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Study on CO_2 huff and puff production mechanism and limit action distance of tight reservoir

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ABSTRACT

CO_2 huff and puff is an important means to achieve efficient development of tight reservoirs. The authors carried out CO_2 huff and puff simulation experiments by using one-dimensional long core to simulate the whole process of CO_2 huff and puff development in tight reservoirs. The main mechanism and the effect of well stuffing time and production pressure difference on the development effect of CO_2 huff and puff in tight reservoir are expounded.The simulation results show that compared with the flow sweep caused by pressure difference, the contribution of molecular diffusion sweep to CO_2huff and puff recovery is higher.

Keywords: Tight reservoir; CO2 huff and puff;Carbon Storage ; Molecular diffusion;

NONMENCLATURE

Abbreviations	
EP	Energy Proceedings
Symbols	
n	Year

1. INTRODUCTION

Tight oil has gradually become an important strategic resource for oil exploration and development[1-3]. Due to its special physical parameters (permeability less than 0.1mD),it shows the development characteristics of rapid production decline and low overall recovery in the actual production and development process.[4-7]Therefore, after relying on natural energy depletion, how to supplement the formation energy and carry out subsequent secondary development has become the main problem to improve the development effect of tight reservoirs[8]. CO_2 huff and puff, as an efficient development method to further improve oil recovery after the depletion of tight reservoirs, can not only improve oil recovery, but also form an effective burial of CO_2 to achieve the dual purpose of economic benefit and environmental protection, so it has been paid more attention [9].

2. MATERIAL AND METHODS

In order to clarify the contribution of different mechanisms in CO_2 huff and puff development to the recovery of formation tight oil and the limit action distance of huff and puff media under different mechanisms under tight reservoir conditions. One-dimensional core throughput contrast test was carried out.

2.1 Experimental conditions

The experimental temperature was 45 ℃ , and the experimental oil was used as the simulated oil. The viscosity was 2.93 mPa.s at 45 ℃ . The experimental water is simulated formation water, the salinity is 35000mg/L(containing30000mg / L manganese chloride used to shield the water signal of NMR), and the viscosity is 0.85mPa.s under the experimental conditions. The experimental gas is CO_2 with purity of 99.9 %.

2.2 Physical Models

The core used in the experiment is composed of columnar cores with Φ 2.5cm and close permeability. Due to the traditional measurement to calculate oil recovery has a large error. So this experiment uses weighing method and nuclear magnetic resonance scanning method to reduce saturation calculation error. Specific long core huff and puff experiment scheme is as follows Table 1 :

Table1 One-dimensional core throughput experiment scheme table

Experiment number	Soaking time/h	Recharging mode	Pressure differential/MPa
1	18	gas injection	10
2	18	gas injection	6
3	18	gas injection	4
4	18	gas injection	2
5	10	gas injection	10
6	4	gas injection	10
7	2	gas injection	10
8	18	oil injection	10

The experimental steps are as follows :

1.After the core is vacuumed for 24h, the saturated water begins, and then the constant pressure saturated oil is carried out. The original oil saturation of the core is calculated by using the discharged water. Then put the core into the gripper and complete the process connection (Figure 1) ;

2.For CO_2 pressurization, after opening the inlet valve, the constant pressure injection of CO_2 was used to boost the pressure. When the inlet pressure remained stable, the soaking was conducted, and the injection-production balance period was 18 h.

3.For oil injection pressurization, after opening the inlet valve, the constant pressure oil injection is used to boost the pressure. When the system pressure is stable, the oil injection is stopped, and then the simulated oil in the dead volume is evacuated to ensure that CO_2 can directly contact the core end face. After fully emptying, close the outlet valve when the inlet pressure is stable, soak well, injection-production balance period 18 h ;

4. After soaking, the inlet valve was closed and the outlet valve was opened to develop to atmospheric pressure. After development, the core was taken out for weighing, NMR scanning and recovery factor calculation.

