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STUDY ON THE CHARACTERIZATION OF GAS CHANNELING IN HOMOGENOUS RESERVOIR

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Abstract- Aiming at the limitations of the characterization of gas channeling strength at present，the gas channeling coefficient is defined by analyzing the dynamic gas ratio curves of CO_2 flooding in tubes. Natural gas flooding experiments are conducted to verify the precision of the defined coefficient，and the results show that the precision could be as high as 0.03，the defined coefficient could be used to preliminarily evaluate gas channeling during gas flooding. The results also show that the defined coefficient is highly sensitive to displacement efficiency，approximately 0.015 change would be induced by per unit change in displacement efficiency.

Keywords- gas channeling coefficient, CO_2 flooding, natural gas flooding, displacement efficiency.

I. INTRODUCTION

The effective characterization of gas channeling strength is one of the keys to study the mechanism and the influencing factors of gas channeling. At present, methods of the evaluation or characterization of gas channeling including improved Hele-Shaw cell model, injection pore volume before gas breakthrough, gas exhaust rate and fingering coefficient[1-5]. However, there still exist some shortcomings in these methods. For example, the improved Hele-Shaw cell model can only observe the fingering trend directly; the pore volume of gas breakthrough and gas exhaust rate can characterize gas channeling properly in some certain conditions, but the universal of which is a big problem. Zhang et al.[3] suggested using fingering coefficient to characterize the extent of gas channeling based on their flat core model flooding experiments, however, big errors would be introduced by the size of model and the high pressure in actual flooding process.

In this study, based on slim tube experiments and the analysis of the dynamic gas ratio of gas flooding, we are trying to define gas channeling coefficient (GCC) to characterize the extent of gas channeling.

II. Materials

Slim tubes (the parameters of which are shown in Table 1), CO_2 with 99.99% purity, crude oil (the parameters of which are shown in Table 2), natural gas (the parameters of which are shown in Table 3).

Table 1. The parameters of slim tubes

Slim tube number	Length (m)	Inradium (mm)	Pore volume (mL)	Permeability (μm^2)
1	12	4	68	6.3
2	12	4	67	6.4
3	12	4	77	6.6
4	12	4	66	6.5
5	12	4	65	6.3

Table 2. The composition of crude oil

Carbon number	Content (mol%)	Carbon number	Content (mol%)	Carbon number	Content (mol%)
C_3	0.13	C_{14}	1.77	C_{25}	0.29
C_4	1.31	C_{15}	1.68	C_{26}	0.22
C_5	4.38	C_{16}	1.29	C_{27}	0.18
C_6	8.92	C_{17}	1.07	C_{28}	0.15
C_7	11.19	C_{18}	0.85	C_{29}	0.12
C_8	8.03	C_{19}	0.76	C_{30}	0.09
C_9	3.23	C_{20}	0.62	C_{31}	0.07
C_{10}	2.82	C_{21}	0.54	C_{32}	0.02
C_{11}	2.62	C_{22}	0.51	C_{33}	0.01
C_{12}	2.26	C_{23}	0.43		
C_{13}	2.20	C_{24}	0.35	Total	100.00

Table 3. The composition of natural gas

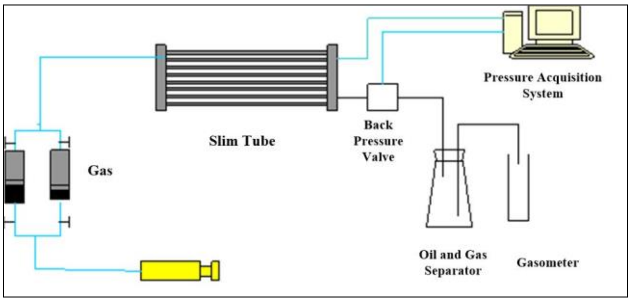
Component	Content (mol%)	Component	Content (mol%)
N_2	19.441	nC_4	0.407
CO_2	1.250	iC_5	0.066
C_1	70.90	nC_5	0.066
C_2	5.300	C_6	0.040
C3	2.240		
iC_4	0.290	Total	1.000

III. Procedure

The flooding experiments are conducted as follows:

1. Saturating the slim tube with crude oil under reservoir temperature (108C), and then increasing the pressure inside the slim tube to the desired pressure by compressing crude oil and calculating the amount of saturated oil.
2. Preparing the injection gas, and then beginning to inject gas under desired pressure and measuring the oil and gas production.

The schematic diagram of the experiments is shown in scheme 1.



