Research and Application of Microbial Enhanced Oil Recovery Technology in High Waxy Oil Reservoirs

Rui Wang[1][a], Guan Wang[1], Pei Wang[2], Shasha Liu[1], Chao Wang[1], Jizhe Jing[1], Ying Liu[1], Yajuan Tang[1], Jinxiu Du[1] and Dong Xuan[3]

[1]*Engineering Technology Research Institute, Huabei Oilfield Company of PetroChina, Renqiu, Hebei, China*

[2]*The Forth Exploitation, Huabei Oilfield Company of PetroChina, Lang Fang, Hebei, China*

[3]*Production Management Department, Huabei Oilfield Company of PetroChina, Renqiu, Hebei, China*

Keywords: High Waxy Oil Reservoir, Microbial Oil Recovery, Compound Bacteria, Nutrition System.

Abstract: To solve the problems of high wax content and high freezing point in block Q, the compound strain which could reduce wax content by 40% was selected through laboratory experiment and performance evaluation. The nutrition system formula suitable for the target reservoir was obtained. After the formulation system was applied to block Q, the colloid asphaltene and wax content of crude oil decreased, which was directly reflected in the decrease of viscosity and solidifying point of crude oil. The solidifying point decreased by 12℃. The oil well fluid production increased and watercut decreased, achieving oil-increasing effect.

1 INTRODUCTION

The average porosity of block Q is 28.8% and average permeability is 197.1mD, which is a high porosity and medium permeability reservoir. The high waxy content (32.1%) and high solidifying point (40.1°C) leaded to poor liquidity and serious paraffin precipitation in wellbore. After water flooding development, the temperature of near-well-bore area decreased. The precipitation and deposition of wax blocked near-well-bore area and reduced the permeability. The wax precipitation in well shaft, string and borehole is serious. It seriously affected the normal production and restricted the efficient development of oil fields.

In order to solve the problems of high wax content and poor fluidity of block Q, the degradation of paraffin in crude oil by microorganisms and the improvement of rheological properties by metabolites were studied. The microorganisms for wax removal generally use wax, colloid and asphaltene as carbon sources (Qin 2015, Chen 2004, Yi 2009), which can actively degrade the heavy components, thus reducing the viscosity and improving the fluidity of crude oil (Wang 2017, Wang 2017). Microbial oil recovery technology is simple in construction and has a long validity period. It can avoid damage to oil layer caused by hot washing with non-toxic and odor-free. It is safe and environmentally friendly, and has good economic, social and environmental benefits.

2 BACTERIA SCREENING

Experimental conditions: Crude oil, produced water and injected water from block Q, temperature of 52℃.

Experimental methods: 100ml of produced water was taken by 2% of the bacteria solution. 10g of oil sample was added. After mixing, the sample was put into a constant temperature shaker and cultured at 52℃. A blank test was conducted at the same time. After 72 hours, the change of crude oil performance was evaluated (Liu 2001, Shi 2008).

2.1 Adaptability Evaluation of Strain Species and Reservoir Environment

The strains were inoculated into the produced and injected water for fermentation and culture, and then the concentration of bacteria was observed with a counter. The results showed that 11 selected strains

[a] https://orcid.org/0000-0001-7876-3954

Wang, R., Wang, G., Wang, P., Liu, S., Wang, C., Jing, J., Liu, Y., Tang, Y., Du, J. and Xuan, D.
Research and Application of Microbial Enhanced Oil Recovery Technology in High Waxy Oil Reservoirs.
DOI: 10.5220/0011190200003443
In *Proceedings of the 4th International Conference on Biomedical Engineering and Bioinformatics (ICBEB 2022)*, pages 127-131
ISBN: 978-989-758-595-1

grew well in formation and injection water. The bacteria concentration was from 2.1×10^8 to 5.4×10^8 /mL, showing perfect adaptability.

Table 1: Comparison of bacterial concentration in different production environments (10^8 /ml).

Bacterial	Produced water	Injected water
1903	3.00	3.12
HB3	5.28	5.07
BB2	2.96	3.45
1906	2.52	2.67
DM-2	3.43	3.12
1665	3.54	3.77
5S	5.44	5.37
5BQ	3.47	3.62
6H	2.89	3.37
6B	3.22	3.47
5BZ	2.14	2.66

2.2 Emulsification Effect Evaluation

The selected strains had different degrees of emulsification effect after acting with crude oil, among which 6H, 6B, 5S, 5BQ and 5BZ had the best emulsification effect, and oil and water were completely mixed without obvious stratification.

Table 2: Oil emulsification comparison.

Bacterial	Emulsification level
1903	4
HB3	3
BB2	4
1906	4
DM-2	4
1665	4
5S	5
5BQ	5
6H	5
6B	5
5BZ	5

The level is based on < Q/SY HB 0209-2016>.

2.3 Viscosity Reduction Evaluation

According to the experimental results, 5S, 6H and 6B had better viscosity reduction effect.

