Study on the influence of different key parameters on EOR in LB block

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Abstract. The high temperature reservoir is in the high water cut stage after long-term development, and the inefficiency or invalid circulation caused by injected water is aggravated. With a long development history, the well pattern has been adjusted many times, and the remaining oil distribution is highly dispersed. Based on the high-temperature reservoir conditions of the target block, the influence analysis of different key parameters on EOR effect of LB- block was carried out. The gas flooding and chemical flooding potential were evaluated by numerical simulation method, and the EOR effect of different oil flooding systems was defined. The gas flooding and binary flooding numerical models were established according to the well pattern, reservoir and fluid physical parameters. The development effect is predicted under different formation dip, reservoir permeability, oil viscosity, oil saturation, effective thickness and reservoir temperature. The simulation results show that the key factors of EOR in gas flooding and binary flooding are formation dip.

Keywords: reservoir permeability; reservoir thickness; viscosity; formation dip; EOR.

1. Introduction

After long-term water injection development, the dominant seepage channels in the middle Liuzan area are developed, and the development characteristics are high and low at present, and the stable production situation is severe. In order to further improve the reservoir development effect, it is urgent to carry out EOR program research on the basis of fine geological re-understanding research. But there are three problems at present: first, because of the strong heterogeneity in plane, inter-layer and inter-layer, the shape of sand body is complex, the inheritance of longitudinal sand body is poor, the superposition relation is complex, and the fine reservoir description is difficult; Second, the reservoir is buried deep, the temperature is high, the high temperature resistance EOR drive medium optimization is difficult, third, the target block is complex fault block multi-layer heterogeneous sandstone reservoir, EOR program design and optimization is difficult[1-5].

①The injection and production well pattern has a high control degree of reserves (91%), a high control degree of water flooding reserves (77.6%), a high utilization degree of water flooding reserves (65.4%), a high recovery degree of geological reserves (32.1%), a high comprehensive water cut (96.5%), a low recovery rate of geological reserves (0.22%), and an unsatisfactory development effect.

② Conventional water flooding has little potential to improve the development effect. Therefore, it is urgent to change the development mode. However, high reservoir temperature restricts the effect of tertiary oil recovery.

2. State of the art

Wu Wei[6] et al. set up an evaluation method for emulsifying performance and emulsifying viscosity of emulsion surfactant to further improve the recovery factor of ultra-high temperature and medium-low permeability reservoirs, and studied the structural-activity relationship of emulsion surfactant. It provides technical support for greatly enhancing oil recovery in ultra-high temperature and low permeability reservoirs.

Shi Jing[7] et al. developed a new dual compound oil drive system to meet the development needs of high temperature and high salt heavy oil reservoirs in Sheng li Oilfield. The successful pilot test provides a reference for similar reservoirs to greatly improve the recovery factor research.

For high temperature and high salt reservoirs, Yuan Chengdong[8] et al. proposed micro-scale dispersing gel and surfactant flooding technology in view of reservoir conditions and water injection development. It provides a new technology and method for enhancing oil recovery in high temperature and high salt reservoir and has practical significance for the efficient development of high temperature and high salt reservoir. It has important

theoretical significance to enrich the oil displacement mechanism of surfactant and the migration and plugging mechanism of disperse adhesives in porous media.

Tao Jiping[9] et al. developed a new nitrogen foam flooding system with temperature and salt resistance and low interfacial tension for high temperature and high salt reservoirs, which can only effectively control the high permeability bands, but also better emulsify the crude oil, peel and carry the crude oil for recovery, and adapt to a wider range of formation conditions.

Aiming at low saturation, high viscosity and high temperature reservoir, Han Qi[10] et al. co-polymerized various functional monomers with AM and synthesized a new high temperature resistant polymer GL-100 under appropriate reaction conditions. The research experience of injection system is provided for the study of enhanced oil recovery technology by chemical flooding in high temperature reservoir.

