Study on Dynamic Characteristics of Microbial Enhanced Oil Recovery

To cite this article: Yang Zhao et al 2018 IOP Conf. Ser.: Earth Environ. Sci. 108 032074

View the article online for updates and enhancements.
Study on Dynamic Characteristics of Microbial Enhanced Oil Recovery

Yang Zhao¹*, Fang Shi¹, Wuying Qin² and Jing Yan²

¹Laboratory of Enhanced Oil Recovery of Education Ministry, Northeast Petroleum University, Heilongjiang, China
²No. 2 oil production plant, Daqing Oil Field Co, Heilongjiang, China

*Corresponding author e-mail: znl00001@sina.com

Abstract. With the rapid development of economy, the demand for oil is increasing day by day. MEOR has the advantages of low cost and no pollution to the environment, attracted widespread attention. In this paper, the dynamic characteristics of microbial enhanced oil recovery were studied by laboratory experiments. The result showed that all the microbial flooding recovery rate could reach more than 5%, and the total recovery could reach more than 35% and if the injection period of microbial composite system was advanced, the whole oil displacement process could be shortened and the workload would be reduced.

1. Introduction
By a direct effect on crude oil and its productions in the process of growth and metabolism of chemical substances, such as biopolymers, biosurfactant, small molecular organic acids, alcohols, Microbial enhanced oil recovery (MEOR) technology can degrade and reduce the viscosity of underground crude oil, increase oil fluidity and increase formation pressure, so as to improve the recovery of crude oil [1, 2]. At present, the domestic and foreign application of MEOR methods can be divided into two categories: one is pouring the microbial system directly into the reservoir, so that it could activate the remaining oil to improve oil recovery by biological metabolism in the underground [3]. The other is using microbial metabolism to produce metabolites on the ground, then pouring these metabolites into the reservoir to enhance oil recovery [4].

In this paper, the heterogeneous cores were used to study the characteristics of depth profile transfer and flooding of microbial composite system. By monitoring the changes of pressure field and seepage field during the process of displacement, the difference between the horizontal pressure field and the seepage field of the high permeability layer and the low permeability layer of the heterogeneous core was compared, the migration law of microorganisms, nutrients and metabolites was evaluated, microbial composite system of profile control oil displacement effect was comprehensive analyzed.

2. Experimental Materials
The experimental water was the simulated water prepared according to the mineralization degree of JQ formation water, the experimental cores were homogeneous in the plane and nonhomogeneous in the longitudinal. The core parameters were shown in Table 1, the model structure and the physical figure

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
were shown in Figure 1 and Figure 2. The strains Ns4, Ns8 and Wp1 were used in the experiments. The experimental temperature was 35 °C.

Table 1. The physical model core parameters.

| Layer        | Permeability (mD) | Length (cm) | Width (cm) | Thickness (cm) |
|--------------|-------------------|-------------|------------|----------------|
| upper part   | 1500              | 30          | 30         | 1.5            |
| middle part  | 3000              | 30          | 30         | 1.5            |
| under part   | 4500              | 30          | 30         | 1.5            |

Figure 1. The physical model core sketch map. Figure 2. The physical map of heterogeneous core.

3. Experimental procedures
Three heterogeneous core physical models A, B and C were developed to carry out experiments. The experimental procedures were as follows.

1. The core A, B and C were evacuated for 12 hours, saturated with experimental water, and placed for 8 hours at constant temperature. Pore volume was calculated and the resistance of monitoring point was collected.
2. The core A, C were saturated JQ block crude oil, core B was saturated W block crude oil, oil saturation of each point was measured, and placed for 8 hours at constant temperature.
3. Water flooding cores A, B to water content reached 98% and Water flooding cores C to water content reached 80%, monitoring oil saturation and pressure value of each point.
4. 0.3 PV of microbial system fluid were injected into the cores, monitoring oil saturation and pressure value of each point, and placed for 48 hours.
5. Subsequent water flooding to no oil production [9].

4. Experimental results

4.1. Oil displacement effect
The core A, B and C were tested according to the experimental procedures, and the results were shown in table 2.

Table 2. Experiment results of oil displacement

| Core number | Water flooding recovery(%) | Enhanced oil recovery after microbial flooding(%) | Total recovery(%) |
|-------------|-----------------------------|--------------------------------------------------|-------------------|
| A           | 28.69                       | 8.05                                             | 36.74             |
| B           | 34.14                       | 6.69                                             | 40.83             |
| C           | 21.31                       | 15.75                                            | 37.06             |

We could see from the table 2 that all the microbial flooding recovery rate could reach more than 5%, and the total recovery could reach more than 35%. Core A and core B are different crude oil and the same microbial liquid injection period. Because of high crude oil viscosity, core A water flooding recovery was only 28.69%, the increase of recovery rate was 8.05% after the injection of microbial...
fluid which was 1.36% higher than that of core B. The results showed that the degrading bacteria in microbial complex liquid played a better role in the process.

Core A and core C are the same crude oil and different injection periods. When the water flooding recovery degree was 21.34%, microbial fluid is injected into the core C, the total recovery was 37.06%, and the total injection volume was 2.47PV. While the total recovery of core A was 36.74%, and the total injection volume was 3.06PV. It showed that if the injection period of microbial composite system was advanced, the whole oil displacement process could be shortened and the workload would be reduced.

4.2. Variation of oil saturation field
In order to further study the dynamic characteristics of microbial flooding, the monitoring of oil saturation field has been carried out [5]. Generally, the matrix of oil and gas reservoir is non-conductive, the difference between water and crude oil is very large, the resistivity of crude oil is nearly infinite, and the larger the concentration of electrolyte in water is, the smaller the resistance value is. Therefore, the variation of oil saturation can be determined according to the electrical variation of core [6, 7].

