Analysis of Enhanced Oil Recovery Technology in Extra-high Water Cut Period in Oilfield

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Abstract. Most onshore oil fields in China are in the later stage of development, and the water content is more than 90%, which increases the difficulty of remaining oil mining. In order to improve the oil production, it is necessary to develop a variety of oil recovery technologies, increase the oil field space pressure, weaken the oil viscosity, and improve the recovery factor. Taking L oilfield as an example, the paper briefly expounds the characteristics of extra-high water cut period, and on this basis, puts forward recovery technology, grasps development rules, and realizes technological innovation. The accumulative oil production reaches 2.32 million tons, and the recovery factor increases by 9%, thus providing reference for related workers.

Key words: Oilfield; Extra high water cut stage; Recovery techniques.

1. Preface

Most of the old oilfields in China are in the stage of ultra-high water cut, the distribution and flow of underground fluid in the reservoir change, the overall recovery rate is low, there are a lot of remaining oil in the watered-out layer, and it is difficult to dig. Various contradictions are highlighted in the late development of oilfields, and it is difficult to maintain the output of oilfields by conventional development. Traditional oilfield recovery is mainly carried out by chemical means and fine water flooding. Due to local enrichment, high dispersion and complex distribution of ultra-high water cut remaining oil, recovery technology must be optimized to improve oil recovery and maintain stable oil production.

2. Overview of oil

L Oilfield is divided into 59 faults, most of which are normal faults. In the north, there is a group of east-west normal faults with a fault distance of > 40m. In the south, there are east-south normal faults with a fault distance of 10-20m. According to the fault development characteristics of L oilfield, seismic interpretation data were used to accurately control the fault extension scale and occurrence, establish the contact relationship between geological layer and fault, and carry out 3d fine modeling, as shown in Figure 1.

![Fault model of L oilfield](image1)

L oilfield is in the middle and late stage of development, with a high degree of well pattern improvement, a relatively complete understanding of geology, and a lot of well point data to ensure the static reliability of reservoir. According to the numerical simulation of L oilfield, the remaining oil distribution is predicted and the remaining oil saturation of main T12-1 small layer is plotted, as shown in Figure 2.

![Remaining oil saturation](image2)
L oilfield is in the stage of high water cut development, and the remaining oil is scattered, mostly flake, with high saturation and insufficient water flooding effect. Features are as follows:

1.1 Water sources are complex. In the ultra-high water cut stage of an oil field, the water layer is thick, the water area is wide, and the water sources are complex, including bottom water and edge water. Bottom water is the main reason for the increase of oil water volume, while edge water has little influence. The combined action of the two will improve the top interface of oil layer, increase the floating type of oil layer, and then reduce oil recovery [1].

1.2 Development law changes. Oil field development rules are different in ultra-high water cut stage, including oil production rate, water cut rise rate, liquid production rate and other parameters, which all reflect the changes of underground macro reservoir parameters.

1.3 The well pattern changes greatly. After the ultra-high water cut, the well pattern of the oilfield has been adjusted for several times. In the process of water flooding, the multi-phase fluid interaction between reservoirs is distributed, and the position of enrichment and highly dispersed remaining oil in some places becomes the mining object, concentrated at the top of the thick oil layer.

1.4 Change of potential objects. With the deepening of development, injection-production Wells are adjusted by multiple infilling, and the plane classification of remaining oil varies greatly. The infilling and adjustment of well pattern is to improve the control degree of reserves at first, and to tap the potential of local remaining oil at the later stage.