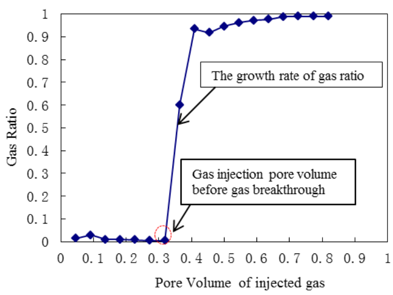
Scheme 1. The schematic diagram of gas flooding

IV. Results and discussion

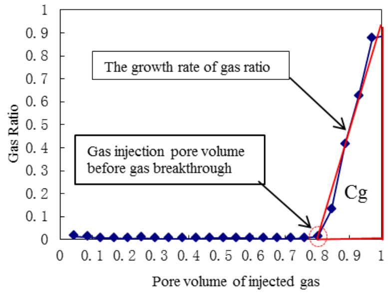
A. The definition of gas channeling coefficient

From the results shown in Figure 1, it can be seen that when the injection pore volume of CO_2 before CO_2 breakthrough is high, the gas ratio in outlet increases slow once CO_2 breakthrough, and the extent of gas channeling is weak; when the injection pore volume of CO_2 before CO_2 breakthrough is low, the gas ratio of outlet increases fast once CO_2 breakthrough, and the extent of gas channeling is strong. The results may indicate that the gas injection pore volume before gas breakthrough and the growth rate of gas ratio are the basic parameters that can reflect the strength of gas channeling. Thus, if define a coefficient-gas channeling coefficient, which is a combination between injection pore volume before gas breakthrough and the growth rate of gas ratio in outlet, to characterize the extent of gas channeling would be more accurate than other methods.

The gas channeling coefficient (C_g) can be defined as the total gas production-to-the total gas injection ratio. In the dynamic gas ratio figure, C_g can be explained as the ratio of the area under curve to the total gas injection pore volume. If inject one pore volume gas, C_g is actually the area that the curve and the horizontal axis enclosed, and thus the size of the area is directly determined by the injection pore volume before gas breakthrough and the growth rate of gas ratio in outlet. In actual study, the area can be calculated by geometric approximation. For example, the area in Figure 1 (b) can be calculated as triangle approximately.



(a)



(b)

Figure 1. The dynamic gas ratio curve of CO_2 flooding.

The value of C_g ranges from 0 to 1. If C_g is equal to 0, then no gas channeling will happen during the whole injection process. If C_g is equal to 1, then gas channeling will happen at the beginning of gas injection and all the injected gas will be exhausted from outlet. If C_g is between 0 and 1, as the increase in C_g, gas channeling becomes stronger.

B. The evaluation of the precision of Cg

To evaluate the precision of C_g, two other natural gas flooding experiments were conducted under the same conditions, and the dynamic gas ratio results are shown in Figure 2 and Figure 3 respectively.

In Figure 2, the C_g can be calculated as the sum of the area of trapezoid (upper line: 0.54, lower line: 0.58, height: 0.63) and triangle (base line: 0.37, height: 0.27) approximately, and thus the C_g is 0.402. In Figure 3, the C_g can be calculated as trapezoid (upper line: 0.41, lower line: 0.52, height: 0.85) approximately, and thus the C_g is 0.395. By comparing the C_g in Figure 2 and Figure 3, it can be seen that the difference between the two C_gs is 0.007. The result indicates that the precision of the defined C_g is high.

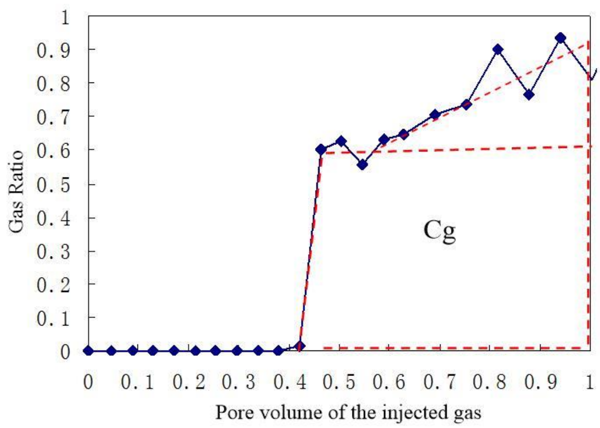


Figure 2. The dynamic gas ratio curve of natural gas flooding I.

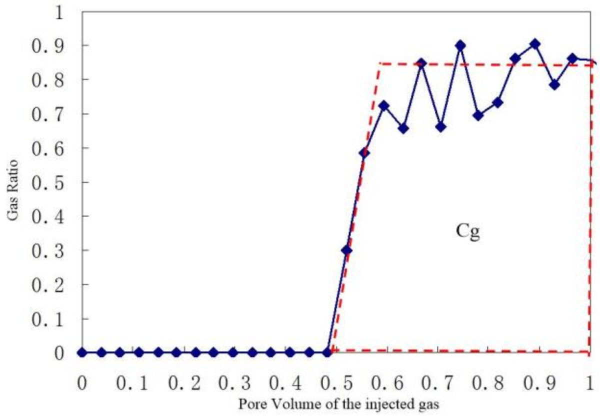


Figure 3. The dynamic gas ratio curve of natural gas flooding II.

