The technical limitation of Separate polymer injection in Second-class Reservoir

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Abstract: Daqing oilfield has entered the water cut rising stage of late polymer flooding, it is necessary for injection well to take measures of separate injection. With the increasing reduction of the main reservoir recoverable reserves, polymer flooding of the Class II reservoirs is an important replacement method to oil development, which has an important meaning to develop reasonable and efficient. However, due to the complexity of the geological conditions of the Class II reservoirs, the difficulty of selecting separate injection wells and layers is relatively large. According to the geological characteristics of the Class II reservoirs, the technical limits of layering polymer injection in the Class II reservoirs are studied by numerical simulation, which can provide scientific basis for the oilfield development decision.

1. Introduction

The basic principle of polymer flooding technology is by increasing the injected fluid viscosity, regulate the oil-water two-phase mobility ratio in the reservoir and reduce the permeability of water flow, in order to achieve the purpose of expanding the sweep volume. During the period of "12th Five-Year Plan", the Class II reservoirs production replacement technology is widely studied, polymer flooding in the Class II reservoirs has been industrialized. However, because the Class II reservoirs have low permeability and small development scale of sand body, the reservoir physical property of the Class II reservoirs was worse than that of the main reservoir, the problems of the polymer get effect in advance and product liquid concentration increased gradually until the breakthrough occur frequently in field, according to the characteristics of the Class II reservoirs, a method suitable for the Class II reservoirs permeability distribution and can effective regulate the reservoir vertical contradiction is widely used in the development of the Class II reservoirs, namely the layering polymer injection technology. This paper established a conceptual model by numerical simulation method, to studied the technical limits of layering polymer injection in the Class II reservoirs, it is of important significance to slow down the differences of polymer absorbing in different layer of a single well and the conflict of layer heterogeneity, it is also useful for improving reservoir sweep volume and recovery.

2 Building conceptual model

The numerical simulation model was established by using Eclipse reservoir numerical simulation software. The model uses Cartesian grid, and the well spacing is 150m with five-probe method. There are two separate injection intervals in the model, using $25\times25\times3$, grid plane step is 9.64m, vertically divided into three layers, and the thickness of the oil level is 2. The thickness from top to bottom is 2m, 1m, 4m, with a barrier in which the barrier beds and the interbeds has half of the well spacing. This model is consistent with the positive rhythm characteristics, in which the permeability ratio is 3, the intermediate layer is not separated into two separate injection part permeability layer permeability average, separated part of permeability for 0 mD. The porosity is 0.25 and the initial formation pressure is 10MPa. The schematic diagram of the model is shown in Figure 1.

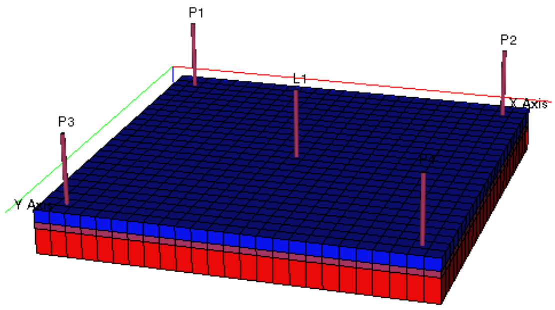
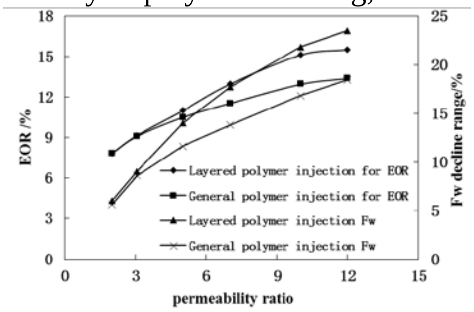


Fig 1 Schematic diagram of model

3 The boundaries between the permeability layer

In this paper permeability contrast boundary of separate-layer polymer injection is studied by the following designs. The design 1~6, positive rhythm, the permeability contrast were 2, 3, 5, 7, 10, 12, with parameters setting for other parameters as shown in Figure 2-1. Until the water cut increase to 98% by water flooding, general polymer flooding of 1PV, polymer injection rate of 0.2PV/a. The commingled polymer injection with molecular weight (1200 -1600 molecular weight) polymer and the concentration of polymer is 1000mg/L. With the subsequent water flooding, when the water content reached 98%, we calculate the enhanced oil recovery and decreasing water cut polymer flooding. The design 7~12 change the commingled polymer injection into separate polymer flooding, other parameters set as shown in the design 1. Design 13~24 change the positive rhythm into inverted rhythm, and other parameters set as shown in the design 1~12. By using the numerical simulation software Eclipse, the above 24 schemes are calculated. The results show that the enhance oil recovery and water cut decline of positive and inverted rhythm reservoirs with different permeability of polymer flooding, as shown in Figure 2 and Figure 3.