3. Technical measures to improve oil recovery during extra high water cut period

3.1 Fine water drive technology

L oilfield is in the stage of ultra-high water cut, and water injection is general in the early stage, resulting in high water cut, local high permeability bands and serious underground invalid water circulation. Fine water flooding technology can be adopted to adjust injection-production parameters, change injection-production working system, optimize liquid flow direction and improve water flooding recovery [2]. In oilfield exploitation, streamline data simulation technology is used to fit the dynamic production of the block, with "water injection efficiency" as the main factor, and the water injection volume of injection well is adjusted to avoid invalid circulation of injected water. The specific steps are as follows:

(1) The production history of the block is simulated by using numerical results of streamlines. After full fitting, numerical results of simulated streamlines are called to calculate the e, I single well water injection efficiency and the average water injection rate of E 12 block. The calculation formula is as follows:

\[ \bar{e} = \frac{\sum q_i}{\sum w_i} \]  (1)

Among them, \( \sum q_i \) is the daily water injection volume in the work area(m³/d); \( \sum w_i \) is the daily oil production of the working area(m³/d).

(2) Optimize water injection volume. Take the average water injection rate of \( \bar{e} \) block as the boundary. Water injection well if \( e_i > \bar{e} \). The injection volume needs to be increased. On the contrary, the amount of water injected is reduced. The calculation method of new injection volume after adjustment is as follows:

\[ q_i^{\text{new}} = q_i^{\text{old}} \times (w_i + 1) \]  (2)

Among them, \( q_i^{\text{old}} \) is the original injection volume(m³/d); \( q_i^{\text{new}} \) is to optimize the injection volume(m³/d); \( w_i \) is the weight coefficient. The calculation formula is as follows:

\[ e_i > \bar{e} : w_i = \left( \frac{q_i^{\text{new}} - q_i^{\text{old}}}{e_{\text{max}} - e_{\text{min}}} \right) \cdot w_{\text{max}} \]  (3)

\[ e_i < \bar{e} : w_i = \left( \frac{e_i - e_{\text{min}}}{e_{\text{max}} - e_{\text{min}}} \right) \cdot w_{\text{min}} \]  (4)

In practical application, the maximum amount of water injection needs to be adjusted due to the limitation of working system and production status, \( w_{\text{min}} \) Set to -0.5, \( w_{\text{max}} \) Set to 0.5. The maximum amount of water injection can be adjusted to the original amount 50% of \( e_{\text{max}} \), \( e_{\text{min}} \) is under existing production. Maximum/minimum water injection efficiency of water injection well in work area, \( a \) is the optimization index, take 2. The weight coefficient changes gently.

(3) To optimize the fluid production of oil Wells, the adjustment of water injection is the main result. According to the situation of production Wells, the associated injection Wells and distribution coefficient of relevant production Wells are calculated. The adjusted water injection volume is multiplied by the distribution coefficient, and the value of adjusted oil production is obtained after summing up [3]. It is assumed that four injection Wells around Px in the production well contribute to its production. The water volume is respectively \( \Delta q_1 \), \( \Delta q_2 \), \( \Delta q_3 \), \( \Delta q_4 \) distribution coefficients are, respectively \( f_{1-Px} \), \( f_{2-Px} \), \( f_{3-Px} \), \( f_{4-Px} \), and \( \Delta q_i = q_i^{\text{new}} - q_i^{\text{old}} \), PxThe adjustment formula of liquid production is as follows:

\[ \Delta q_{PX} = \Delta q_1 f_{1-Px} + \Delta q_2 f_{2-Px} + \Delta q_3 f_{3-Px} + \Delta q_4 f_{4-Px} \]  (5)

Formula of fluid production after adjustment of production well:

\[ q_i^{\text{new}} = q_i^{\text{old}} + \Delta q_i \]  (6)

(4) The streamline model prediction is a domestic effect. The optimized liquid production and injection volume are simulated for a period of time, and the water injection efficiency is calculated again. The above steps are repeated to optimize the water injection efficiency.

