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

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Abstract

This paper discusses the new progress and field application of CO_2 flooding in low permeability reservoirs enhanced 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.

Keywords

Low Permeability Oil Field, CO_2 Flooding, Enhanced Oil Recovery, Storage

1. Introduction

The existence of natural fractures in low permeability reservoir has a negative effect on water injection development in oil field. Using area or linear water injection well network, recovery ratio is less than 30%. The recovery ratio of ultra low permeability reservoir is lower, less than 19% [1]. The development of many oilfields abroad and domestic shows that CO_2 flooding can improve more recovery than water flooding [2]. The CO_2 flooding project in the Kelly-Snyder oilfield and the Chao-She oilfield in China is an example. They basically belong to the medium-high permeability reservoir, the CO_2 flooding oil recovery ratio is more than 10%. However, for low permeability reservoir, especially ultra-low permeability reservoir (permeability less than 1×10^{-3} um^2), there are natural fractures and artificial fractures, reservoir heterogeneity is strong. The reservoir performance in oilfield development is faster than that of water, and the liquid mining index decreases with the increase of water production, and the oil recovery index decreases more quickly [3]. The remaining oil saturation in the plane is banded distribution after water drive, and the low permeability reservoir in the profile is in the unused state. Improving the effect of reservoir development is mainly to improve displacement efficiency and increase sweep volume. CO_2 displacement mechanism shows that CO_2 has a strong permeability, which is easy to enter micro pores, and the effective displacement of crude oil in the formation [4] [5]. The characteristics of interphase mass transfer, oil and gas mixing phase and volume expansion are beneficial to improve oil recovery [6]. The EOR and buried rate of CO_2 flooding after water flooding in low permeability reservoir require both research and mine practice. This paper discusses the effect of CO_2 flooding to improve the recovery ratio of low permeability reservoir and the effect of CO_2 sequestration [7].

2. Geological Characteristics of the Study Area

The study area is located in H3 area of Jiyuan oilfield, western Ordos basin, China. The reservoir is a Triassic formation, belonging to an ultra low permeability reservoir [8]. The area is 3.5 km^2, and has 9 injections for 37 oil wells. The permeability is 0.39×10^{-3} $\mu \cdot m^2$ .The porosity is 7.1%. The crude oil density of the formation is 0.7 t/m^3, the viscosity of crude oil is 0.73 MPa/s, the original gas-oil ratio is 85 m^3/t. The formation water is $CaCl_2$ water type and the content of Ca^{2+} and Mg^{2+} are high, the total mineralization degree is 35.42 g/l. The formation temperature is 85˚C, the original formation pressure is 19.7 MPa, the pressure coefficient is 0.7, which belongs to low pressure reservoir. The initial production capacity of the oil well is 2.6 tons.

Prior to the early adoption of oil production, water injection began to maintain sufficient ground energy. Influenced by natural fractures, the water production of oil well rises rapidly. After the control of water injection, the increase of water volume decreases, but the formation pressure cannot be maintained, the pressure drops to 14.4 MPa, only 66.3% of the original pressure. Oil well productivity is 1.5 tons, water drive recovery rate is only 9.5%.

3. The Technical Difficulties in EOR of Low Permeability Reservoir by CO_2 Flooding

Low permeability reservoir physical property is poor, CO_2 injection capacity can meet the requirements of complementary formation energy. The reservoir water salinity is high, Including Ca^{2+} and Mg^{2+}. The deposition and dissolution of the chemical reaction with carbonate have an effect on the oil displacement effect. The development of reservoir fracture, how to improve the sweep volume of CO_2 flooding in oil reservoir with oil saturation after water drive, need to carry out the research of CO_2 flooding miscible technology [9] [10]. At the same time, the geological safety risk assessment study of CO_2 sequestration and the economic benefit of CO_2 flooding to improve recovery efficiency are also required.

4. Field Test of CO_2 Flooding

The selection of test area mainly consider the following four factors: reservoir can achieve the conditions of miscible pressure. The reservoir has a certain area, reserves and number of central wells, convenient for comparative analysis. Select the reservoir block close to the gas source to reduce the transportation cost. The reservoir has the sealing property of CO_2.