According to Zhou Yumeng[11] et al., the contradiction between reservoir layers is prominent, the intra - layer interference is gradually intensified, the heterogeneity is enhanced, the water absorption profile is not uniform, the injection water line is rapidly advancing along the crack of high permeability large pore channel, and the water channeling phenomenon is serious. The composite ion gel profile control agent and the slow expansion flexible viscoelastic particle profile control agent were developed to effectively solve the phenomenon of injected water advancing rapidly along the high permeability large pore, and the effect of oil increase and precipitation was obvious, which played an important guiding role in the comprehensive management of deep reservoir profile control in this block.

In order to meet the requirements of high reliability and stability in oilfield fracturing development and high performance of profile control agent, Wenjin Zhao [12]et al. adopted layer-by-layer assembly technology, microfluid technology, ion gelation method and reverse microemulsion polymerization method to prepare a series of composite gel profile control agent with temperature sensing function and intelligent control of gel water plugging.

Liu Xiaomin[13] et al. systematically screened and evaluated the surfactant foam flooding system in view of the problem of surfactant foam being exposed to oil and the conditions of high temperature and high salt reservoirs in Daqing oil reservoir. After that, nanoparticle were introduced to improve the foam performance, providing guidance for finding a system that can simultaneously obtain ultra-low oil/water inter-facial tension and excellent foam performance.

Weijia Cao[14] et al. Aiming at the problem of the large distance between oil and water in high-temperature oil reservoirs, the electrode gel was used as the displacement agent and evaluated. The research results provided theoretical and technical support for the development of inorganic gel and its application in Wells.

For surfactant flooding in high-temperature and high-salt oil reservoirs, Yuan-Li Li[15]ect. Study adopted sulfobetaine and sulfonate surfactant derived from 1, 3-dialkyl glycerol ether as the surfactant complex system. This formula has good resistance to the adsorption of quartz sand, and reduces interface tension, making it easier for crude oil to form water-in-oil emulsion.

Fenglan Zhao[16] et al. Feasibility of using organic base instead of inorganic base for ASP flooding in heterogeneous high temperature reservoir. The effect of alkali on formation was evaluated in laboratory environment, and the mechanism of organic alkali ASP flooding was studied, which provided guidance for high temperature heterogeneous reservoir composite flooding system[16].

3. Result Analysis and Discussion

Numerical Simulation Methods Gas Flooding and Chemical flooding potential Evaluation In order to determine the EOR effect of different oil flooding systems under different key parameters, the project team established the ideal numerical simulation model of gas flooding and binary flooding according to the well pattern, reservoir and fluid physical parameters of the fault block in the north of Liu90. This model is used to study the influence of key parameters on EOR of gas flooding and binary flooding.

1、Potential evaluation of gas flooding and chemical flooding by numerical simulation method.

The numerical simulation model of typical well group is used to predict the potential of enhanced oil recovery efficiency by chemical flooding and gas flooding, the results are shown in the figure 1 and figure 2 below.

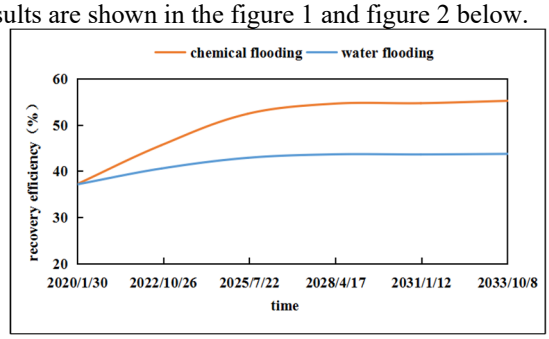

FIG. 1 Effect of chemical flooding on EOR

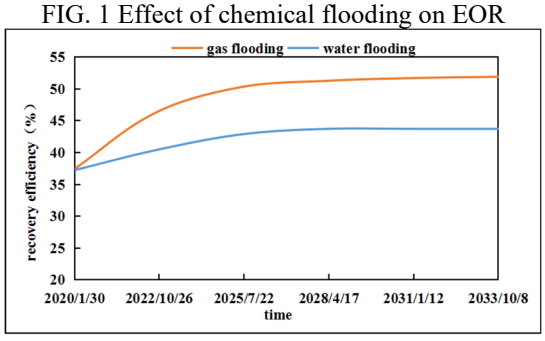

FIG. 2 EOR effect of gas flooding

The results show that compared with water flooding, chemical flooding increases oil recovery efficiency to 12.33% when rate of water content reaches 98%, compared with water flooding, gas flooding increases oil recovery efficiency to 8.31% when rate of water content reaches 98%. So the application of gas flooding and water flooding in complex fault block reservoirs can have a good effect of enhancing oil recovery efficiency.

