Optimization of gas injection development parameters in carbonate reservoirs by numerical simulation

Yu Miao*

Geological Team of third oil production plant in Daqing Oilfield, Daqing City, Heilongjiang Province China.

*Corresponding author e-mail: 52zjw@163.com

Abstract. The fluid seepage in the carbonate fractured whole type reservoir is complicated. With the production, the effect of water injection is worse and the recovery rate is relatively low. In this paper, the studying after water flooding failure of fractured buggy reservoirs, the remaining oil is mainly located in the high position of fractured buggy bodies. The location of remaining oil can be exploited by gas injection. The combination of gas injection for oil exploitation and analysis of mechanism of factors and effect on the single well water injection for oil production practice feature, Through numerical simulation, the parameters of gas injection type, gas injection time and gas injection mode are optimized. To improve the development effect, the establishment of appropriate evaluation method of gas injection development.

Keywords: numerical simulation, carbonate and gas injection development

1. Introduction

Carbonate reservoir is one of the most important fields of oil and gas exploration and development in the world. It has the characteristics of large scale, large reserves and strong heterogeneity [1-3]. Fracture cavity type is an important type of reservoir space. There are various flow states in the reservoir. The fluid flow in the main fracture cavity medium is not consistent with Darcy seepage law[4]. During the development process, the production decline rate is large, the water cut rate is rising rapidly, and the number of oil displacement wells has increased significantly. The remaining oil is mainly in the form of "attic oil" and "self-locking oil"[5]. Gas injection can effectively start the high position "loft oil" and "self-locking oil", so that it can migrate to the lower part of the cave and crack under gravity, and form the enriched oil zone again. At the same time, the oil and water interface is continuously raised with the bottom water injection, so that the oil is continuously pushed to the bottom of the well to be picked out, and the improving the recovery is obvious. According to the change of the flow line and the oil saturation of the fixed bottom, the effect of gas injection is better for the remaining oil, such as "the attic oil" and so on [6-7].

2. Gas injection stage division

Gas injection for oil can carry out multiple cycles. Each cycle is divided into three stages according to its basic steps: gas injection stage, stew stage and opening and oil recovery stage [8-9].
Figure 1. The basic principle for displacing oil by gas

(1) Gas injection period
Due to gravity differentiation, the displacing oil by water. The oil-water interface continues to uplift, and more and more oil is gathered at the high part of fracture and cave. The energy of formation is decreasing. After the water injection was developed, some of the energy was supplemented. At this time, the gas injection was developed and the energy of the formation continued to be supplemented.

(2) Soak period
The purpose is to soaking the injected gas fully diffused in the reservoir. After closing the well, the balance stage is entered, the formation pressure is redistributed, and the new pressure field is formed. Through the effect of gravity differentiation, the oil and gas interface continues to decline, and the injection gas is quickly moved to the top of the structure, forming an artificial gas top and replacing the remaining oil at the top.

(3) Well start-up period
With the development of production, the formation energy release in well start-up period. Most of the injected gas accumulation in a compressed state in the bottom of the well, the gas content is very high of the initial extraction. With the exploitation that after the fracture cavity high parts of the oil is produced, the oil and water interface is raised again, resulting in the decrease of oil production, and the daily oil production will increase first and then decrease.

3. Optimization of gas injection development parameters

3.1. Optimization of injection gas type
Based on the ideal carbonate reservoir model, the numerical simulation of gas injection (CO2 and N2) is carried out respectively, so as to evaluate the influence rule of injected gas type on the replacement of oil by gas injection. According to the results, (Fig. 4), the effect of retaining pressure, expansion and viscosity reduction and gravity differentiation of N2 is better than CO2, which can better drive the remaining oil of water drive.

3.2. Optimization of the timing of gas injection
Optimization of gas injection timing under different water content: case 1: the water content=0% (Initial gas injection development); case 2: the water content=50%; case 3 the water content=80%; case 4: the water content=90% and case 5: the water content=98%. The results show that (figure 5), when the water content is 0%, the oil production is lower because of the serious gas channelling; With the opportunity of the gas injection be postpone, the cumulative oil production increased gradually, and the cumulative oil production of case 4 was the largest. However, when the water content 98% was used for gas injection, the final recovery rate was lower than that of case 4 because of the low oil production initial injection oil content, so the optimal injection time was 90%
3.3. Optimization of gas injection mode

Three kinds of gas injection modes are compared with continuous gas injection, gas water mixing and gas water alternation. The comparative analysis shows that:

(1) The rule of N2 continuous injection of gas flooding after water flooding is as follows: The density of N2 is small and flows into the high position, which mainly acts on the "loft oil" formed after the high part of water flooding, which does not play a role in the remaining oil in the lower part.