4.1. Miscible Reservoir

First method: The minimum miscible phase pressure (MMP) of the oil field was calculated by using the modified minimum miscible pressure calculation formula [11] [12]. The minimum miscibility pressure (MMP) of CO_2 flooding in the H3 area was 20.78 MPa.

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

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

r_0: relative oil density; T: formation temperature, ˚F.

The second method: The minimum miscible phase pressure test of CO_2 flooding is usually based on slim tube test method [13]. The saturated formation crude oil is injected into CO_2, the experimental temperature is 92˚C and the displacement speed is 15 ml/h. The minimum miscible pressure of CO_2 flooding is 19.8 MPa (**Figure 1**).

The results of the two methods are quite similar .MMP is close to the original reservoir pressure of 19.7 MPa, which can be miscible.

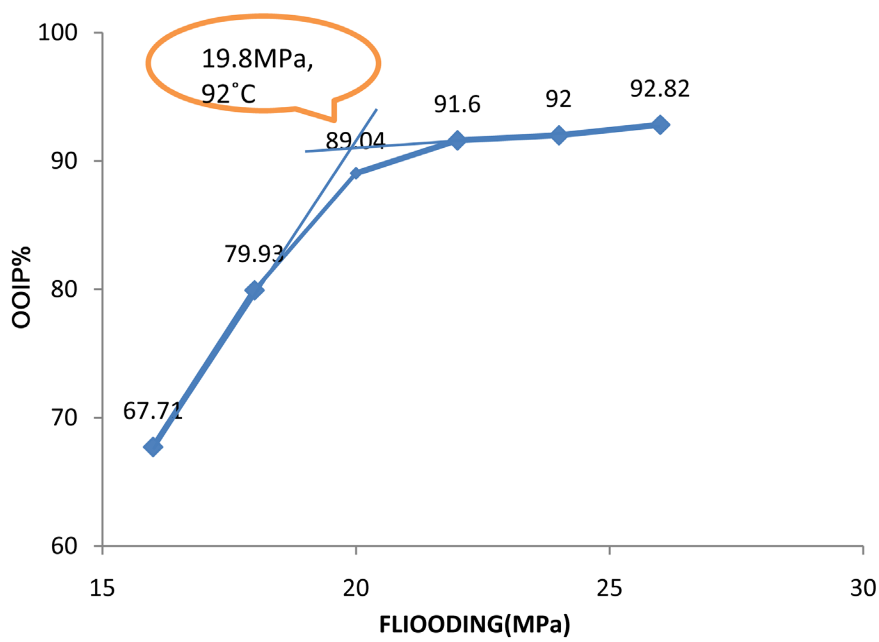

Figure 1. Thin-tube experiment to determine miscibility pressure.

4.2. Application of CO_2 Flooding Oil Field

The technology process uses the sledge CO_2 liquid high pressure injection technology. Injection parameters: pump pressure 25 MPa, temperature −17˚C to −15˚C; Injection pressure of 17.2 - 15 MPa, daily injection of 30 tons, lower than the water injection pressure 2 MPa. The inhalation index has a gradual upward trend. In the formation of high content of Ca^{2+} and Mg^{2+} ions, whether the dissolution ability of carbon dioxide is greater than that of the deposition, further study is needed.

4.3. Indicator Projections

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

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 (Figure 2), and the amount of oil injected per ton of CO_2 increases 0.49 tons (Figure 3). After CO_2 flooding, the final recovery can be increased by 1.2%, to 20.9%.

