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Development status of enhanced oil recovery by gas injection

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Abstract

With the development of oil and gas fields, most oilfields use various EOR methods. In recent years, the country has put forward the construction of beautiful China, and people's awareness of environmental protection has been continuously improved. It puts forward higher requirements for traditional EOR methods, so a lot of research on EOR by gas injection has been carried out. At present, the main gas drive media for EOR by gas injection are CO_2, N_2, flue gas and natural gas. In this paper, the gas drive by gas injection of N_2, flue gas and natural gas and the latest research results are described.

Keywords

N_2 flooding, flue gas flooding, natural gas flooding, fracture-cavity type carbonate reservoir

1. Introduction

At present, gas injection to enhance oil recovery is relatively mature. The main gas drive media are CO_2, N_2, natural gas and so on. When the reservoir geology of injection-production oilfield is different, the action mechanism and injection mode of various gas flooding will be slightly different.

The main characteristics of low permeability reservoir are weak physical property, low porosity and great difference in permeability distribution. There are three contradictory points in the process of exploitation of low permeability oil reservoir: interlayer, plane and inner layer, and the technical difficulties mainly include cracks and unreasonable exploitation technology[1]. Gas injection media include CO_2, N_2, natural gas, etc., and gas injection modes include gas-water simultaneous injection synergy, gas-water alternating injection synergy and multi-well group injection synergy. Gas-water alternating injection can not only solve the problem of gas channeling during gas injection, but also improve oil recovery[2].

The enhanced oil recovery can be achieved through fracturing, establishing horizontal well patterns and shortening well spacing, or other measures to achieve good communication of a large number of micro-traps in the reservoir[3]. For the exploitation of heterogeneous reservoirs, suitable gas injection medium should be selected according to the actual geographical environment and gas source to improve the production efficiency[4]. Therefore, the application and mechanism of N_2 injection, flue gas and natural gas are briefly introduced in this paper.

2. Nitrogen injection to enhance oil recovery

N_2 flooding is not easy to miscible in the reservoir, which helps to maintain formation pressure. Li Erdang[5] studied the micro pore structure of tight sandstone reservoir by using the core sampling and the relaxation time of core pore fluid at the same interval of online NMR system. After the experiment, the oil recovery degree of small pore is equivalent to that of large pore. However, small pore tight sandstone core is larger than large pore tight sandstone core in terms of production degree.

2.1. Karst-fissure-cave carbonate reservoir

Tahe oilfield is the main research object of fracture-cavity type carbonate reservoir. Yan Junbao[6], in the late development of Tahe Oilfield, proposed a new occurrence mode for remaining oil. The gas-water ratio is approximately 2.5:1 ~ 3.5:1 in the field practice of the three gas-water synergy modes mainly consisting of nitrogen and water.

Firstly, the minimum mixing pressure was studied in laboratory by Zhang Hui et al[7], and the system composed of N_2 and Tahe crude oil was tested at 20 MPa, 30 MPa, 40 MPa, 50 MPa and 60 MPa respectively. Finally, the experimental results show that N_2 is not mixed with crude oil.

Li Manliang et al[8]. took Unit A of Tahe Oilfield as the main object to study the field test of nitrogen injection in late stage of water injection. The remaining oil in Unit A of Tahe Oilfield mainly exists in the form of "attic oil", which accounts for 28.16% of the remaining reserves at the depth of 0 ~ 60m. The well group with high injection and low production has high gas injection, slow effect and large sweep volume: the well group with low injection and high production has quick effect and is prone to gas channeling. Later well pattern and gas injection mode still need to be adjusted according to the specific situation.

Through physical simulation of the plate-like model, Zhao Qing [9]. came to the following conclusions: (1) In terms of oil recovery rate, the effect of pure gas injection on enhanced oil recovery is better than that of gas-water co-injection, gas-water alternation and foam injection. (2) In terms of recovery appreciation, foam flooding has the best effect, followed by gas-water injection, pure helium flooding and gas-water alternation respectively. Combined with the actual situation, low concentration foaming agent can be added to water to implement weak foam flooding.

Shi Fenggang [10]. took full-diameter cores as experimental research objects. Experiments show that the effect of gas flooding is not obvious after the end of the stuffy well. In the late water flooding, N_2 flooding has the highest enhanced oil recovery of 22.28%, and CO_2 flooding has the lowest enhanced oil recovery of 5.53%. In the later water-flooding process, the water content in N_2 flooding increases slowly and the recovery rate is high. Due to the good connectivity of the fracture-vuggy reservoir, the oil recovery from the bottom of the reservoir is high in the early stage by water flooding, and the gas injection in the later stage can not only displace the "attic oil" but also lower its position for subsequent water flooding. Combined with the site construction and economic cost, N_2 flooding effect is better.

Su Wei [11]. built a visual model based on similarity design. There are four types of residual oil after water flooding in fractured-vuggy carbonate reservoir: attic oil, residual oil in unaffected area, circulating oil and oil film. Experiments show that the optimal injection speed range is 6-12 ml/min, and the ultimate enhanced oil recovery is about 27.37%. The effect of injection well type on remaining oil displacement effect of high injection and low production is obviously better than low injection and high production.