Table 3: Comparison of viscosity reduction effects of different strains.

Bacterial	Viscosity, mPa.s	Reduction rate, %
Blank	39.8	/
1903	29.1	26.85
HB3	35.6	10.58
BB2	42.1	-5.80
1906	32.1	19.34
DM-2	43.2	-8.57
1665	33.5	15.65
5S	25.4	36.02
5BQ	30.2	24.10
6H	25.8	35.17
6B	27.4	31.02
5BZ	32.3	18.76

3 NUTRITIONAL SYSTEM SCREENING AND EVALUATION

3.1 Nutritional System Screening

The selection of nutrients follows these principles: (1) Five nutrient elements for strain growth are basic. (2) The cost is low. (3) A good effect of strain proliferation and viscosity reduction is needed. (4) The compatibility with reservoir formation water is well with no precipitation reaction.

Crude oil is the main carbon source, and glucose and sucrose are added as supplements. Nitrogen sources are mainly nitrate, ammonium salt, urea, etc. Inorganic salts are phosphate, sulfate and compounds containing sodium, potassium and other metallic elements. Growth factors are mainly vitamin, amino acid, purine and pyrimidine. Yeast extract and peptone contain production factors. Based on the above principles, six formulas in Table 4 are formed.

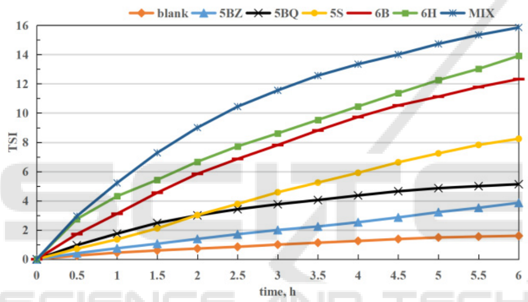
Table 4: Six different microbial formulations (unit: %).

Component	F-1	F-2	F-3	F-4	F-5	F-6
Nitrogen source a	0.25	0.20	*	*	*	*
Nitrogen source b	*	*	*	0.45	0.45	0.45
Sodium	0.10	0.10	0.10	*	*	*
Growth factors	0.20	0.20	0.20	0.10	0.15	*
Inorganic salt a	*	0.35	0.35	0.01	0.01	*
Inorganic salt b	0.35	0.35	*	*	0.35	0.35
Inorganic salt c	0.35	*	0.50	0.40	*	0.35
Nitrogen source c	*	*	0.45	0.45	0.45	0.45

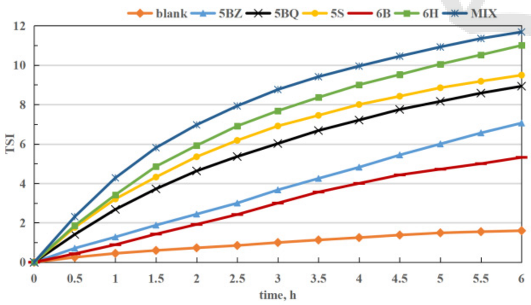
Inorganic salt d	0.03	0.03	0.03	*	*	*
Microelement	0.17	0.17	0.17	*	*	*
Carbon source	0.10	0.10	0.10	*	*	*

3.1.1 Emulsifying and Dispersing Effect

After being activated for 24 hours, 2% of selected strains were transferred to the corresponding nutritional formula added with 10% of crude oil. The culture medium was carried out on a 150rpm shaker at 52℃ for 5 days. Then the dispersion performance was evaluated by using NIR Turbiscan with the instability coefficient. The higher the instability coefficient was, the better the dispersion performance was. The results showed that 6H, 6B and 5S of the selected strains had strong emulsifying and dispersing effect in two different formulations. But the emulsifying and dispersing effect was better when the three strains were mixed in equal proportion.



(a) F-3



(b) F-6

Figure 1: Dispersion effects comparison of different strains.

3.1.2 Surface Activity of Microbial Fermentation Broth

The culture solution was centrifuged (at 5000rpm for 20min), and the residual crude oil and cells were removed by extraction and filtration to obtain a clear liquid sample. The surface tension was measured after standing at 25℃ for 1 hour. The results showed that the combination strain could better reduce the surface tension.

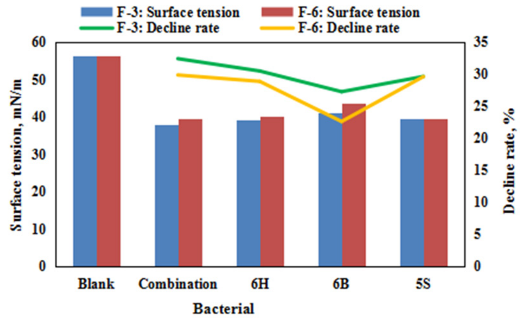


Figure2: Comparison of surface activities of different strains.

