Research and Application of CO_2 Flooding to Improve Oil Recovery in Low Permeability Oilfield

CHENG Qigui[1,a],LI Zhongxin[2,b] , ZHU Guangshe[3,c]

[1,2,3] Changqing Oilfield , Petrochina, Xi' an, Shaanxi, China

[a]cqg_cq@petrochina.com.cn， [b]lzx_cq@petrochina.com.cn, [c] zgs_cq@petrochina.com.cn

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Abstract: This paper discusses the new progress and field application of CO_2 flooding in low permeability oil field to improve oil recovery. The study shows that CO_2 flooding can improve the oil recovery rate of low permeability oilfield by more than 10 %.The practice shows that the liquid CO_2 injection in low permeability reservoir is easier than water injection, and the reservoir generally has better CO_2 storage.

After 60 years of exploration and practice, the United States has formed a series of CO_2 flooding technology and business model. The industrial application of CO_2 flooding oil output exceeds 13.7 million tons [1]. Both domestic and international studies show that CO_2 flooding has obvious effect in improving oil recovery [2][3]. CO_2 flooding can not only improve the oil recovery rate, promote the sustainable development of oil field, but also provide the possibility of CO_2 storage and emission reduction. However, CO_2 capture, utilization and storage (CCUS) is an innovative work[4]. In terms of technology, management, national policy and many other aspects, this paper discusses the practice of CO_2 flooding in low permeability oil field to improve oil recovery technology.

Research purpose

(1) To explore the EOR technology of CO_2 injection after waterflooding in low permeability oilfield.
(2) To explore the production technology of CO_2 flooding in low permeability oilfield
(3) To evaluate the inject of CO_2 flooding and the storage capacity of CO_2 by pilot test.

Development status of ultra - low permeability reservoir

The waterflooding recovery ratio is expected to be about 19 % in the Triassic reservoir of CHANGQING oilfield, which is different from the average recovery ratio of 23 % in other low permeability reservoirs [5]. According to the reserves calculation of oilfield, the recovery ratio is increased by 1 %, and the oilfield production capacity can be improved for more than 1 year. Therefore, the research on EOR technology of CO_2 flooding is of great significance to the sustainable development of oilfield. The experimental results show that CO_2 flooding is effective in improving the effective and well productivity of low permeability reservoir, and can improve oil recovery ratio of 10 ~ 15 %, and has good application prospect [6][7].

Technical difficulties in EOR of oilfield by CO_2 flooding

The fracture of low permeability reservoir is a common phenomenon. The residual oil saturation of the plane after water drive is strip distribution. The water washing thickness on the profile increases gradually, but the low permeability layer is still in the unused state [8]. How to improve the volume and storage efficiency of CO_2 flooding through reservoir engineering is the main technical problem. At the same time, the implementation of CO_2 flooding also faces the problem of pipeline corrosion safety, and the geological safety risk of CO_2 sequestration.

Question1: the study of CO_2 miscible technology in low permeability reservoir.
Poor physical property of low permeability reservoir. The porosity is 8 % - 12 % and the permeability is 0.2 ~1 × 10^{-3} μ m^2. The pressure coefficient is only 0.7, the oil reservoir needs to carry out the research of CO_2 miscible technology.

Question 2: the adaptability of the injection-production process. The formation water salinity of the Triassic reservoir in CHANGQING oilfield is generally more than 5000 ppm, and the content of Ca^{2+} and Mg^{2+} is high, so it is necessary to study the mechanism of formation water and CO_2 deposition and the effect of oil displacement.

Question 3: research on the risk control of ground engineering and buried storage.

Question 4: research on enhanced oil recovery policy and sustainable development of CO_2 flooding

According to the statistics of CO_2 flooding project in the United States, the contract price of CO_2 transportation to the wellhead of the oilfield is 40 $ /bbl, and the dynamic investment recovery period of the project is 9 years [9] when the oil price is more than 80 $ / bbl. In the aspect of CO_2 utilization, because of the characteristics of many areas, industries and enterprises, the project needs innovative commercialization mode, and also needs to carry out sustainable development research.

Field test of CO_2 flooding

Screening of the test area
Four main factors are considered:
a. Select the reservoir with the formation pressure close to the minimum miscible pressure.
b. The reservoir test area is representative and has the conditions for expansion and popularization.
c. The reservoir has a certain area, reserves and number of central wells, which is convenient for comparison.
d.The economic factors such as ground and transportation. Select the oil field near the gas source.