5.Replace core and conduct huff and puff experiment according to table 1 after saturation

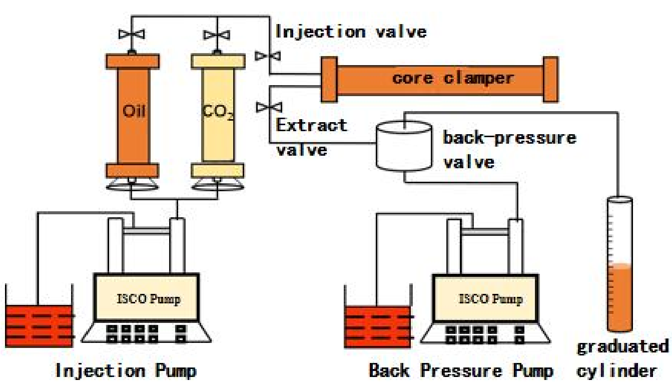

Figure 1 Experimental flow chart

3. RESULTS

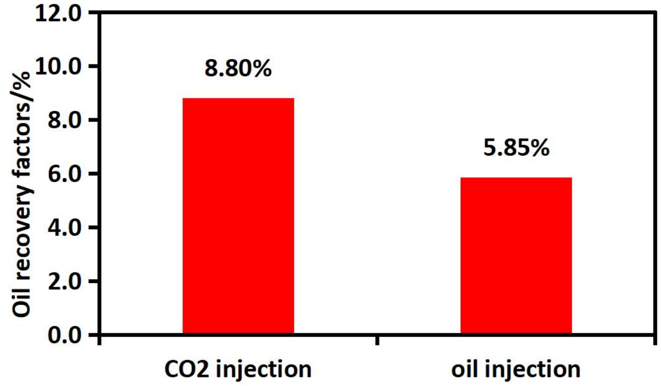

Fig 2 Experimental results of different boost modes

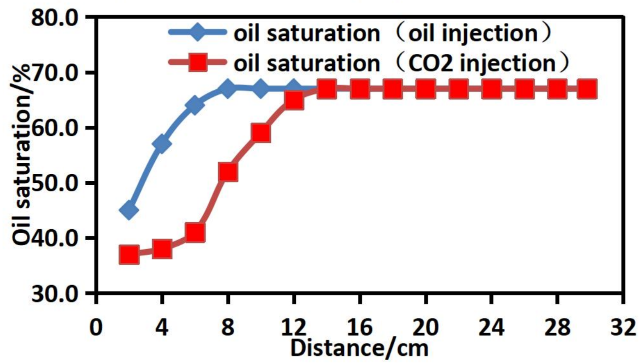

Fig 3 Oil saturation distribution map at different distances

The experimental results are shown in Fig 2 and Fig 3. The recovery degree of huff and puff development by gas injection pressurization is greater than that after oil injection pressurization. The recovery of huff and puff after gas injection (pressure difference effect) is 8.80%, while the recovery of huff and puff after oil injection (no pressure difference effect) is 5.85%, and the limit action distance developed by different pressurization methods can be obtained : the sweep distance of CO_2 injection pressurization(pressure difference effect) is 10cm, and the action distance of oil injection pressurization(no pressure difference effect) is 6cm.

Combined with the experimental results, Figure.4. As a whole, the longer the injection-production balance time is, the higher the huff and puff recovery is. However, when the injection-production equilibrium time exceeds 6h, the increase of recovery rate decreases rapidly. And gradually tend to a fixed value.

