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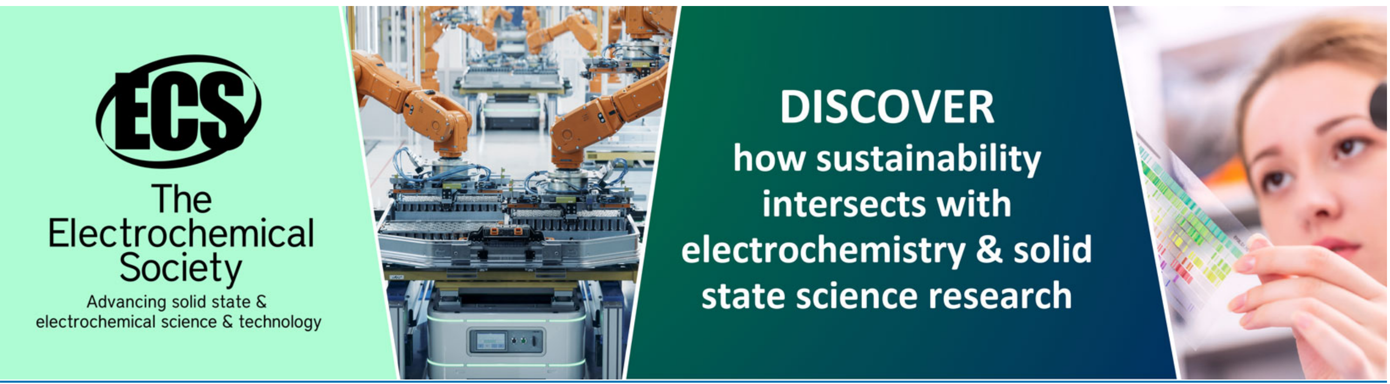

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Yushulin Oilfield CO_2- Comparison of minimum miscibility pressure test results for crude oil system

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Abstract. Miscible displacement of carbon dioxide in low permeability sandstone reservoirs can greatly improve oil recovery. The minimum miscible pressure is the starting point of miscible flooding. Its determination is very important for oilfield development. In this paper, the error analysis of the results measured by empirical formulas is carried out by the internationally accepted slim tube experiment method. Research results show that the minimum miscibility pressure obtained by slender tube displacement experiment is 22.12 MPa. The maximum, minimum and average miscibility pressures predicted by empirical formula method are 32.33 MPa, 7.85 MPa and 19.76 MPa, respectively. The relative error of the average minimum miscibility pressure predicted by all empirical formulas is 10.67%. The least relative error is the Yelling and Metcalfe correlation method, the relative error is 8.82%.

1.Introduction

The application of CO_2 in oilfield flooding is increasing, and it has become an important and mature method for enhancing oil recovery at home and abroad. The minimum miscibility pressure of CO_2 is an important parameter for CO_2 injection development. There are three methods to determine the miscibility pressure: experimental method, empirical formula method and equation of state method. This paper mainly applies the empirical formula method. There are many empirical formulas for the minimum miscibility pressure of CO_2-crude oil system. The results of their calculations are quite different from each other. In this paper, the minimum miscible pressure of Yushulin Oilfield is measured by using slender tube displacement test method, and the error analysis of the prediction results by the empirical formula method is carried out. Finally, a method suitable for predicting the minimum miscibility pressure in similar blocks is selected.

2. Prediction of Minimum Miscibility Pressure by Empirical Formula Method

The oil-gas ratio of Yushulin Oilfield is 25.25m3/m3, the density of crude oil is 0.782g/cm3, the volume coefficient is 1.1175, and the viscosity is 2.8 mPa·s. The following are common prediction formulas:

(1) Natl.Petrolelm Council Method

This method first determines the minimum miscible pressure corresponding to the crude oil density table, and then corrects the results according to formation temperature.