3.2 Well pattern reconfiguration technology

The oil field is at the stage of ultra-high water cut, and the remaining oil distribution is characterized by "local enrichment and overall dispersion". About 30% of
recoverable reserves remain to be developed. Therefore, in order to improve oil recovery, local infill Wells can be used to develop the remaining oil and improve the development effect. The location of infill Wells is an important problem, especially when oil prices are low and drilling costs are high, so the location of infill Wells must be optimized. In the past, the optimization was mainly based on the index of remaining oil reserves richness, and the formation pressure and reservoir physical properties were ignored because of single factors [4]. During well pattern reorganization, the optimized production potential calculation formula can be adopted to select the infill well location based on the remaining oil. Taking L oilfield as an example, there are 25 production Wells in total and 6 injection Wells have been shut down for a long time. Analysis shows that most of them are located at the edge of the oilfield, and it is speculated that the intrusion of edge water causes oil well flooding and reduces the efficiency of injection Wells. In the adjustment well deployment, the oil well diversion mode is selected to transfer the production Wells and high water content Wells in the periphery of the well area. Some production Wells are longitudinal-flooded and shut down for a long time; some production Wells are water-cut high and in the marginal area; some production Wells are poor in water plugging operation, so they are all transferred.

3.3 ASP flooding technology

In order to improve oil recovery, the "self-efficient oil displacement" composite technology was developed. Details are as follows:

(1) Design and synthesis technology of polymer molecules and surfactants. Based on the strong base alkylbenzene sulfonate surfactant products used for oil displacement, the microscopic oil displacement mechanism was deepened, the molecular performance and structure relationship of surfactants were determined, and the weak base alkylbenzene sulfonate products with high symmetry and high branched degree were developed [5]. For high temperature, high salinity, low permeability oil field conditions, the product can use non-ionic, anionic, amphoteric ionic alkali free surfactants, reduce the amount of composite flooding polymer, increase the technical and economic effects, reduce the cost of 20% and 40% of the polymer amount, achieve good results.

(2) Multi-parameter quantization scheme. Reservoir geological and developing factors affecting the thorough analysis, build a series of strata combination, object of exploitation, the degree of control, well pattern well spacing design standards and technologies such as line, form the best technical effect of asp flooding engineering plan, build in order to enlarge sweep volume efficiency, improve to effective prescription, standard of parameters and design process.

(3) Tracking adjustment technology. Oil field development, in order to ensure the effect of asp flooding, different mining stages in order to enhance the capacity of reservoir flood, used as the key point, follow the "power, adjustable pressure, ability to control water cut, to protect, prevent breakthrough" the adjustment of the tracking principle, realizes the whole control, key adjustment, increase the single well oil recovery, a quantitative targets, advanced prediction analysis, classification, form, active control adjustment. Through this method, the tracking and control standards of plugging, pressure, control and adjustment can be formed to realize accurate control of oilfield adjustment. The compliance rate of implementation plan is > 90%, and the whole oilfield can maintain high injection-production capacity and low water cut stable period.

3.4 Chemical flooding technique

L oilfield is an edge water structure oilfield composed of multi-layer sandstone and ultra-deep rock. Long-term waterflood development is in the stage of ultra-high water cut. Individual contradictions in well area are prominent, and injection water wave efficiency is low. The process is as follows: the water content of oilfield injection reaches 99%, and the mixture system of 0.3PV cross-linking agent and polymer is injected to carry out chemical flooding. The polymer of weak gel system is high polymer. When flowing through high permeability core, water solution can enter the pore space of core. Coupled with the high viscosity of weak gel system, the water-oil fluidity ratio can be controlled. The larger the permeability range is, the lower the recovery rate of weak gel flooding is; on the contrary, the recovery rate increases, and the maximum recovery rate is achieved when the permeability range is 15.

4. Development effect

Since 2016, the oilfield has gradually used the fine water flooding technology to recombine the field well pattern, and the ASP flooding technology has also been used in different stages. By 2021, the accumulative utilized geological reserves have reached 50 million tons, producing 2.32 million tons of oil and increasing the recovery factor by 9%.

5. Conclusion

To sum up, the extra-high water cut stage of oilfield is faced with the problems of insufficient resources, increasing production decline pressure and serious imbalance between production and storage. It is necessary to lock the main direction, solve the bottleneck restricting oilfield development and deepen oilfield development through technological innovation. Therefore, in order to stabilize the output of oil field, fine water flooding technology, well pattern recombination technology and ASP flooding technology can be taken into consideration.
of the actual situation to rationally plan oil field production and improve oil field recovery.

References