5. 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

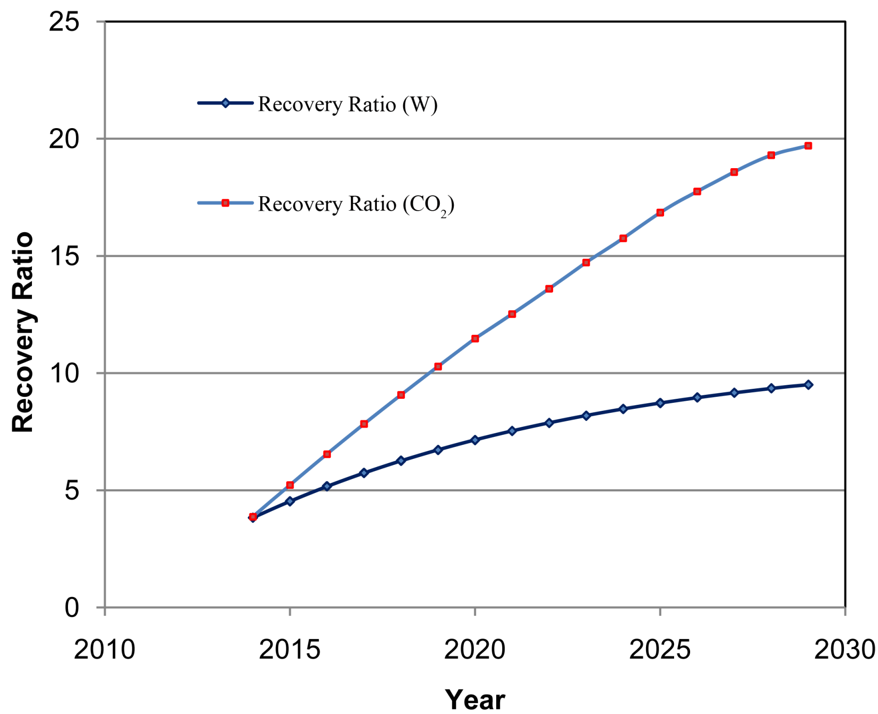

Figure 2. The recovery ratio curve of CO_2 and water flooding.

is lithology sheltered, and the top is the mudstone with thick thickness and stable distribution. The study of the top surface structure of reservoir (**Figure 4**) 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. Therefore, the CO_2 storage stability of reservoir is better. However, the stability monitoring of CO_2 sequestration still needs to be strengthened.

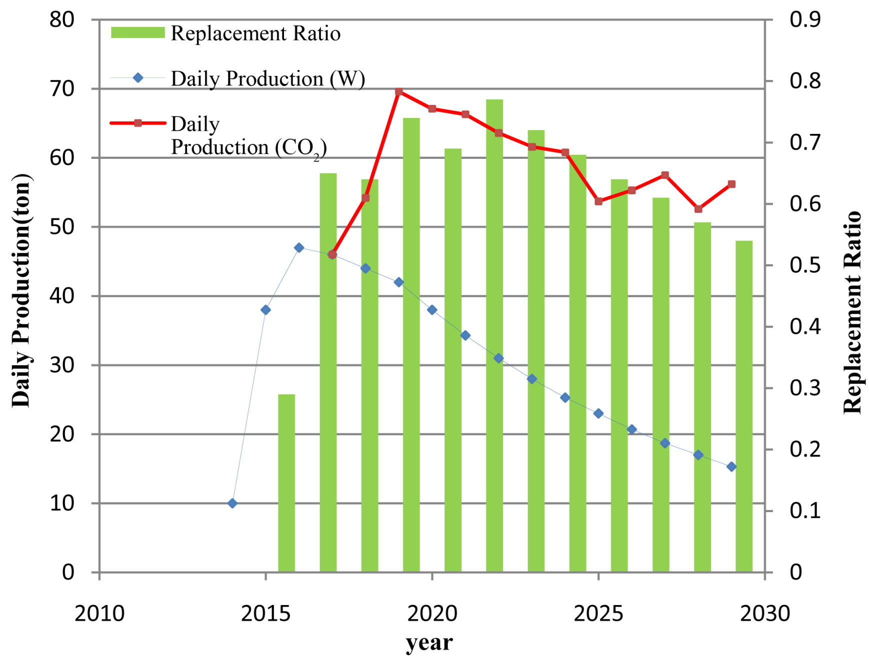

Figure 3. The rate of CO_2 displacement and the cumulative oil change.