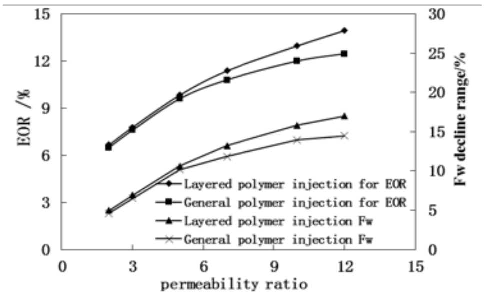


Fig 2 Comparison of the effects of separated polymer injection development

Fig 3 Comparison curve of the effect of commingled polymer injection and separated layer polymer injection in reverse rhythm layer

The simulation results indicate that when the permeability ratio is 3, the separated layer polymer injection of polymer flooding to enhance oil recovery and water cut dropped only 0.06 higher than general injection and 0.4 points based on the positive rhythm model, which is similar to the effect of commingled injection. When the permeability ratio is greater than 3, separated layer polymer injection production effect was significantly better than that of commingled injection, and with the increase of permeability contrast, the gap between the two increases, when the permeability ratio increased to 12, separated layer polymer injection polymer recovery and water cut will decline 2.12 and 5.08 percentage points higher than commingled injection.

In the reverse rhythm model,when the permeability contrast is 5,the increase of oil recovery an d the decline of moisture content by the separated layer polymer injection are only 0.25 and 0.44 pe rcentage points higher than that of the general polymer injection.The effect of the two approaches is similar.When the permeability contrast is more than 5, the effect of the separated layer polymer inje ction is obviously better than that of the general polymer injection.With the increase of the permeab ility contrast, the difference between the two approaches is bigger.When the permeability contrast in creases to 12, the increase of oil recovery and the decline of moisture content by the separated layer polymer injection are 1.48 and 2.53 percentage points higher than that of the general polymer injecti on.

4 The limit of the injection layer number

In order to study the limit of the injection layer number, as follows scheme 1~4, scheme design model for positive rhythm, the permeability contrast was 3, respectively, one, two, three and four separate injection interval model, with fig 1 model set other parameters. Water drive to fw=90%, general polymer flooding 1PV, polymer injection rate of 0.2PV/a, general polymer polymer injection with molecular weight (12 million -1600 molecular weight) polymer, the concentration of 1000mg/L. Follow water drive to fw=98%. Calculation of polymer flooding enhanced oil recovery and water cut. The software of Eclipse was used to calculate the above 4 schemes, and the polymer flooding enhanced oil recovery and water cut in the number of different sub layer segments was obtained, as shown in Figure 4 below.

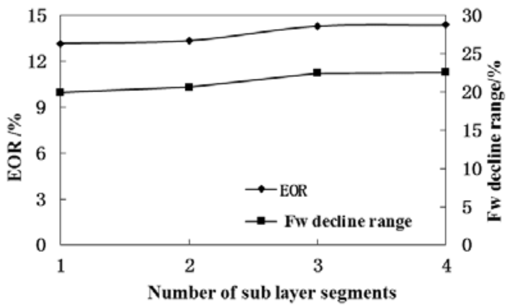


Fig 4 The development effect contrast curve of the number segments

The numerical simulation results show that, when the injection layer segment is 3, the polymer flooding enhanced oil recovery ratio is 1.15 percentage points, which is higher than the general polymer flooding, and the water cut is 2.55 percentage points. When the layer is 4, the polymer flooding enhanced oil recovery ratio is 1.21 percentage points higher than the general polymer flooding, the water cut is 2.67 percentage points. And the number of sub layer segments was 4, the change of polymer flooding enhanced oil recovery and water cut increased by 0.06 and 0.12 percentage points. After more than 3 layers, the polymer flooding enhanced oil recovery and water cut increase trend slowed down.

5 The boundaries of the interlayer area

In order to study boundary layer polymer interlayer area ,the following scheme is designed,designs1~4: model is the positive rhythm maximum permeability/minimum permeability=3, three layer segments, the interlayer area were 0, 1/3, 1/2, 2/3and 1 well spacing other parameters are set with the fig 1 model, Water drive to fw=90%, general polymer flooding 1PV, Injection rate of 0.2PV/a, molecular weight (12 million -1600 molecular weight) polymer for polymer flooding, concentration of 1000mg/L, follow water drive to fw=98%. calculating of polymer flooding enhanced oil recovery and water cut, the interlayer distribution among various schemes as shown below fig 5. Modle 6~10 to change the general polymer flooding for the layered polymer flooding, other parameters setting the same scheme 1-4.