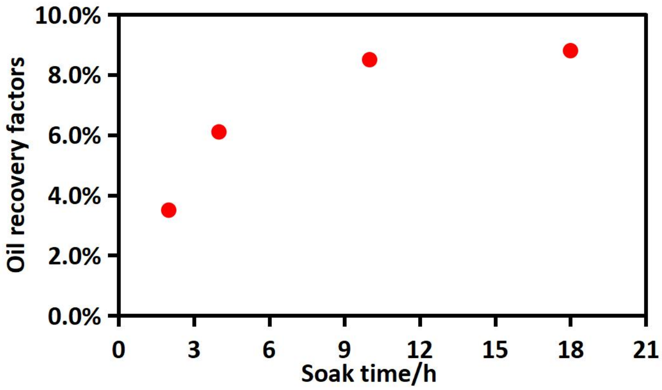

Fig 4 The relationship between soak time and recovery factor

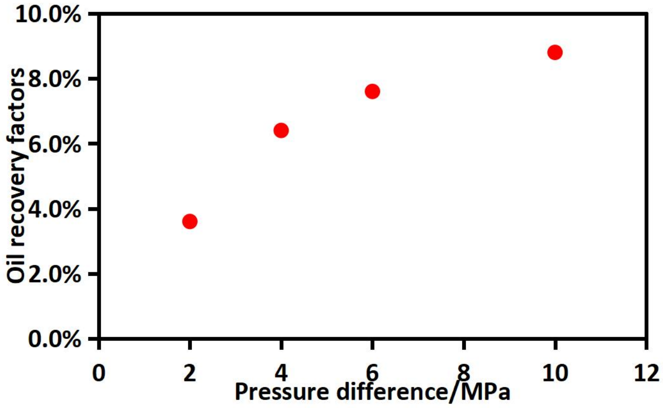

Fig 5 Relationship between production pressure difference and recovery factor

With the increase of working pressure difference, the cumulative recovery rate increased gradually from 3.6% to 8.8%, but the increase of recovery degree began to decrease when the injection-production pressure difference was greater than 6MPa, and gradually stabilized.

4. DISCUSSION

It can be seen from previous studies that the common sweep effects of CO_2 huff and puff media include pressure difference flow sweep and diffusion sweep[10]. In order to clarify the contribution of different action mechanisms to the recovery of crude oil and the limit action distance of huff and puff medium under different action mechanisms. Two sets of core huff and puff comparative tests are carried out, as shown in the table. Different pressurization methods are used in the experiment: gas injection pressurization and oil injection pressurization. The mechanism of pressure difference flow sweep and diffusion sweep is included in the process of gas injection pressure huff and puff, while the diffusion sweep of oil injection pressure huff and puff is only part of CO_2.

Therefore, Fig.2 is obtained. From the experimental results, it can be seen that the recovery rate contributed by diffusion sweep is significantly greater than that contributed by flow sweep under laboratory experimental conditions. It can be seen from Fig. 3 that the ultimate action distance of CO_2 huff and puff under gas injection pressurization is greater than that under oil injection pressurization. Under the same experimental environment, the recovery difference caused by different energy supplement methods is the contribution of flow sweep to recovery, which is 2.95 %. Similarly, the difference between the limit action distance of the two, so the limit action distance of the flow ripple is 4cm.

Combined with the experimental results, Figure 4. As a whole, the longer the injection-production balance time is, the higher the huff and puff recovery is. However, when the injection-production equilibrium time exceeds 6 hour, the increase of recovery rate decreases rapidly. As shown in the figure, when the injection-production balance time exceeds 6 hour, the bottom hole flow pressure tends to be stable, and increasing the injection-production balance time after 6 hour has little significance. This is mainly because the flow of CO_2 under pressure difference and gas diffusion have been completed, and the throughput medium has reached its own limit. Therefore, in the production and development process, the soaking time should be optimized to maximize the range of CO_2 and improve the utilization efficiency of CO_2.

Fig.5 can be obtained from the results of Experiment1-Experiment4 in Table 1. With the increase of working pressure difference, the cumulative recovery rate also gradually increases from 3.6% to 8.8%, and when the working pressure difference of huff and puff is greater than 6 MPa, the increase of recovery rate begins to increase. The main reason is that with the increase of pressure difference, the free CO_2 originally located in the pore begins to expand due to the decrease of pressure. The greater the pressure drop, the better the effect of expansion gas flooding. At the same time, the higher working pressure difference is also helpful to the discharge of free CO_2 in the near wellbore area, so as to reduce the degree of reservoir damage to a certain extent. Therefore, increasing the working pressure difference of reservoir huff and puff appropriately in practical application is helpful to improve the recovery degree of reservoir.

5. CONCLUSIONS

In the process of CO_2 huff and puff, there are different factors that affect the ultimate action distance, namely differential pressure flow and diffusion. The results of one-dimensional core experiment show that the recovery ratio based on flow sweep is 2.95 % and that based on diffusion sweep is 5.85 %. According to the difference of action distance (flow sweep 4cm, diffusion sweep 6cm), it can be concluded that the molecular diffusion sweep is the key factor affecting the limit action distance in the process of CO_2 huff and puff.

CO_2 soaking time and production pressure difference are sensitive factors affecting the effect of CO_2 huff and puff. The increase of injection-production equilibrium time helps to improve the development effect of CO_2 huff and puff. However, when the time exceeds 6 hour, the medium has reached the limit action distance, and it is not significant to continue to extend the injection-production equilibrium time. In the actual field construction, more attention should be paid to the parameter optimization of CO_2 soaking time and working pressure difference to ensure the efficient utilization of CO_2.

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