https://doi.org/10.1051/e3sconf/202235201053

Study on technical measures to improve oil recovery during extra high water cut period

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Abstract. China's petroleum resources are mainly continental facies with high petroleum density. Due to high heterogeneity, mining by traditional methods is not effective, and nearly half of the resources are not developed. The onshore oil fields that have been developed in Daqing area; Liaohe, Shengli and other large oil fields have entered high water cut stage, but there are still a lot of problems such as scattered remaining oil distribution, flooded reservoir, low recovery factor, reduced production and poor economic benefits. Based on this, this paper mainly analyzes the related technical measures to enhance oil recovery in the ultra-high water cut period.

Key words: Oilfield; Extra high water cut stage; recovery.

1. Introduction

At present, there are two research emphases of flow field regulation development technology. First, according to the fluid permeability characteristics inside the reservoir; At present, there have been many studies on the identification and characteristics of the dominant flow field, which can intuitively reflect the flow field distribution in the reservoir and describe the position and development state of the large pore channel, so that the reservoir flow field can be described qualitatively + semi-quantitatively. Secondly, a great deal of research has been done on how to adjust the flow field in the mine, forming the circulation line of well pattern adjustment. Flow field regulation technology models include coordinated injection-production drainage line, comprehensive treatment of equalized flow field, multistage subdivision section and injection-production coupling flow regulation line. In these two processes, due to the imbalance of the flow field, the flow field must be adjusted to improve the development efficiency of the reservoir. Therefore, there is no quantitative analysis method for the reservoir at present.

2. High water cut oil field situation at home and abroad

2.1 Foreign high water cut oil field situation

Oil fields in many countries have stepped into the stage of high water cut and extra high water cut after decades of waterflooding. Kuleshov in Russia, Ford Geraldine in the U.S. and East Texas are producing more than 50 percent of oil on average with 97 percent water content. These high water-cut oil fields are mostly lithologic and structural, and their reservoirs have good physical properties. Especially after entering the ultra-high water-cut stage, the recovery factor declines, and the production decline rate is slow in general. They are mainly river sedimentary facies, and most of them are edge and bottom water, and their energy levels differ greatly.

2.2 Domestic high water cut oil field situation

At present, the water content of the main oil sac in many oilfields in East China is more than 90%, and it has entered the high water cut stage. Although it has been exploited for several times, only 30% of the crude oil reserves are available, and a large amount of remaining oil can be exploited to improve the recovery of crude oil. In recent years, with the development of oil fields, the relationship between oil and water and the distribution of remaining oil become more and more complicated, which brings difficulties to the development of oil fields. In the ultra-high water cut stage, the remaining oil distribution is relatively scattered, and the mining efficiency is low, the mining efficiency is low, and the energy consumption is high, which affects the production and economic benefits.

3. Characteristics of extra high water cut stage in oil field

After water layer comparison, the characteristics of high water cut oil field are: large water area. The mixture of oil and water will slowly become thick and fluctuate greatly, which is not good for oil field development. Through the active application of multiple horizontal Wells, the water cut state and floating state of the oilfield can be better understood. When the thickness of oil layer is less than the measured thickness, the horizontal height of oil-water mixture layer will change to some extent, so that the fluctuation range of water-bearing oil layer can be accurately judged. The significant characteristics of the ultra-high water cut stage are: large sea area; Water layer thickness and water source are complex, such as edge water, bottom water and so on. In an oilfield, bottom water is an important factor causing water increase, while edge water has relatively little effect on water content. The combined action of bottom water and edge water has a great influence on the water content of the oilfield, which can raise the top interface of the oil layer, increase the buoyancy of the oil layer, and reduce the oil recovery factor. In the ultra-high water cut period, there are special exploitation laws in the oilfield, that is, the change of water cut increase rate, oil production rate, liquid production rate and other indicators, which essentially reflect the change of formation macro parameters. In the late stage of high water cut, due to the constant change and adjustment of well pattern, multi-phase fluids such as oil, gas and water are distributed mutually during water flooding, and the remaining oil enriched and highly dispersed in some places becomes the target of development. The remaining oil is mainly distributed in the thicker upper part. With the improvement of oilfield development level, the injection-production well network has been adjusted and encrypted for many times, and the horizontal distribution of remaining oil has changed obviously in the late development period. From the beginning, the well pattern was adjusted and infilled solely to improve reserve control, and later, the exploration target shifted to localized residual oil.