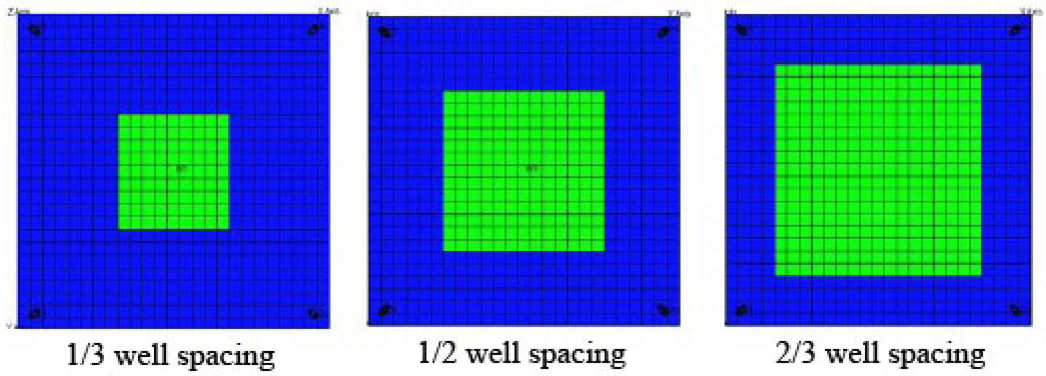
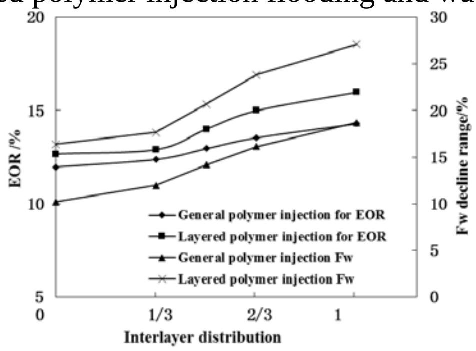


Fig 5 interlayer area distribution map

The application of numerical simulation software Eclipse, the above 10 schemes to calculate the distribution layer is 0 and 1/3, 1/2, 2/3 and 1 wells from the general polymer injection and layered polymer injection flooding and water yield decline, as shown in Figure 6 below



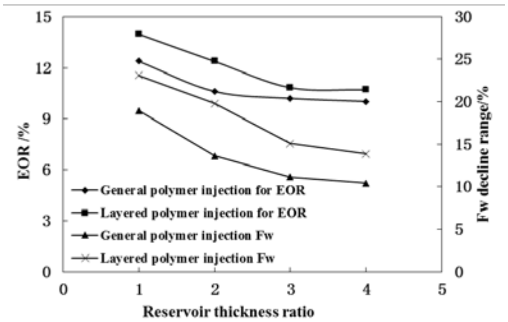


Fig 7 Development effect contrast curve of general polymer injection and layered polymer injection under the ratio of different oil layer thickness

Fig 6 Development effect contrast curve of general polymer injection and layered polymer injection under various restraining barriers spread

The numerical simulation results shown that both the size distribution of interlayer, layered polymer injection development effect will be significantly better than general polymer injection, and with the increase of restraining barriers spread, development effect became better. When the distribution of 1/3 restraining barriers spread, layered polymer injection to improve oil recovery and water cut decline than general polymer injection high 0.52 and 5.7 percentage points. When the restraining barriers spread more than 1/3 well spacing, layered polymer injection development effect is obviously better than the general injection. When the distribution of 1/2 restraining barriers spread, layered polymer injection to improve oil recovery and water cut decline than general injection high 1.05 and 6.51 percentage points, and the distribution of 1/3 restraining barriers spread compared to an increase of 0.53 percentage points and 0.81 percentage points.