For verifying the precision of geometric approximation in calculating C_g, another geometric approximation of the dynamic gas ratio results shown in Figure 3 was conducted (Figure 4). In Figure 4, the C_g is approximated as the sum of the area of trapezoid (upper line: 0.44, lower line: 0.52, height: 0.66) and triangle (base line: 0.44, height: 0.32), and the result of the calculation is 0.387. The difference between the two different geometric approximations of the same dynamic gas ratio results is 0.008, which indicates that the precision of using geometric approximation to calculate C_g is high.

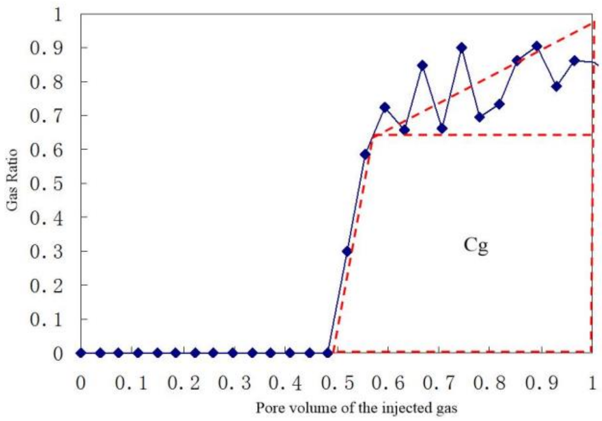


Figure 4. The dynamic gas ratio curve of natural gas flooding II.

C. The sensitivity of Cg on gas channeling

Fingering gas channeling is one of the main factors affecting the displacement efficiency of gas flooding in homogeneous model. The differences between the displacement efficiency of gas flooding can reflect the strength of gas channeling to some extent. Thus, the sensitivity of C_g on displacement efficiency of gas flooding can reflect the sensitivity of C_g on gas channeling indirectly.

Aiming at the above purpose, natural gas flooding experiments were conducted under different pressures, and the results are shown in Figure 5. From Figure 5, it can be seen that the C_g is sensitive to the displacement efficiency of gas flooding, and the 0.015 change on C_g would be introduced by the unit change of displacement efficiency. The result indicates that the C_g defined in the study can be used to preliminarily evaluate the strength of gas channeling in gas flooding.

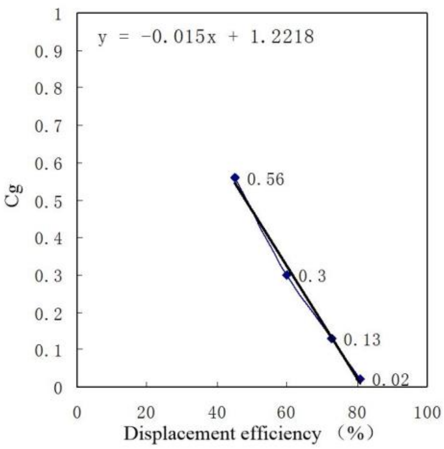


Figure 5. The corresponding relation between C_g and displacement efficiency.

V. CONCLUSIONS

The gas channeling coefficient C_g is defined to evaluate the strength of gas channeling in gas flooding. The results of the precision and sensitivity analysis indicate that the defined C_g can be used to preliminarily evaluate the strength of gas channeling in gas flooding.

REFERENCES

[1] Xie, G., Chen, J-j., Zhao, J .and Chen, J-s. 2000. Studies on viscous fingering in a hele-shaw model II. Effect of mobility ratio and surface roughness on viscous fingering, *Journal of natural science of Heilongjiang University,* 17(2), 70-72.

[2] Xie, G., Wang, S., Chen, J-s., Gong, W-c., Yang, Q-y., Jia, Z-w. 2000. Studies on viscous fingering in a hele-shaw model III. The effect of the oil exit pore number and the radius of holes pitch on viscous fingering, *Journal of natural science of Heilongjiang University,* 17(3), 71-73.

[3] Zhang, Y., The study on the influencing factors of viscous fingering in oil reservoir, *master thesis*, China University of Petroleum, Beijing, 2010.

[4] Pons, M. N., Weisser, E, M. 1999. Characterization of Viscous Fingering in Aradial Hele-Shaw Cell by Image Analysis, *Experiments in Fluids*, 26, 153-160.

[5] Sinha, S. 2008. Adhesion and Fingering in the Lifting Hele-Shaw cell: Role of the Substrate, *Eur. Phys.*, 25, 267-275.