Miscible reservoir

The minimum miscible phase pressure (MMP) of the oil field is calculated by using the modified minimum miscible pressure calculation formula (NPC), and the CO_2 minimum miscibility pressure (MMP) is 19.8 MPa. Visible, the original formation pressure of the reservoir is close to miscible pressure.

$$G = \frac{141.5}{r_0} - 131.5 \qquad MW = \left(\frac{8864.9}{G}\right)^{\frac{1}{1.012}}$$

$$MMP=[-329.558+(7.727\times MW\times 1.005^{T})-4.377\times MW)]/145$$

r_0——relative oil density ； T ——formation temperature，℉

Application of CO_2 flooding oil field

The test area is H3 district of JIYUAN oilfield, with 9 injection and 37 mining (4 central well). The reservoir is an ultra low permeability reservoir. The reservoir area is 3.5 km^2.

The reservoir porosity is 7.1%, permeability 0.39 x 10^{-3} um^2, crude oil density of 0.7 t/m^3, crude oil viscosity of 0.73 mPa. S, the original gas-oil ratio of 85 m^3 / t, formation water is $CaCl_2$ water model, the total salinity of 35.42 g/l, formation temperature 85 ℃, the original formation pressure 19.7 MPa, the pressure coefficient of 0.7, belongs to low pressure of reservoir. The initial production capacity of single well is 2.6t/d.

The reservoir area of H3 area is affected by natural fractures, the water production of oil well rises rapidly, and the development of low injection mode is mainly adopted. At present, the formation pressure is 14.4 MPa and the pressure holding level is 66.3%. The production capacity of the oil well is 1.5 t /d, with water cut of 49.1 %, and the cumulative injection-production ratio is 1.52. The recovery rate of water flooding in the evaluation period is 9.5 %[10].

The above calculated results show that the minimum miscible pressure of CO_2 is 19.8 MPa. The reservoir can achieve miscible displacement after the reservoir supplementary energy.

The technology process uses the sledge CO_2 liquid high pressure injection technology. Injection parameters: pump pressure 25 MPa, temperature - 17 ℃ to - 15 ℃; Injection pressure of 17.2 ~15 MPa, daily injection of 30 tons, lower than the water injection pressure 2 MPa. Moreover, the inhalation index has a gradual upward trend.

indicator projections

Compared with the CO_2 flooding in the same type of reservoir abroad, it is expected to produce about 2.1 ton / day. The output of the center well is 3.3 ton/ day.

The evaluation period is based on 15 year production: the cumulative injection gas is 0.376 million tons, oil production is 0.315 million tons, gas production is 89 thousand tons, and CO_2 sequestration rate is 73. 2 %. The gas drive is increased by 0.199 million tons than water drive. The recovery was 19.6 %. Recovery rate is increased by 10.1 % compared with water drive (Fig.1), and the amount of oil injected per ton of CO_2 increases 0.49 tons (Fig.2). After CO_2 flooding, the final recovery can be increased by 1.2 %, to 20.9 %.