6 The proportion limit of reservoir thickness

In order to study the reservoir thickness proportion limit of layered polymer injection, the following schemes are designed:

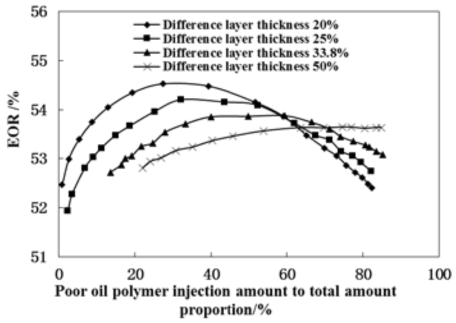
From scheme 1 to scheme 4: Model of positive rhythm and the permeability ratio is 3, three separate injection layer segment, the permeability and thickness of the set model is shown in tab.2-2, distribution of 1/3 restraining barriers spread, layer thickness is 1m, thickness ratio was 1, 2, 3 or 4, the thickness of the oil set as shown in tab.2-4, other parameters are set with the fig1 model. Water flooding to the water content of 90%, general polymer flooding 1PV, polymer injection rate of

0.2PV/a, general polymer polymer injection with molecular weight (12 million -1600 molecular weight) polymer, the concentration of 1000mg/L. Subsequent water flooding to the water content of 98%. Calculate the yield of polymer flooding and the decrease of water content. From scheme 5 to scheme 8, changed the general polymer flooding for the layered polymer flooding, other parameters are set to the Scheme 1. Eclipse numerical simulation software was used to calculate the oil reservoir thickness ratio of 1, 2, 3, 4, and the general polymer flooding enhanced oil recovery and water cut, as shown in Fig 7.

According to the simulation results, the separated layer polymer injection and general polymer injection development effect difference, layered polymer injection polymer flooding to enhance oil recovery and water cut decline than general injection high 0.65 and 3.91 percentage points when the thickness ratio is 3 as shown in Figure 2-8. The separated layer polymer injection and general polymer injection development effect is increased when the thickness ratio is less than 3, the polymer flooding enhanced oil recovery and water cut by 1.78 and 6.17 percentage points when the thickness ratio is 2.7. Determination of the boundary on the polymer flooding layered injection

(1) Effect of the ratio of layer to layer on the best injection point

The total recovery rate increased gradually and decreased gradually after reaching the highest point with the increase of the amount of polymer poor reservoir in the same permeability condition (Figure 8). With the increase of the proportion of poor reservoir thickness ratio, the optimal injection ratio gradually shifted to the right (dosage proportion increased). The recovery curve under permeability condition of 5:1 as an example, the best dosage of total amount ratio of 30.8% when poor reservoir thickness ratio is 20%, the best dosage of total amount increased to 77.4% with poor oil thickness ratio increased to 50%.



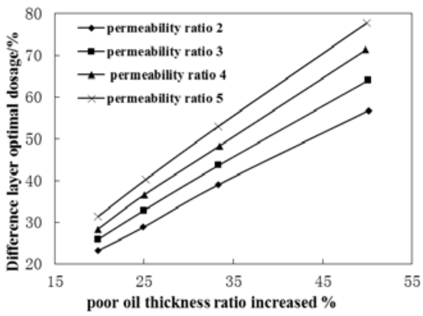


Figure 9 the relationship between the ratio of the optimum dosage and the ratio of the reservoir thickness

Figure 8 recovery variation of different thickness ratio (permeability ratio 5)

(2) The influence of permeability ratio and thickness ratio on optimum distribution point

With the increase of the ratio of the thickness of the poor reservoir to the total thickness, the optimum dosage percentage increased linearly, And the greater the permeability ratio, the greater the amount of the optimum proportional increase(Figure 9), with the increase of permeability ratio, the optimum dosage percentage increased linearly, and the greater the slope of the curve, the greater the proportion of the optimum increase.

7 Conclusion

1.In the case where the reservoir is positive rhythm, the injector wells with permeability ratio greater than 3 should be stratified and polymer injection in time.In the case where the reservoir is inverse rhythm, the injection wells with a permeability ratio greater than 5 should be stratified and polymer injection in time.

2.Layered polymer injection of the development effect is significantly better than the general polymer injection, and with the increase of the injection layer, the greater the number of dispense layers, the better the development effect in the process allowable range, however, after adding more than 3 layers, the effect of increasing the concentration of injection layer on the sweep efficiency of polymer flooding is not significant.

3. The greater the coefficient of the inactive zone is, the smaller the interference between each layer, the more the polymer flooding enhanced oil recovery. When the distribution distance of inactive reservoir is more than 1/3 times distance of wells, it should be carried out in time to distinguish each layer of polymer flooding in the well.

4. The ratio of oil layer thickness increases, and the thickness of high permeability layer becomes larger. Under the action of gravity, the polymer solution breakthrough phenomenon more obvious, the sweep volume decreased gradually. When the thickness ratio is less than 3, layered polymer injection development effect is obviously better than the general polymer injection.

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