4. Necessity evaluation dimension of flow field adjustment

From the mining practice, the contradiction between resource base and mining is the two prerequisite conditions for mining adjustment. In flow field regulation technology, we must first determine whether there is residual oil in the formation to ensure that flow field regulation can improve the exploitation effect, that is, to clarify the necessity of flow field regulation from the material basis of remaining oil. Secondly, according to the flow field regulation technology connotation (for long-term fixed streamline; The high water consumption zone is developed, and the old well conversion streamline is adopted to adjust the high water consumption zone vertically. By adjusting the high water consumption area horizontally and effectively regulating the flow field, balanced reservoir displacement is achieved. This requires that the regulation of flow field must be clearly recognized from the point of view of reservoir equilibrium state. On this basis, the relationship between injection-production status and balanced displacement must be clarified, and the necessity of flow field regulation must be clarified. To sum up, the evaluation dimensions for flow field regulation mainly include: residual oil material basis, reservoir equilibrium displacement conditions, injection-production conditions and matching degree of equilibrium displacement. These three evaluation dimensions are progressive, and no matter whether flow field regulation technology is adopted or not, none of them is indispensable.

5. Representational indicators of different evaluation dimensions

5.1 Residual oil material basis characterization index

On the one hand, the difference between the current and theoretical recovery factors (enhanced oil recovery) can determine whether or not residual oil has been recovered and adjusted. The single control of remaining geological reserves is a function of remaining oil saturation, which can reflect the remaining potential of reservoir comprehensively and objectively. The method of increasing oil recovery and controlling the remaining geological reserves as evaluation index is put forward.

5.2 Reservoir equilibrium displacement status characterization index

The permeability impedance difference calculated by numerical simulation method is an important index to reflect the average reservoir displacement level. Considering that the pseudo-permeability resistance level difference reflects the difference of saturation, the saturation difference is caused by the difference of mining intensity. The cumulative fluid production intensity difference index (cumulative fluid production intensity variation coefficient and cumulative oil production intensity variation coefficient) is proposed and applied to the identification of reservoir equilibrium displacement state. It should be pointed out that many development units cannot immediately provide numerical simulation results when evaluating the potential of variable flow-line regulation on a large scale, so the pseudo seepage resistance grade difference index cannot be used for prediction. By using the method of mine mathematical statistics, the cumulative mining intensity difference index can be easily obtained, which makes potential assessment more effective and feasible.

5.3 Injection-production status and characterization indexes of equilibrium displacement matching

Since the pressure gradient field can well reflect the current injection-production well pattern and injection-production strategy, and the pseudo permeability resistance field can well reflect the reservoir displacement balance, the pressure gradient field and pseudo seepage resistance field are adopted as evaluation indexes. Using the Tanimoto coefficient method, the similarity of two vectors is transformed into two N-dimensional vectors, and their similarity analysis is carried out.

6. Evaluation criteria for characterization indicators

6.1 Evaluation standard of material base characterization index

According to the data of flow field adjustment in 16 mining areas, the results show that: before the adjustment, the recovery factor distribution range of each oil field is 45.0%~57.6%, with an average of 49.9%. The theoretical oil yield of 65.7%~72.1% was obtained through laboratory test, with an average of 67.3%. Compared with the theoretical calculation results, the actual production varies from 13.5% to 20.6%, with an average of 17.4%. In terms of the minimum and maximum stimulation potential, the evaluation criterion is to improve the recovery potential by 15%. Prior to the adjustment of this development unit, the distribution of controlled reserves per well for each field ranged from 50,000 to 177,000 tons, with an average of 90,000 tons per well. From the Angle of minimum single well controlling the remaining geological reserves and single well controlling the remaining geological reserves, it is determined that the single well controlling the remaining geological reserves is more than 70,000 tons.

6.2 Evaluation criteria for reservoir equilibrium displacement characterization index

The evaluation criterion of pseudo seepage resistance grade difference is discussed by using reservoir numerical simulation method. AANg3-4 unit as an example, using the similarity criterion, and has set up a representative average middle and high permeability, effective thickness of similar pattern, its main parameters are shown in table 1, in vertical direction, two small layer is 6 to 3 Wells are respectively the determinant pattern, determinant in the well is 6-6-6 pattern (see figure 1), liquid withdrawal rate is 10%. Based on an injection-production intensity analysis of more than 30 production units at the site, the differences in injection-production intensity at the site were identified, and six different injection-production scenarios were identified, with a 40% recovery factor as the baseline. This method can well reflect the difference of reservoir flow field distribution under different injection and production conditions, so as to provide a basis for formulating the corresponding flow field regulation policy. On this basis, this paper firstly calculates the simulated permeability resistance level difference for different injection-production schemes at 40% of production level. On this basis, the flow field is adjusted for different permeability resistance levels, and the production benefit of 10 years is simulated. On this basis, the variation of resistance level and exploitation degree of quasi seepage is studied. With the increase of permeability resistance level difference, that is, the displacement inhomogeneity of reservoir, the improvement of recovery degree is more obvious after flow field adjustment, and the correlation curve shows an obvious inflection point. In other words, the increase of exploitation degree is limited when the quasi-permeability coefficient is less than 2.5. In the case that the quasi-permeability resistance level difference is greater than 2.5, the increase of mining degree is significantly improved. Therefore, the pseudo-permeability coefficient >2.5 is taken as a mathematical model to predict the balanced reservoir displacement state.