Table 1 EOR effects of chemical flooding and gas flooding

Medium of displacement	Chemical drive	Gas drive	Water drive
Ultimate recovery factor （%）	55.32	51.30	42.99
Increased oil recovery value (%)	12.33	8.31	-

In order to determine the effect of different oil displacement systems on enhanced oil recovery efficiency under different key parameters,the project team has established the ideal numerical simulation model of gas flooding and binary flooding according to the well pattern form, reservoir and fluid physical parameters of Liu90 north fault block. The ideal model is used to study the influence of key parameters on the enhanced oil recovery efficiency effect of gas flooding and binary flooding. In the study, the effects of gas flooding and binary flooding under the conditions of different formation dip, reservoir permeability,crude oil viscosity, oil saturation, effective thickness and reservoir temperature are predicted respectively,,and thus clarify the influence of key parameters on gas flooding and binary flooding effect.

The effect of strati-graphic dip on enhanced oil recovery efficiency by gas flooding and binary flooding.

The oil reservoir in Liuzan Middle Area belongs to a typical complex fault block oil reservoir, each fault block is affected by the ground stress in the process of sedimentation. While forming fault block, it will cause a certain inclination and strati-graphic dip.Influenced by the strati-graphic dip, the three-phase flow of oil, gas and water in the reservoir will be affected by the strati-graphic dip, Three phases generate differentiation under the effect of gravitational differentiation, so as to affect the development effect of the reservoir. It is great significant for the efficient development of complex fault block reservoirs in Liuzan central area to clarify the effect of formation dip on the effects of different enhanced oil recovery efficiency methods.

In this study, ideal models are used to predict the effect of enhanced oil recovery when the strati-graphic dips are 5 °, 15 ° and 30 ° respectively. Through the enhanced oil recovery effect of binary flooding and gas flooding under different strati-graphic dip, the influence of strati-graphic dip on enhanced oil recovery effect of binary flooding and gas flooding is clarified. See Fig.3 for enhanced oil recovery effect of binary flooding and gas flooding under different strati-graphic dip.

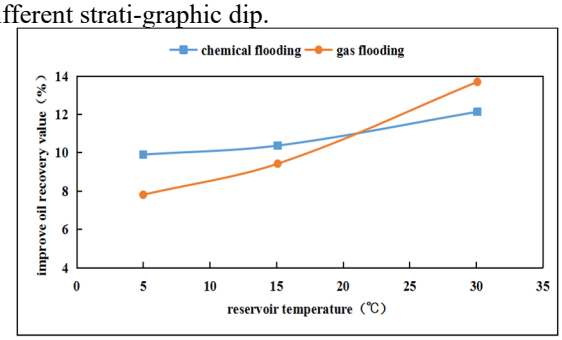

FIG. 3 EOR effects of chemical flooding and gas flooding under different dip angles

It can be seen from the enhanced oil recovery effect of binary flooding and gas flooding under different strati-graphic dip that the enhanced oil recovery of chemical flooding and gas flooding increases with the increase of strati-graphic dip , When the strati-graphic dip increases from 5 ° to 30 °, the enhanced oil recovery value of binary flooding increases from 9.89% to 12.15%, and that of gas flooding increases from 7.89% to 13.45%, It shows that when the strati-graphic dip is increasing, the increase of enhanced oil recovery by gas flooding is greater than binary flooding, the influence of strati-graphic dip on the development effect of gas flooding is greater than that of enhanced oil recovery by binary flooding. Therefore, the greater the strati-graphic dip in the actual reservoir, the better the effect of enhanced oil recovery by binary flooding and gas flooding . At the same time, it shows that the strati-graphic dip is the key factor affecting the enhanced oil recovery by gas flooding.

The effect of reservoir permeability on enhanced oil recovery by gas flooding and binary flooding.