The saturation degree is calibrated by the theoretical method of Archie saturation and lithology, and the saturation exponent $n$ and lithology coefficient $B$ in Archie formula are determined, and the formula of water saturation is obtained [8].

\[ I = \frac{R}{R_0} = \frac{b}{S_w^n} \] (1)

There are two methods to determine the coefficients $b$ and $n$: core displacement experiment and empirical coefficient method. In this paper, $b = 1$ and $n = 2$. The plot of oil saturation field is plotted by SURFER8.0 software, and the experimental results are shown in figure 3-5.

![Figure 3. Saturation map of different horizons after subsequent water flooding in core A](image1)

![Figure 4. Saturation map of different horizons after subsequent water flooding in core B](image2)
Figure 5. Saturation map of different horizons after subsequent water flooding in core C

From Figure 3 to figure 5 could be seen that as the permeability of high permeability layer was small and the liquid absorption was large, the injection water appears along the high permeability layer at the early stage of water flooding, and soon formed a dominant flow channels, which made the mid and low permeability area low degree of impact. As a result, the permeability of the high permeability layer was large and the remaining oil saturation was low at the end of water flooding. On the contrary, the low permeability layer had low degree of dispersion and high residual oil saturation.

In the stage of microbial flooding, water flooding had been formed dominant flow channels in high permeability layer, the microbial system firstly entered the dominant channel, and was detained in the mainstream line near the residence, to increase flow resistance and the injection pressure. With the increase of injection pressure, the imbibition amount in low and medium permeability layer was increased, the range of spread was increased, and the remaining oil saturation was decreased. In the subsequent water flooding stage, due to microbial products had occurred in high permeability layer and near the mainstream line area stranded, made up the water into the surrounding areas of lower permeability, low permeability flooding absorption capacity was increased, and the spreading range was enlarged and the remaining oil saturation was decreased.

4.3. Variation of pressure field
Each pressure point data was monitored and recorded. The location of pressure test point was shown in figure 6. The relationship between pressure and injection volume was plotted, and the experimental results are shown in figure 7-9.

Figure 6. Diagram of pressure monitoring points
Figure 7. Relationship curves between injection pressure and injection pressure of core A

Figure 8. Relationship curves between injection pressure and injection pressure of core B

Figure 9. Relationship curves between injection pressure and injection pressure of core C

From Figure 7 to Figure 9 could be seen that because No. 1 well was the injection well, the pressure changed obviously. The distances from No. 2, No. 3 and No. 4 wells to the injection wells were the
same, the pressure variation is not big. While the pressure of No. 5, No. 6 well pressure were not obvious.

5. Conclusion
Through the research, we get the following conclusions.

(1) All the microbial flooding recovery rate could reach more than 5%, and the total recovery could reach more than 35%. Thereinto the degrading bacteria in microbial complex liquid played a better role in the process.

(2) If the injection period of microbial composite system was advanced, the whole oil displacement process could be shortened and the workload would be reduced.

(3) In the subsequent water flooding stage, due to microbial products had occurred in high permeability layer and near the mainstream line area stranded, made up the water into the surrounding areas of lower permeability, low permeability flooding absorption capacity was increased, and the spreading range was enlarged and the remaining oil saturation was decreased.

Acknowledgments
This work is financially supported by the National Natural Science Foundation of China—“Fractal Description of Non-linear Growth of Microbes and the Mass Transportation of Dispersion in Porous Media” (Grant No.51374075); And the Northeast Petroleum University Innovation Foundation For Postgraduate—“Study on The Retention and Migration of Microbial System in Porous Media ” (Grant No. YJSCX2016-008NEPU).

References
[1] Alkan, H, E Mahler, N Klueglein et al. SPE 179580, 2016, to be presented at Twentieth SPE Improved Oil Recover Conference.
[2] Brown, Lewis, R. Microbial enhanced oil recover(MEOR). Current opinion in Microbiology of biofilm phase in porous media. Environmental microbiology. 2010, 13(11): 3010-3023.
[3] Kowalewski, E, I Rueslatten, KH Steen et al. Microbial improved oil recovery—bacterial induced wettability and interfacial tension effects on oil production. Journal of Petroleum science and Engineering. 2006, 52(1): 275-286.
[4] Gerbersdorf, SU, S Wieprecht. Biostabilization of cohesive sediments: revisiting the role of abiotic conditions, physiology and diversity of microbes, polymeric secretion, and biofilm architecture. Geobiology. 2015, 13(1): 68-97.
[5] Park, Aeri, Heon-Ho Jeong, Jintae Lee et al. Effect of shear stress on the formation of bacterial biofilm in a microfluidic channel. BioChip Journal. 2011, 5(3): 236-241.
[6] SEN R. Biotechnology in petroleum recovery: the microbial EOR. Progress in Energy and Combustion Science, 2008, 34(6): 714-724.
[7] Zhang Y X, Kim P, Victor A, et al. Genome shuffling leads to rapid phenotypic improvement in bacteria. Nature, 2002, 415: 644-646.
[8] Crescente C., Rekdal A., Abriz A., Torsaeter O., Hultmann L., Stroem A., Rasmussen K., Kowalewski E.. A porelevel study of MIOR displacement mechanisms in glass micromodels using Rhodococcus sp. 094, SPE paper 110134, 2008.
[9] Yang Z, Jingchun W, Fang S. Evaluation of the Effect of Microbial Combination Flooding. Advances in Petroleum Exploration and Development. 2016, 11(2):52-56.