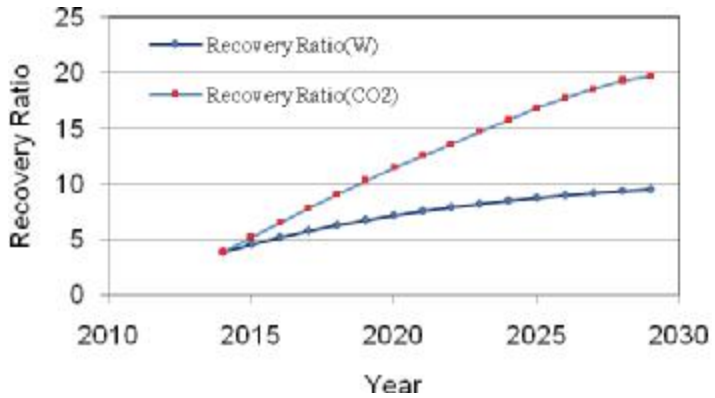

Fig.1 The Recovery Ratio Curve of CO_2 and Water Flooding

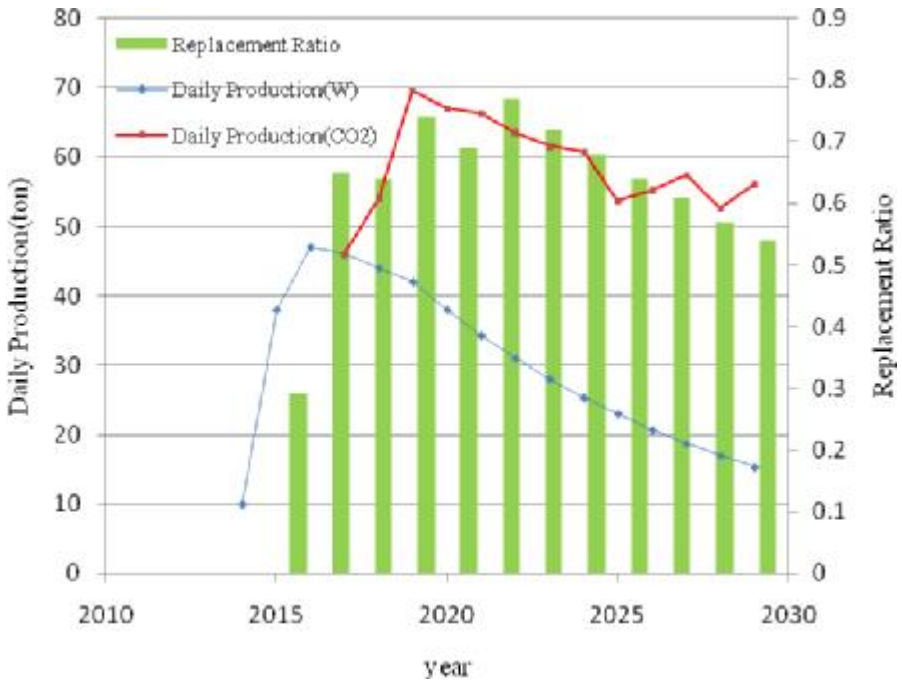

Fig.2 The Rate of CO_2 Displacement and The Cumulative Oil Change

Study on the stability of CO_2 sequestration

The H3 area belongs to the structure of inclined to west, and the sand body distribution of reservoir is consistent with the fault. The upper part of the reservoir is lithology sheltered, and the top is the mudstone with thick thickness and stable distribution. The study of the top surface structure of reservoir (Fig.3) shows that the fault direction is parallel to the extension of the sand body, so the sealing property of the CO_2 storage area is not destroyed. And the thickness of the interlayer is 16.3 m, and the distribution range is wide[11]. Therefore, the CO_2 storage stability of reservoir is better. However, the stability monitoring of CO_2 sequestration still needs to be strengthened.

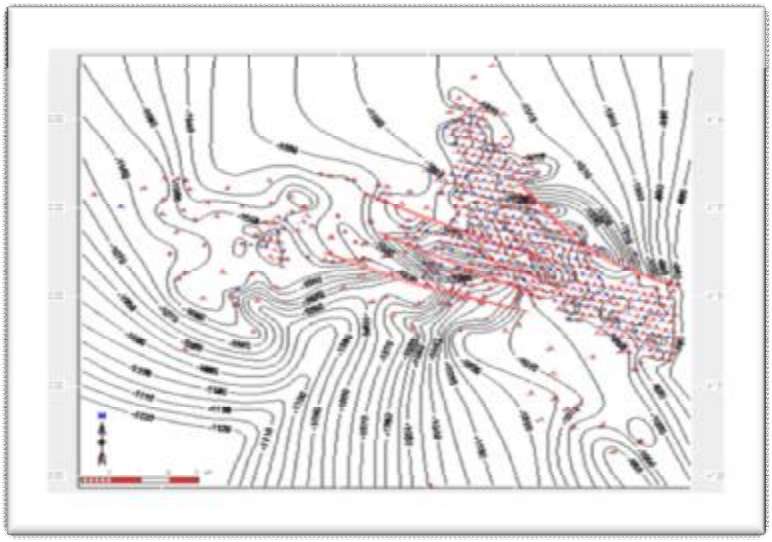

Fig.3 The C7 Bottom Structure of the H3 Region

conclusion

(1) The CO_2 flooding field test shows that it is easier to inject liquid CO_2 into the ultra-low permeability reservoir than water injection.

(2)The experimental results show that the test area can achieve miscible conditions, and the CO_2 flooding improves the oil recovery ratio of oil field by more than 10 %.

(3) Reservoir is also a good CO_2 storage area, the CO_2 sequestration rate is 73.2 %, which can provide support for CO_2 emission reduction. However, the monitoring of CO_2 stability still needs to be strengthened.

Thanks

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