Permeability is an important parameter to evaluate the physical property of the reservoir. The value will affect the characteristics of oil and water flow and enrichment in the reservoir.If the permeability is too low, the residual oil saturation in the reservoir will be too high, and the movable oil saturation will decrease, thus affecting the crude oil production of production wells. In the study, the effects of binary flooding and gas flooding on enhanced oil recovery are predicted under the conditions of 50, 100, 150 and 300mD permeability respectively, so as to clarify the influence of reservoir permeability on the effects of binary flooding and gas flooding on enhanced oil recovery. See Fig.4 for enhanced oil recovery effect of binary flooding and gas flooding under different permeability conditions.

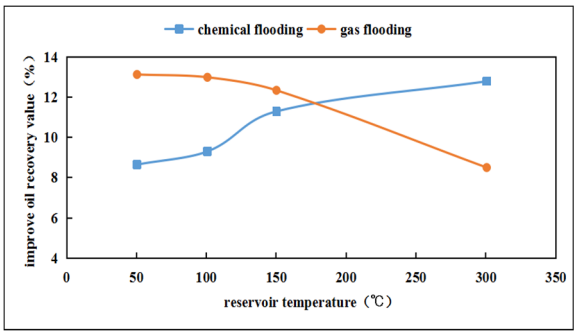

FIG. 4 EOR effects of chemical flooding and gas flooding under different permeability conditions

From the numerical simulation results of binary flooding and gas flooding under different reservoir permeability conditions, it can be seen that with the increase of permeability, the recovery efficiency of binary flooding increases, while that of gas flooding decreases gradually. When the permeability increases from 50mD to 300mD, the enhanced oil recovery value of binary flooding increases from 8.71% to 12.83%, and that of gas flooding decreases from 13.17% to 8.58%. This is because in the process of permeability increase, the adsorption loss of surfactant and polymer and the viscosity loss of polymer decrease during the injection of surfactant and polymer into the reservoir, so the effect of enhanced oil recovery by binary flooding increases with the increase of reservoir permeability; When the permeability is too high, the gas

in the gas flooding tends to burst along the high permeability formation, thus forming a gas channeling channel between injection and production wells, thus reducing the effect of gas flooding on enhancing oil recovery. Therefore, it can be seen from the above analysis that permeability is one of the key factors affecting the effect of binary flooding and gas flooding to enhance oil recovery.

（3） Effect of crude oil viscosity on the effect of enhanced oil recovery by gas flooding and binary flooding. The viscosity of crude oil will affect the mobility ratio of displacement medium to displaced fluid in the process of gas flooding and binary flooding.If the mobility ratio is too large, it will lead to the injected binary system or gas channeling too early, thus greatly reducing gas flooding and binary flooding to improve oil recovery.In this study, the effects of enhanced oil recovery of gas flooding and binary flooding are predicted when the viscosity of crude oil is 3.6,10,20.The effect of enhanced oil recovery of binary flooding and gas flooding under different crude oil viscosity is shown in figure 5 .

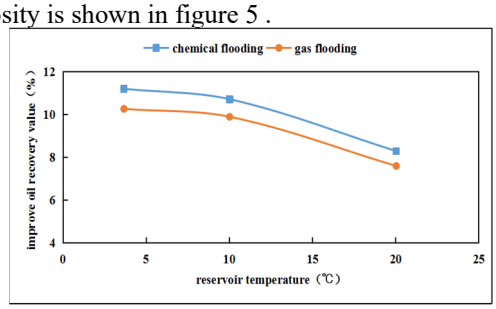

FIG. 5 EOR effects of chemical flooding and gas flooding under different crude oil viscosity

From the effect of enhanced oil recovery of binary flooding and gas flooding under different crude oil viscosity conditions, it can be seen that the effect of enhanced oil recovery of binary flooding and gas flooding decreases with the increase of crude oil viscosity. When the crude oil viscosity increases from 3.6 to 20, the recovery efficiency of binary flooding decreases from 11.25% to 8.28%, and the recovery efficiency of gas flooding decreases from 10.35% to 7.65%.It shows that in the process of increasing the viscosity of crude oil, the effect of improving mobility ratio of binary flooding becomes worse, and the effect of adverse mobility ratio of gas flooding increases, so the recovery efficiency of both binary flooding and gas flooding decreases with the increase of crude oil viscosity.

