Introduction

Since the 1960s, China has been paying attention to CO_2 flooding technology and has conducted indoor research on CO_2 flooding. However, due to insufficient understanding and limitations in gas source conditions, the development of CO_2 flooding technology was slow before 2000. In 2005, the Research Institute of Petroleum Exploration and Development of China National Petroleum Corporation and the Chinese Academy of Sciences jointly initiated the Xiangshan Conference on "China's Greenhouse Gas Emission Reduction Strategy and Development", where the concept of combining CO_2 flooding utilization with storage (CCUS) was proposed. The research on CO_2 flooding technology has entered a fast lane [1-2]. Domestic researchers have conducted extensive theoretical research on the microscopic experiments of CO_2 flooding, the influence of crude oil components on CO2 flooding, the mechanism of CO_2 storage, CO_2 capture technology, and CO_2 pipeline transportation technology [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]. Zheng Wenkuan et al. studied the extent of enhanced oil recovery by different injection and production patterns through physical simulation(Zheng et al. 2023), and Lan Jingjing et al. investigated the impact of different injection parameters on the enhanced oil recovery by CO_2 through experiments (Lan et al. 2023). However, due to the lack of on-site supporting facilities and gas source issues, the scale of on-site application and promotion is relatively small. Currently, the research on the injection volume and recovery degree of CO_2 is still at the theoretical level, and the combination of theory and on-site technology is not yet sufficient. Therefore, it is very necessary to select typical blocks to clarify the relationship between the injection volume and recovery degree in the CO_2 flooding stage, which will facilitate the subsequent large-scale application and promotion.

Method and/or Theory

By analyzing the seepage law of reservoir fluids, a splitting method for the gas injection volume flowing into different zones from each gas injection well was established to obtain the CO_2 injection volume of each zone, form the relationship curve of pore volume (HCPV) of injected hydrocarbons - recovery degree, and verify it with numerical simulation.

Results

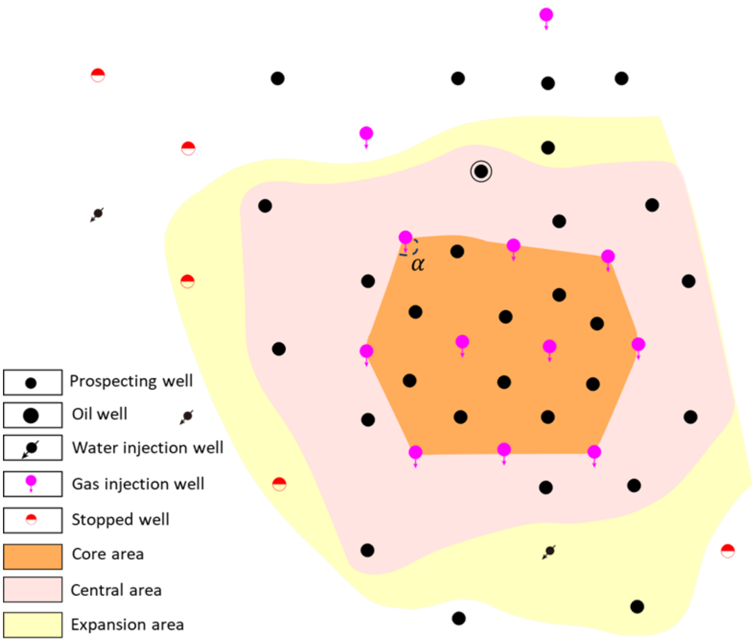

Fig.1 Well location map of the test area

The injection volume splitting method of the irregular reverse 7-point well pattern was proposed. the splitting coefficient β is the ratio of α to π, as shown in formula (1). Then, the flow rate flowing into the core area is Q_i, as shown in formula (2) :

$$\beta = \frac{\alpha}{\pi} \tag{1}$$

α : The Angle of the well in the core area;

β : Splitting coefficient

$$Q_i = Q * \frac{\alpha}{\pi} \tag{2}$$

Q_i: Flow rate flowing into the core area, t/d;
Q: Injection volume, t/d;
After clarifying the cumulative gas injection HCPV numbers in each zone, the relationship between the cumulative gas injection HCPV and the recovery degree was further analyzed. With the increase of the carbon dioxide injection HCPV number, the recovery degree in the core area increased significantly. When 1.95HCPV of CO_2 was injected, the recovery degree in the core area was 53.2%. When the injected gas volume is between 0.4 HCPV and 1.2HCPV, with the increase of this injected gas, the recovery degree increases rapidly. It is found through fitting that the extraction degree curve in the gas injection stage follows the Arps harmonic decreasing law, as shown in formula (3)

$$y=15.422 \ln x+43.331 \tag{3}$$

Y: Recovery degree;
X: The number of injected HCPV;

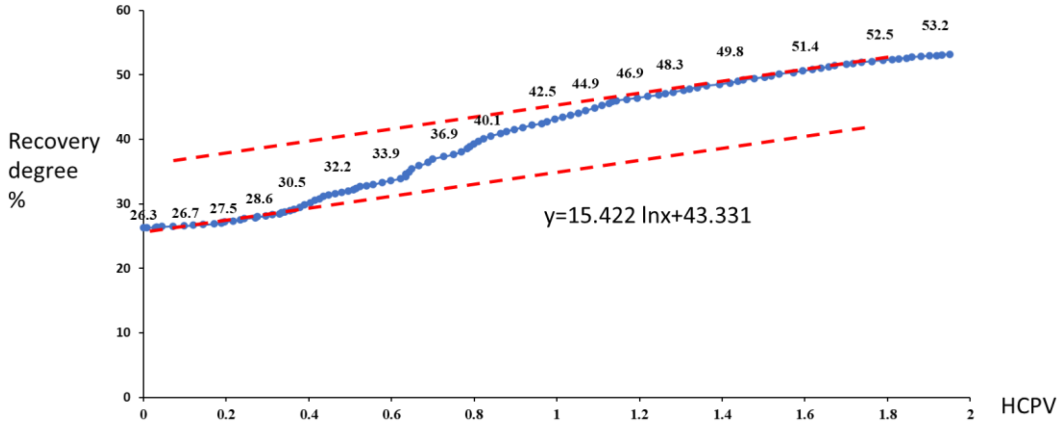

Fig.2 Curve graph of the extraction degree during the gas injection stage in the core area

By establishing a numerical simulation model, a method for calculating the inflow of carbon dioxide in different regions using the numerical model was proposed. The inflow of different regions evaluated by this method has a smaller error than that obtained by the angular flow splitting method, verifying the reliability of the angular flow splitting method.

Conclusions

(1) An injection volume splitting method for irregular reverse 7-point well patterns was proposed, and a production degree model for CO_2 mixed-phase flooding in low-permeability reservoirs was established, which can achieve the evaluation and prediction of the production degree in the CO_2 mixed-phase process.

(2) The injection volume and the recovery degree show a harmonic decreasing law of Arps. When the injection gas volume is between 0.4 HCPV and 1.2HCPV, the recovery degree increases rapidly with the increase of this injection gas. A model for predicting the extraction degree through the injection volume is presented, and the prediction formulas for the extraction degree of this block are given respectively through fitting. This formula can provide guidance for the subsequent development of CO2 drive in other blocks where it is difficult to establish numerical models.

(3) The conclusion of the numerical simulation is similar to that of the angular flow splitting method, verifying the reliability of the angular flow splitting method.

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