Su Wei[12]. established a hup-and-puff experimental simulation device, and designed four experimental schemes respectively: direct CO_2 injection, direct N_2 injection, N_2 before CO_2, and CO_2 before N_2. The experimental results show that CO_2 huff and puff is better than N_2 when injected into a single medium. The huff and puff effect of injected composite medium is better than that of injected single medium, and the huff and puff effect of injected N_2 and CO_2 (1:1) is the best.

2.2. Viscous oil reservoirs

Flooding can be divided into N_2 miscible flooding, immiscible flooding and gravity flooding. N_2 gas is abundant and cheap. However, when N_2 is used in combination with CO_2 and hydrocarbon gases, it is easy for CO_2 to form slug[13]. Liu Qiang [14]. studied the Triassic reservoir in the middle lukeqin area, which belongs to deep heavy oil reservoir, and carried out

displacement mainly by foam oil mechanism during nitrogen injection. (1) Gas injection volume; (2) Air injection pressure: maximum suction pressure & GT;30MPa, (3) gas injection speed: gas injection speed & gt; 20,000m^2/day, (4) Days of well soaking: 10-15 days. Nitrogen flooding can effectively improve single well production in the middle and late stage of heavy oil reservoir water-flood development.

2.3. N_2 foam flooding

Song Xinli[15] takes small 22 reservoir as the research object. Enhanced oil recovery, production per well, and saturation were compared through experiments in the gas injection test area and SIMULATION by CMG-STARS software. The results showed that N_2 bubbling bath flooding had the best effect in lumbar injection, and the gas-liquid ratio was 2:1 and the injection-production ratio was 1:1. N_2 bubble flooding can help to slow down or inhibit bottom water coning in reservoirs with bottom water development.

3. Three injection of flue gas to enhance oil recovery

Flue gas flooding not only has the dual mechanism of CO_2 flooding and N_2 flooding, but also has the functions of top gas gravity flooding, improving reservoir permeability and strengthening distillation, and can reach small pores that water cannot enter to improve sweep coefficient. In China, only Liaohe oilfield and Karamay oilfield have studied flue gas flooding[16].

Li Haibo [17]. Flue gas flooding is not only a method to inject flue gas into reservoir to improve oil recovery, but also to bury harmful gas to achieve the purpose of environmental protection. The interlayer contradiction of multilayer conglomerate reservoir can be improved by using the method of stratified gas injection and alternating water gas injection. When the optimal water gas ratio is 1:1 and the alternating period is 7 days, the development effect of injection gas can be improved obviously.

Taking Qi 131 block of Liaohe Oilfield as the research object, Song Xinli[18] used CMG-Winprop phase analysis software to fit the fluid components. In the study of block 131, it is shown that the actual and overall fitting effect is relatively good. The development mode of using top gas injection is better than that of using bottom gas injection. The development effect of using the top four gas injection Wells is the best overall effect and reduces the safety factor. Considering the comprehensive benefit, air injection is more efficient than nitrogen injection.

Li Jiayan[19]. The flue gas injection was first applied in the Reservoir of Kexia Formation of Hong48 fault block on November 30, 2018. In the early stage, some eastern Wells were injected with flue gas and the other injection Wells were injected with water according to the original injection scheme. After one month of practice, all parameters were consistent with the design scheme.

Lin Liang [20]. Took the associated gas of the south oil transfer station in block γ North of Rananor Oilfield as the gas injection source. After three pressurization (3.6MPa, 11.5MPa, 32MPa) and the corresponding pipeline transportation to the gas injection well. Condensate recovery increased by 1.21 times.

4. Gas injection to enhance oil recovery

At present, natural gas injection is mainly used to enhance oil recovery: Tuhalukqin oilfield, Zhongyuanwennan oilfield and Changqing Jing 'an oilfield.

Song Gangxiang[21] fitted the parameters of crude oil viscosity in light S reservoir according to the thermodynamic theory of fluid phase equilibrium. The numerical simulation of gas injection huff and puff process was carried out by using CMG-WinProp phase analysis software. The results show that condensate gas injection can achieve better development results than dry gas injection.

Liu Xin[22]. Studied shale reservoirs in Bakken Oilfield of The United States and Canada. Through gas injection flooding, the ultimate recovery factor is assumed to be 1430% at a volume sweep factor of 50%. Final recoverable reserves are expected to increase by 25% during pilot trials between 2011 and early 2014.

5. Conclusion

For fracture-cavity type carbonate reservoirs, N_2 injection after hydraulic fracturing and gas-water cooperation are the main development methods. N_2 foam flooding has better development effect than N_2 flooding alone. Flue gas flooding not only has the dual mechanism of CO_2 flooding and N_2 flooding, but also improves oil recovery and reduces CO_2 emissions. In the study of natural gas flooding, the speed of gas injection, the ratio of gas to water alternate flooding and the way of gas injection have been deeply studied and good results have been obtained.

At present, the technology of gas injection to enhance oil recovery has not been tested in large-scale field, and it mainly faces the following problems: (1) Insufficient gas source; (2) Decline of oil adding effect in later period; (3) asphaltene deposition; (4) Gas channeling problem. Strengthening research in these four aspects will help to further improve oil recovery.

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