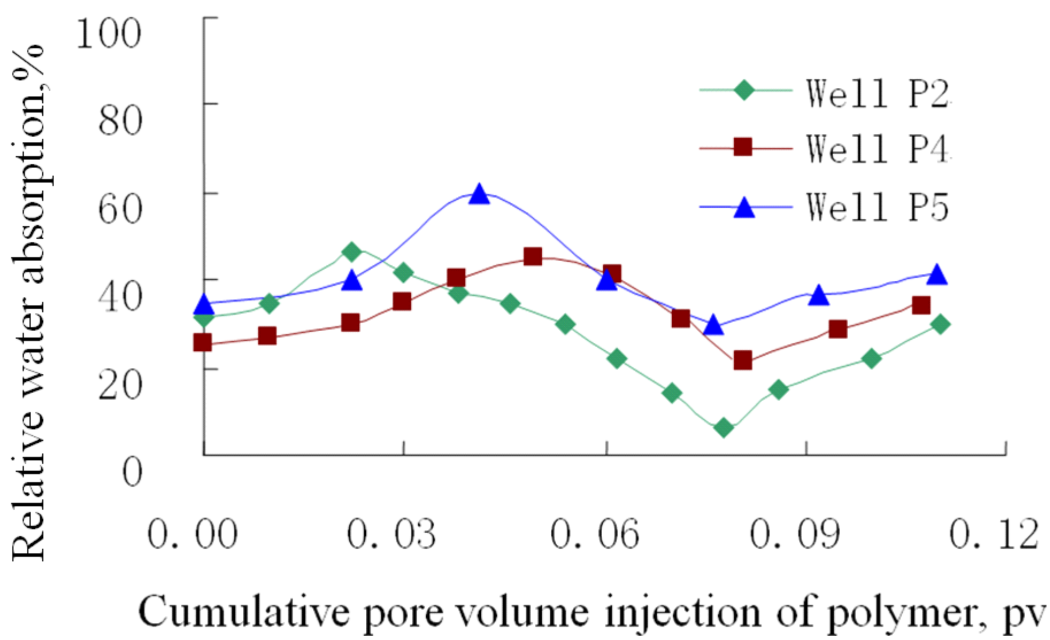

Figure 4. The trend of relative water absorption volume of in three wells, Suizhong Pilot Area.

effect of polymer flooding.

Injected polymer volume

In general, in order to achieve better adjustment of vertical water absorption profile of reservoir by polymer flooding, it is better to ensure appropriate differential formation conductivity between layers and suitable polymer volume, so as to ensure certain fullness in the reservoir. In addition, it's important to generate resistance which can shift the follow-up fluid. In this section, study is conducted on the change of reservoir water absorption profile under certain conditions of the same differential formation conductivity (Well P2, P4 and P5 are approximately of the same level of differential formation

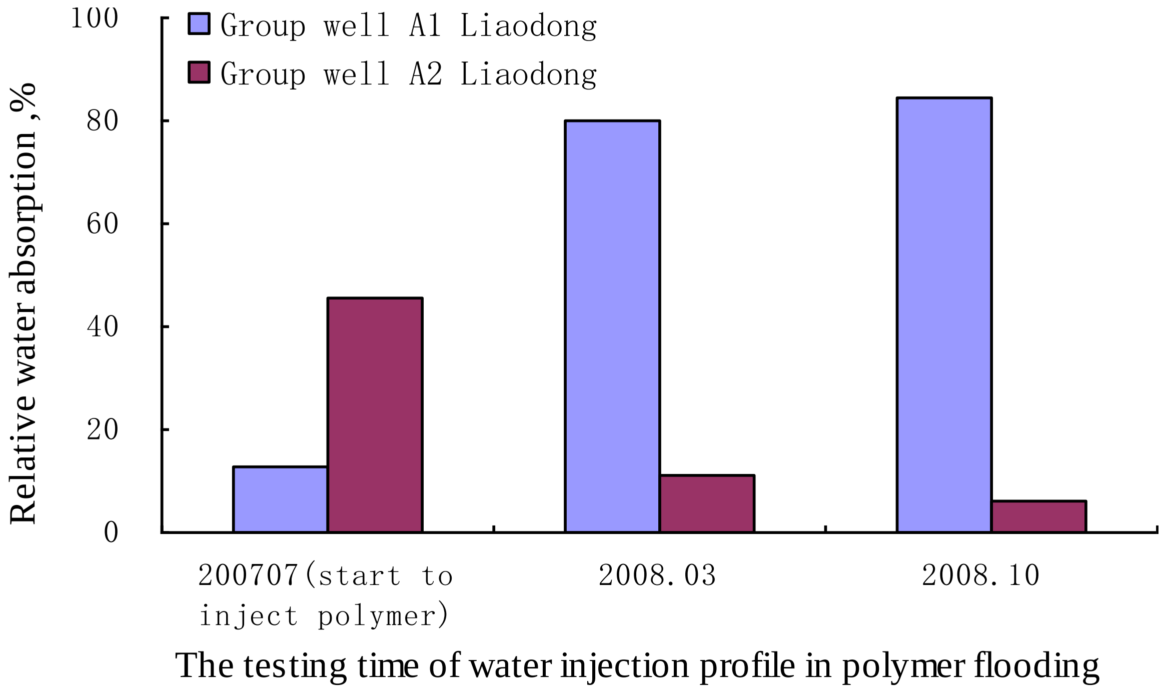

Figure 5. The histogram of low permeable layers of two well groups in Liaodong Pilot test district.

conductivity with values between 2.80 and 3.45) (Figure 4).