(2) After water flooding, the mixing and flooding rule of gas and water is manifested as follows: N2 and water are differentiated by gravity. N2 still moves along the high position channel, and the water is still at a low position. The two phases are rapidly differentiated, and the remaining oil in each part of the reservoir is displaced.

(3) Alternate water and gas flooding after water flooding. It is similar to the displacement law of mixed water flooding after water flooding. In the process of alternating water and gas drive, N2 is first injected into the high position to suppress remaining oil, and then injected water to replace the crude oil which is depressed to the low part. The recovery rate depends on the degree of high position remaining oil being injected into N2.

Through numerical simulation study (Fig. 6), for reservoirs with gas injection driven by water content of 90%, the mixed gas water can not only reduce the injection pressure, but also drive the remaining oil which is suppressed by N2 to the low part. However, the effect of gas and water
alternation injection is better than that of continuous gas injection and gas water injection at Late Stages.

3.4. Selection of soaking time for gas injection
It takes time to inject gas from the wellbore to the reservoir and to stabilize the gas. According to the simulation results (Figure 7), when the soaking time for 5 days which the soaking time is too short, the oil and gas gravity effect is poor and low oil recovery, when the soaking time is 30 days, which the oil and gas gravity while fully compressed, but compressing the production time, the ultimate recovery rate is low. When the soaking time is 10 days, the oil and gas gravity effect is good, and does not reduce the excessive production time, increase the cumulative oil production, the ultimate recovery rate has improved significantly.

![Figure 4. Change curve of oil production in different gas injection modes](image-url)
4. Conclusion

(1) According to the results of numerical simulation, it is known that the effect of retaining pressure, expansion and viscosity reduction and gravity differentiation of N2 is better than CO2. Meanwhile, CO2 is easy to become acid corrosion pipe when encountering water. Therefore, N2 flooding can better drive the remaining oil of carbonate reservoir water drive.

(2) The optimal timing of gas injection affects the final recovery of reservoir displacement. The initial gas injection will lead to serious gas channeling and low oil production. With the gradual delay of gas injection, the cumulative oil production will gradually increase, and the recovery will increase. When the water displacement is 98%, the displacement effect of the gas drive will be worse.

(3) The optimization of gas injection mode shows that after water flooding, the effect of gas and water alternate injection is superior to continuous injection and gas water mixing, which can better drive high and low residual oil and enhance oil recovery.
References

[1] Hui Jian, Liu Xueli, Wang Yang, et al. mechanism research on gas injection to displace the oil remaining in fractured—vuggy reservoirs of tahe oilfield[j].drilling and production technology, 2013,36(2):55-57

[2] Jiang Huaiyou, Song Xinning, Wang Yuanji, et al. current situation and forecast of the world’s carbonate oil and gas exploration and development[J]. Offshore Oil ,2008,28(4):6-13.

[3] Zhang Ximing. the characteristics of lower Ordovician fissure-vug carbonate oil and gas pools in tahe oil field,xinjiang[j].petroleum Exploration and Development, 2001,28(5):17-22

[4] Li Yang, the theory and method for development of carbonate fractured-cavity reservoirs in tahe oilfield [j].acta petrolei sinica, 2013,34:116-120

[5] Han Dakuang. the achievements and challenges of eor technology for onshore oil fields in china[c].Proceeding of the 15th World Petroleum Congress.1997:240-249

[6] Hu Rongrong, Yao Jun, Sun Zhixue, et al. study on the mechanism of improving oil recovery by gas injection flooding in sewn cavern carbonate reservoirs in Tahe Oilfield [J], Journal of Xi’an Shiyou University(Natural Science Edition),2015,30(2):50-53

[7] Guo Ping,Yuan Zhiwang, Liao Guanzhi. status and enlightenment of international gas injection eor technology[J].Natural Gas Industry,2009,29(8):92-96

[8] Lu Xinbian, Cai Zhongxian. a study of the paleo-cavern system in fractured-vuggy carbonate reservoirs and oil/gas development-taking the reservoirs in tahe oilfield as an example[j].oil and gas Geology,2010,31(2):22-25

[9] Kang Zhijiang. new method of coupling numerical simulation and application to fracture-cavern carbonate reservoir[j].xijiang petroleum geology,2010,31(5):514-516