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(2) The second part of Cronquist correlation

$$P_{mm} = 15.988T^{0.744206+0.0011038M_{C_{5^+}}+0.0015279MPCI}$$

(3) Yelling and Metcalfe correlation

$$MMP = 1.5832 + 0.19038T - 0.00031986T^2$$

(4) Glaso correlation

On the basis of Benham et al's prediction chart, Glaso considers the influence of intermediate component on the measurement of miscibility pressure, and takes the molar fraction of intermediate component up to 18% as the limit, gives the following two relations:

① When the molar content of intermediate components in crude oil is less than 18%:

$$P_{mm} = 20.3214 - 0.0235M_{C_{7^+}} + \left(1.6673\times10^{-9}M_{C_{7^+}}e^{786.8M_{C_{7^+}}^{-1.0582}}\right)\times(0.0127T+0.225) - 0.8356f_{RF}$$

② When the molar content of intermediate components in crude oil is more than 18%:

$$P_{mm} = 5.5805 - 0.0235M_{C_{7^+}} + \left(1.6673\times10^{-9}M_{C_{7^+}}^{3.73}e^{786.8M_{C_{7^+}}^{-1.0582}}\right)\times(0.0127T+0.225)$$

(5) The correlation of Alston et al.

For the injected gas to be pure CO_2:

$$P_{mm} = 6.5036\times10^{-6}\times(1.8T+32)^{1.06}M_{C_{5^+}}^{1.78}(n_{vol}\div n_{\min t})^{0.136}$$

(6) Silva prediction method

① Analysis of the composition of crude oil by gas chromatography,and normalized weight fractions of C2-C_{31^+} fractions were calculated by the following formula $W_{iC_2^+}$:

$$W_{iC_2^+} = W_i \div \sum_2^{31} K_i W_i$$

$$F = \sum_2^{31} K_i W_{iC_2^+}$$

(1) When F<1.467, $\rho_{MMP} = 0.542F + 1.189$

(2)When $F \ge 1.467$, $\rho_{MMP} = 0.42$

(7) Sebastian correlation

In 1985, Sebastia considered the effect of impurities on the measurement of miscible pressure and proposed a correlation of carbon dioxide flooding with impurities.

$$P_{mm}^{imp} = P_{mm}^{pure}\times\left[1.0 - 0.0213(T_{cm}-304.2) + 2.51\times10^{-4}\times(T_{cm}-304.2)^2 - 2.35\times10^{-7}\times(T_{cm}-304.2)^3\right]$$

$$T_{cm} = \sum_i x_i T_{ci}$$

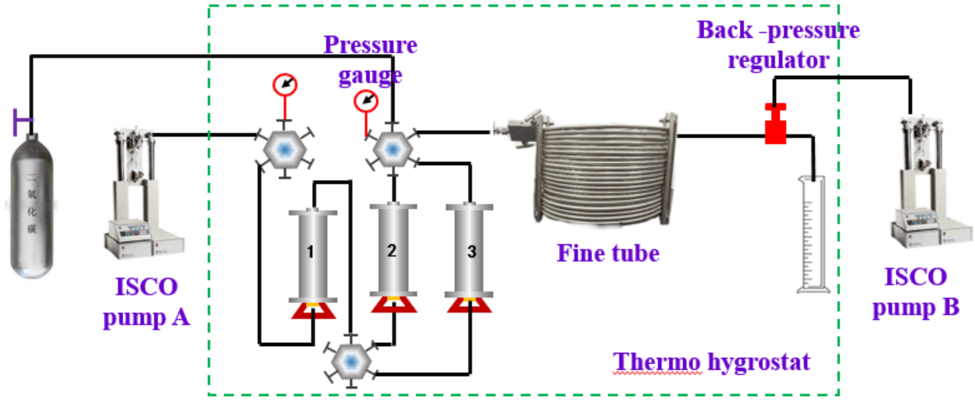
3.Determination of Minimum Miscibility Pressure by slender tube displacement experiment

3.1 Equipment and device diagram for experiment

(1) ISCO advection pump;
(2) SG-83-1 twin self-control incubator;
(3) Direct high speed rotary vane vacuum pump;
(4) Carbon dioxide cylinder;
(5) Slim tube;
(6) Hand pump;
(7) Piston containers filled with 500 ml white oil and two empty piston containers;
(8) A number of back pressure control valves, pressure gauges and 6-way valves;

(9) Electronic balance;

The experimental set-up diagram connection is shown in Figure 1 below:



piston container 1-white oil, piston container 2- CO_2 add pressure middle container, piston container 3-CO_2 Injection container

Figure 1 Slim tube experimental device connection diagram

3.2 Experimental procedure

(1) Experimental preparation: cleaning test tubes with petroleum ether, after the washing is completed, the slim tube is blown dry with a suitable pressurized nitrogen gas. The tubes are then placed in an incubator for drying.