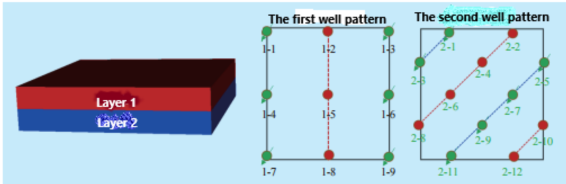

Figure 1 Schematic diagram of similar conceptual model of Aang 3-4 unit

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

Water drive

In order to improve the production efficiency of reservoir and achieve the purpose of increasing production and stability, water flooding is generally adopted. 92% of the major oil fields in China are continental clastic rocks, and there is great heterogeneity in the longitudinal direction. Therefore, water flooding is easy to advance along the highly permeable layer, resulting in water channping. In the ultra-high water cut period, it is necessary to strengthen the water injection in the middle and low permeability layers, develop the same well layered water injection, periodic water injection and other technologies, so as to make the multi-layer water injection get effective water injection, and then improve the recovery of water injection.

7.1 Nitrogen foam drive

Nitrogen foam flooding is a widely used stimulation technology in oilfield exploitation. It has many advantages such as simple technology and rich gas source. Low price, economy, no corrosion and other advantages, widely used in Liaohe, Shengli, Daqing, central Plains, Jianghan, Xinjiang and so on. Especially after the oil field enters the stage of ultra-high water cut, the vertical water channeling of oil reservoir is very serious, and there are great differences. To further increase the production of crude oil, it is necessary to prevent water intrusion along highly permeable formations. Nitrogen foam flooding can be used to plug in areas with high permeability and low saturation, and can be used to drive in areas with low permeability and high saturation to further increase production during high water cut periods.

7.2 Water delivery note

The water-gas cross injection technology can realize the organic combination of gas and water flooding, and inject gas in the reservoir after water flooding, which reduces the permeability and fluidity of water phase, increases the influence range of water, and overcomes the defect of "gas channeling", and improves the recovery of crude oil. Compared with water and chemical flooding, water-gas cross injection technology has higher investment value and better stimulation effect. Water-gas crossinjection process is suitable for low permeability; The reservoirs with large channels and high heterogeneity are applied in Xinjiang, Tuha, Central China and North China.

7.3 Polymer flooding

In the period of high water cut, the use of tertiary recovery technology can further improve the oil recovery. The laboratory experiments and practice of many important technology research projects in China have proved that the use of chemical oil flooding technology can significantly improve the oil recovery, and has reached the world advanced level. Chemical flooding is the main technology of tertiary recovery, and polymer flooding is the most mature and suitable technology for oilfield development. Polymer flooding is mainly realized by increasing the viscosity of liquid injection, changing the fluidity ratio of oil-water two phases and increasing the sweep volume.

8. Conclusion

In a word, after entering the stage of high water cut, water consumption increases and production decreases. The distribution of remaining oil is relatively dispersed and the development cost is high. However, considering the reserves and annual production in use, ultra-high water-cut oil fields still play a pivotal role in domestic production, and it is necessary to continue to intensify development efforts in ultra-high water-cut period. Therefore, oilfield developers should strengthen the research of crude oil recovery technology, constantly learn, learn and improve their own technology, apply and innovate in practice, accumulate working experience, and lay a foundation for the sustainable development of the oil industry.

References

1. ZHANG Junting, ZHOU Zheng, XIE Yue, et al. Petroleum Geology and Engineering, 2021, 35(2):6.
2. LI Yang. Discussion on enhanced oil recovery in deep development of high water cut oilfield [J]. 2022(8).
3. J.Tingas,M.Greaves,T.J.Young,Field Scale Simulation Study of In-situ Combustion in High Pressure Light Oil Reservoirs.Presented at the SPE/DOE Improved oil Recovery Symposium, Tulsa, Oklahoma, 21-24 April, 1996,SPE-35395-MS.
4. Ji Bingyu, Li Yan xing. Main Technical Countermeasures of Enhanced Oil Recovery during High Water Cut Stagein La-Sa-Xing Reservoirs [J]. Petroleum Geology&Oil field Development In Daqing,2004,23(5):94~95
5. B.F.DemblaDhiraj, Simulating Enhanced Oil Recovery (EOR)by High-pressure Air Injection (HPAI)in West Texas Light Oil Reservoir, Msc. Thesis, The University of Texas at Austin,2004.