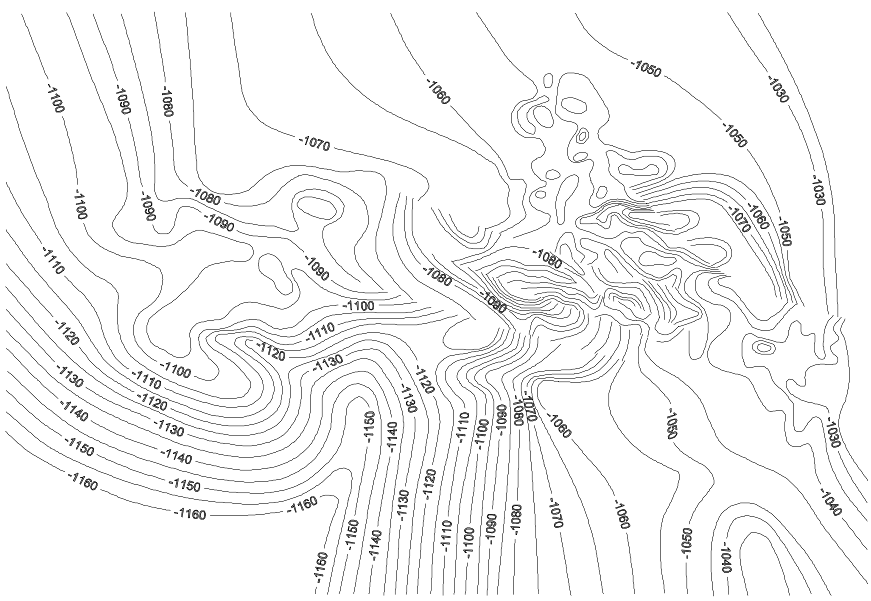

Figure 4. The C7 bottom structure of the H3 region.

6. Conclusions

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. Whether the dissolution ability after the chemical reaction of carbonate is greater than the deposition, further study is needed.

The test area can reach miscible conditions, and the oil recovery ratio of the oilfield can be increased by more than 10% by CO_2 flooding.

Reservoir is also a good CO_2 storage area. The CO_2 sequestration rate was 73.2%. Support can be provided for CO_2 abatement governance. But it is also necessary to strengthen the monitoring of formation CO_2 stability.

References

[1] Cheng, Q.G. (2015) The Evaluation and Development Technology of Large Low Permeability Reservoir. Petroleum Industry Press, Beijing, 73-82, 232-237.

[2] Qin, J.S., Han, H.S. and Liu, X.L. (2015) The Application and Implications of CO_2 Flooding Technology in USA. *Petroleum Exploration and Opening*, **42**, 209-216.

[3] Cheng, Q.G. (2014) The Typical Example of Low Permeability Reservoir Development. Petroleum Industry Press, Beijing, 20-24, 104-115.

[4] Gu, L.B., Li, Z.P. and Ou, J. (2007) The Research Progress in Improving Oil Recovery by CO_2. *China Mining*, **16**, 66-69.

[5] Li, M.T., Chan, W.W., Liu, X.G. and Shan, G.H. (2006) The Experimental Study on the Mechanism of Miscible Displacement of Supercritical CO_2. *Acta Petrolei Sinica*, **27**, 80-83.

[6] Gao, H.M., He, Y.F. and Zhou, X.S. (2009) The Research Progress in EOR Technology by CO_2 Injection. *Special Oil & Gas Reservoirs*, **16**, 6-12.

[7] Research Group of Earth Science Development Strategy (2009) Chinese Academy of Sciences. Report of China Earth Science Development Strategy in the 21st Century. Science Press, Beijing, 288-294.

[8] Du, S.L. (2014) The Analysis of the Effect of Fine Stratified Water Injection in H3 Area of JIYUAN Oilfield. Petroleum Industry Press, Beijing, 68-70.

[9] Xia, H.F. and Xu, Y. (2017) The Research on the Mechanism and Application of CO_2 Flooding in Low Permeability Reservoirs. *Contemporary Chemical Industry*, **46**, 471-474.

[10] Green, D.W. and Wilhite, P. (2003) Enhanced Oil Recovery. 2nd Edition, SPE, Texas.

[11] Wang, X.Z. and Go, R.M., *et al.* (2017) Modified Method for Minimum Miscible Pressure Prediction. *Journal of Petrochemical Universities*, **30**. http://c.g.wanfangdata.com.cn/periodical/syhggdxx/2017-1.aspx

[12] Hua, Y. and Jhons, R.T. (2003) Simplified Method for Calculation of Minimum Misscibility of Pressure or Enrichment. *SPE Annual Technical Conference and Exhibition*, 29 September-2 October 2002, San Antonio, Document ID: SPE-77381-MS.

[13] Teklu, T.W., Ghedan, S.G., Graves, R.M., *et al.* (2012) Minimum Miscibility Pressure Determination: Modified Multiple Mixing Cell Method. *SPE EOR Conference at Oil and Gas West Asia*, 16-18 April 2012, Muscat, Document ID: SPE-155454-MS.