（4） Effect of oil saturation on the effect of enhanced oil recovery by gas flooding and binary flooding.

The level of oil saturation directly affects the crude oil reserves in a certain area of the reservoir, which is affected by the residual oil saturation. if the oil saturation in a certain area of the reservoir is too low, the oil well production is affected because the oil phase relative permeability is too low, thus affecting the recovery efficiency of gas flooding and binary flooding. This study predicts the effect of enhanced oil recovery of gas flooding and binary flooding under the conditions of 30%,40% and 60% oil saturation respectively, so as to clarify the effect of oil saturation on the effect of enhanced oil recovery of gas flooding and binary flooding. The prediction effect of enhanced oil recovery by gas flooding and binary flooding under different oil saturation conditions is shown in figure 6.

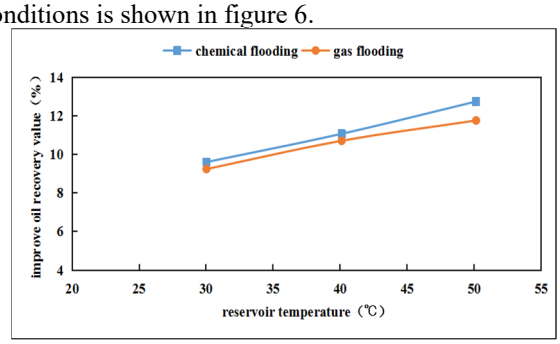

FIG. 6 EOR effects of chemical flooding and gas flooding under different oil saturation conditions

From the chart of predicting the effect of enhanced oil recovery of gas flooding and binary flooding under different oil saturation conditions, it can be seen that the recovery efficiency of gas flooding and binary flooding increases with the increase of the initial oil saturation. When the oil saturation increases from 30% to 50%, the recovery efficiency of binary flooding increases from 9.57% to 12.65%, and the recovery efficiency of gas flooding increases from 9.31% to 11.85%. It shows where the higher the remaining oil saturation after water flooding, the higher the effect of gas flooding and binary flooding to improve oil recovery, At the same time, oil saturation is also an important parameter affecting gas flooding and binary flooding, but it has little variability due to the distribution of initial oil saturation in the reservoir. therefore, in the actual production process, this parameter has little influence on the enhanced oil recovery of gas flooding and binary flooding.

Influence of reservoir thickness on gas flooding and binary flooding for enhanced oil recovery.

Reservoir thickness affects the distribution of oil, water and gas in flooding process.The larger the reservoir thickness is, the more obvious the gravity differentiation of gas, water and oil will be, which will significantly affect the inflow and output dynamics at the production well end.In this study,the effect of enhanced oil recovery gas flooding and binary flooding were predicted under the conditions of oil reservoir thickness of 0.5m, 0.7m, 1.0m and 2.0m, so as to clarify the influence of oil reservoir thickness on the effect of enhanced oil recovery gas flooding and binary flooding.The chart of the effect of enhanced oil recovery gas flooding and binary flooding under different reservoir thicknesses are shown in Figure 7.

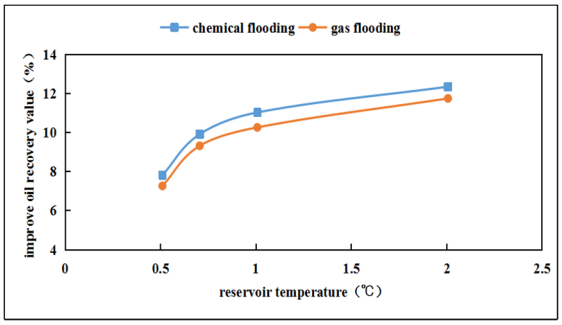

FIG. 7 EOR effects of chemical flooding and gas flooding under different reservoir thicknesses