As can be seen from the figure, with the injection of polymer, the relative water absorption volume of the layer tends to increase in the early stage. However, when the absorption volume increase to certain degree, the water absorption began to decline until it reach the lowest point where it started to incline, while continuously injecting polymer. Obviously, it presented a periodic changes trend. The main reason of this phenomenon occurrence is as follows: In early stage of polymer injection, due to preferential access to a large number of polymer flow resistance of the smaller hypertonic layer, leading to the larger resistance that the subsequent polymer flows, resulting in its transformation into a smaller penetration horizon. The specific manifestation is the relative water absorption of the strata whose permeability is smaller showing a continuous decline; at the same time, the amount of injected polymer rush into the strata with high permeability, resulting in increase of the flow resistance in the strata, the sequent injection gradually turned into the layer with low permeability. Such a cyclical can adjust absorbent profile in the low permeability layers and improve vertical reservoir heterogeneity. According to these laws, we can get qualitative judgments on the rules that the relative absorbent capacity in low permeability change with the number of injection PV, to understand these laws, can serve as evidence on the choice of some measures that can be implemented in polymer injection process. In addition, according to the changes in the number of profiles with the PV, combined with a number of live dynamic data, we can get qualitative judgments for the response time and the response period of the polymer injection.

EFFECT OF INJECTION PROFILE IMPROVEMENT ON POLYMER FLOODING

Normally, the behaviors of water injection profile in medium and low permeability layer after polymer flooding is an important symbol that shows whether it is effective or not. Figure 5 indicated the behaviors of water injection profile in low permeability layer of the two well groups. In Group A1, the injection profile is better improved after polymer flooding, the relative water absorption increased by nearly 65%, which will be good for polymer profile, and oil increment and water reduction are obvious. But relative water absorption of A2 was not increased in low permeability layer after polymer flooding; on the contrary, it was greatly reduced by more than 40%, which is not benefit to the water cut drop off of the well group after polymer injection (Figure 6).

By combining Figures 5 and 6, it can be concluded that it is the time when the low permeable layer of A1 group wells' relative absorption increase significantly that the oil production rate increase dramatically, according to the production time and corresponding testing time. Consequently, it could be used to judge the polymer flooding effects through the behaviors of water injection profile in medium and low permeable layers and change of oil production rate at different time.

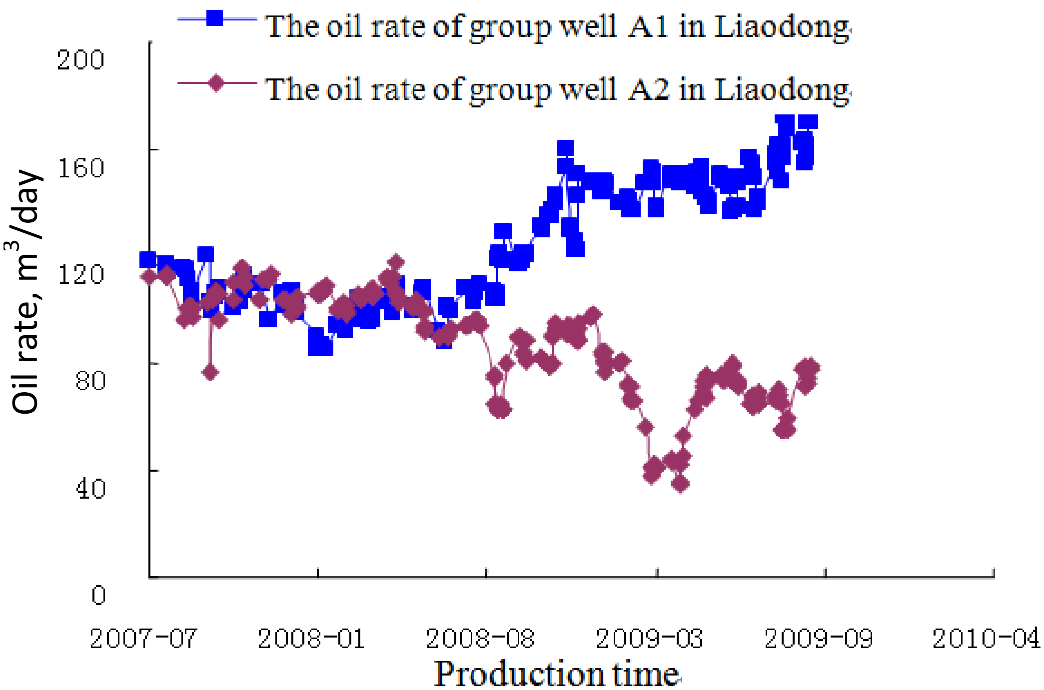

Figure 6. The oil rate curve of two well groups in Liaodong Pilot district.

CONCLUSIONS

Based on the on-site data of polymer flooding in Bohai Pilot areas, the following conclusions could be draw from the analysis:

1. Productivity factor differential is the deterministic parameters which directly determine the test results of polymer flooding. Thus, to inject polymer directly to reservoir that the productivity factor differential is large should be avoided. If it is inevitable, deep profile adjustment on this kind of wells should be considered before conducting polymer flooding.
2. For those wells whose water absorption volume turns good, emphasis should be placed on the change in absorption profile with the injection of polymer flooding. Measures such as separate layer polymer flooding, profile adjustment or increasing polymer volumes should be applied when the relative absorption volume decrease.

Conflict of Interests

The authors have not declared any conflict of interests.

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