(2) Measuring pore volume: vacuum pumping, connect the slim tube to the vacuum pump, vacuum pumping for more than 12h, saturated distilled water, calculate the porosity of the slim tube.

(3) Saturated oil: Inject 1.5PV of analog oil into the slim tube through the piston container using ISCO constant speed and pressure pump. Calculation of oil saturation based on injection rate and liquid production.

(4) CO2 displacement: Connect the experimental equipment as shown in Figure 1. Set back pressure by hand pump.When no oil is produced, the displacement is stopped and the experimental data are recorded. After the experiment is stopped,clean the correlation instruments, repeat the above steps, and carry out the next pressure displacement experiment.

(5) Data handling:There are at least three test pressure points in the miscible and immiscible phases. Draw a graph of each displacement pressure and displacement efficiency. The pressure corresponding to the intersection point of immiscible and the miscible phase curve is the lowest miscibility pressure point of carbon dioxide-crude oil.

3.3 Laboratory findings

As shown in Figure 2, the relationship between experimental pressure and crude oil recovery degree determines that the minimum miscibility pressure of Yushulin 101 block is 22.12 MPa.

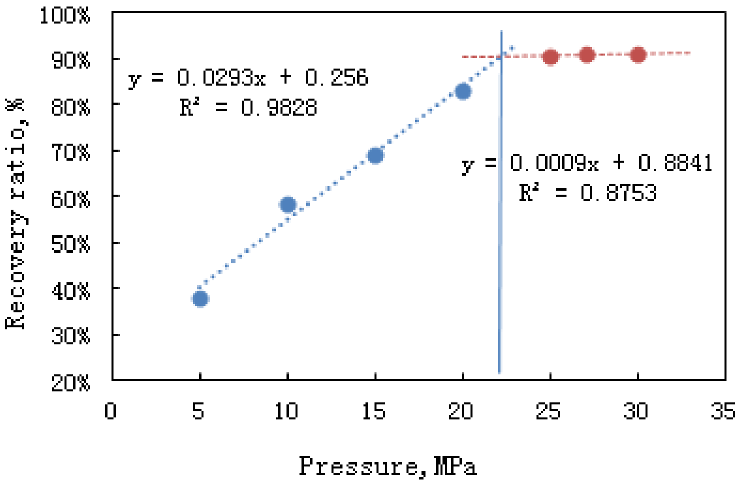


Figure 2 Slim tube experimental measurement curve

4. Comparison of Minimum Miscible Pressure Prediction Results

The minimum miscibility pressure predicted by the generally accepted long slim tube displacement experimental method is compared to the minimum miscibility pressure predicted by each empirical formula method(Table 1). It can be seen that the minimum miscibility pressure obtained by long slim tube displacement experiment is 22.12 MPa; The minimum miscible pressure predicted by the empirical formula method,the minimum value is 32.33 MPa, the minimum value is 7.85 MPa, and the average value is 19.76 MPa; The relative error of the average minimum miscibility pressure predicted by all empirical formulas is 10.67%. Among them,the least relative error is the Yelling and Metcalfe correlation, the relative error is 8.82%;followed by the Sebastian correlation, the relative error is 12.01%. The prediction results of other empirical formula methods are relatively large.

Table 1 Comparison of minimum miscibility pressure prediction results

Forecasting Methods	Minimum miscible pressure prediction /MPa	Fractional error /%
NPC method	7.85	64.52
Cronquist correlation	15.83	28.44
Yelling and Metcalfe correlation	24.07	8.82
Glaso correlation	32.33	46.15
Alston et al’s correlation	16.65	24.71
Silva Prediction method	16.78	24.14
Sebastian correlation	24.78	12.01
lender tube displacement experiment	22.12	/

5. Conclusion

The error results of the empirical formulas determined by the slim tube experiment are as follows: The NPC method error is as high as 64.52%, the Glaso correlation method error is 46.15%, the Alston et al. correlation and the Silva prediction method between 24% and 25%, and only the Sebastian correlation and the Yelling and Metcalfe correlation errors between 8% and 12%. The comprehensive comparison shows that the difference between the Yelling and Metcalfe correlations and the actual test results in the empirical formula is the smallest.

6. Acknowledgement

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