It can be seen from the chart of the effect of enhanced oil recovery of gas flooding and binary flooding under different reservoir thicknesses,with the increase of reservoir thickness, the effect of enhanced oil recovery of chemical flooding increases first and then flattens out, but the effect of enhanced oil recovery of gas flooding increases first and then slightly decreases.When the reservoir thickness increases from 0.5m to 2.0m, the effect of enhanced oil recovery of binary flooding increases from 7.84% to 12.35%, and the effect of enhanced oil recovery of gas flooding increases from 7.32% to 11.83%.It indicates that the effect of enhanced oil recovery of gas flooding and binary flooding will increase with the increase of reservoir thickness. When the reservoir thickness is too large, a large amount of residual oil will be formed in the reservoir due to binary, injected gas and gravity differentiation of three phases of crude oil, which will affect the effect of enhanced oil recovery of gas flooding and chemical flooding.

Influence of reservoir temperature on gas flooding and binary flooding for enhanced oil recovery.

Reservoir temperature will affect the physical properties of crude oil and injected fluids in the reservoir, which will affect the effect of enhanced oil recovery of gas flooding and Two element drive.In this study, the effect of enhanced oil recovery gas flooding and binary flooding were predicted respectively at reservoir temperatures of 90, 100 and 110, so as to clarify the influence of reservoir temperature on the effect of enhanced oil recovery gas flooding and binary flooding.The chart of the effect of enhanced oil recovery gas flooding and binary flooding under different reservoir temperature conditions is shown in Figure 8.

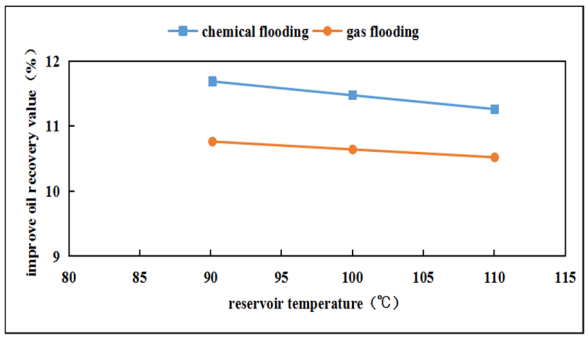

FIG. 8 EOR effects of chemical flooding and gas flooding at different reservoir temperatures

It can be seen from the chart of the effect of enhanced oil recovery of gas flooding and binary flooding under different reservoir temperature,With the increase of reservoir temperature, the effect of enhanced oil recovery gas flooding and binary flooding decreases.When the reservoir temperature increased from 90 to 110, the recovery efficiency of binary flooding decreases from 11.68% to 11.25%,, and the recovery efficiency of gas flooding decreases from 10.78% to 10.35%.However, it can be seen from the effect of enhanced oil recovery that the change of reservoir temperature has little influence on the effect of enhanced oil recovery gas flooding and binary flooding.

Based on the above analysis results, it can be concluded that the key factors for enhanced oil recovery with gas and binary flooding are formation dip Angle, reservoir permeability, crude oil viscosity and reservoir thickness.The influence degree of formation dip > reservoir permeability > reservoir thickness > crude oil viscosity.

4. Conclusion

(1) The EOR potential of chemical flooding and gas flooding was predicted by using typical well group numerical simulation model. The EOR potential of chemical flooding and gas flooding could be increased by 12.33% and 8.31% respectively on the basis of water flooding. Both gas flooding and water flooding can enhance oil recovery in high temperature fault block reservoirs.

(2)Based on the reservoir conditions of the target block, the paper analyzes the influencing factors of formation dip, reservoir permeability, oil viscosity, oil saturation, reservoir thickness and reservoir temperature, and identifies the key factors of EOR in gas flooding and dual flooding as formation dip, reservoir permeability, oil viscosity and reservoir thickness respectively. The influence degree is the formation dip > Reservoir permeability > Reservoir thickness > Viscosity of crude oil.

(3) Based on the numerical simulation method, the sensitive factors were analyzed, and the results showed that the permeability limit was:Chemical flooding & GT. 150 mD, gas flooding & Lt. 150 mD; single layer thickness limit: both chemical flooding and gas flooding should be greater than 0.7 m; reservoir dip limit: both chemical flooding and gas flooding should be greater than 15° ; The viscosity of crude oil should be less than 10 mPa·s, and the oil saturation should be more than 30% .

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