3.1.3 Viscosity Reduction Effect

The strains were inoculated into a mixture of crude oil sample and nutrient solution at a ratio of 3:7, and cultured on a shaker for 5 days. Then the samples were dehydrated to test the crude oil viscosity. The experimental results were shown in Figure 3. The results showed that the compound formula had better viscosity reduction effect.

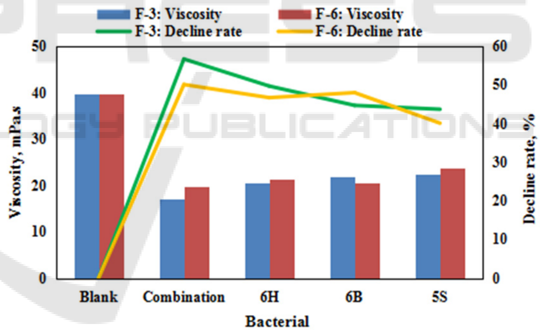


Figure 3: Comparison of viscosity reduction effects of different formulas.

The wax content and freezing point of crude oil were measured after dehydration. The experimental result showed that F-3 had better effect.

Table 5: Comparison of wax content and freezing point of different strains.

	Wax content %	Decline rate %	Freezing point ℃
Blank	30.84	/	41.3
F-3	18.47	40.1	28.2
F-6	24.27	21.3	32.5

3.2 Evaluation of Formula Optimization

In order to further reduce the field injection cost, the formulation 3 and 6H, 6B and 5S were selected for further optimization. By comparing the properties of different formulas, N-2 had better effect of emulsifying, reducing wax content reducing and crude oil viscosity decline.

Table 6: Optimized system formula (unit: %).

Component	F-3	N-1	N-2	N-3
Microorganism	2.00	2.00	2.00	2.00
Sodium	0.10	0.08	0.05	0.03
Growth factors	0.20	0.15	0.10	0.05
Inorganic salt a	0.35	0.30	0.25	0.20
Inorganic salt c	0.50	0.35	0.25	0.20
Nitrogen source c	0.45	0.35	0.20	0.10
Inorganic salt d	0.03	0.02	0.01	0.01
Microelement	0.17	0.10	*	*
Carbon source	0.10	0.10	0.10	0.10

Table 7: Performance parameters comparison of optimized systems.

Formula	Blank	F-3	N-1	N-2	N-3
Viscosity mPa.s	39.8	17.2	17.5	17.9	18.9
Surface tension mN/m	56.50	38.15	40.12	40.65	42.31
Wax content %	30.84	18.47	18.67	17.95	19.34

4 FIELD APPLICATION EFFECT

From 2019 to 2020, microbial oil recovery was carried out in 2 well groups in block Q. After the measures, the total bacterial concentration was effectively increased from 10^4 /mL to 10^7 /mL. The surfactant content was increased from 12.1mg/L to 60.4mg/L, which was conducive to crude oil recovery. After microbial action, the gelatinous asphaltene content and wax content decreased, which was directly reflected in the decrease of the viscosity and freezing point of crude oil. The freezing point decreased by 12℃. The ascending current of oil well decreased significantly and the load was reduced.

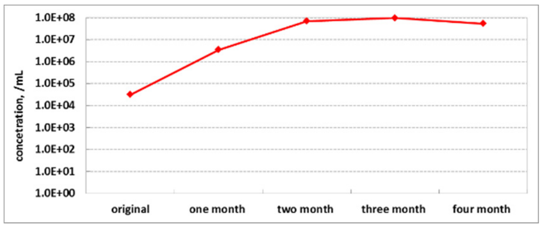


Figure 4: Changes of microbial concentration of well Q53.

Table 8: Changes of crude oil properties before and after the microbial measures of Q53.

Time	Before	After
Viscosity, mPa.s	16.1	9.8
Wax content, %	40.3	30.1
Freezing point, ℃	40.0	28.0
Colloid asphaltene content, %	8.6	8.3
Saturated hydrocarbon content, %	62.2	54.2

After the implementation of huff and puff, the liquid production of well Q53 increased and watercut decreased. The daily production of liquid increased from 2.1t/d to 5.3t/d. The daily production of oil increased from 0.8t/d to 3.2t/d, watercut reduced by 22.3%. The accumulative oil was 266t.

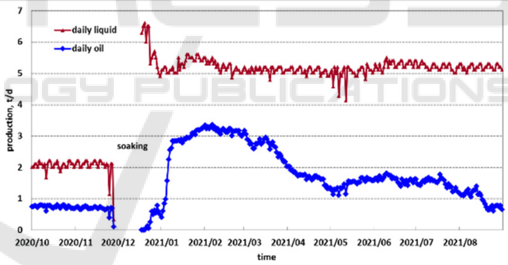


Figure 5: Production curve of well Q53.

5 CONCLUSION

1. Aiming at high waxy oil reservoirs, the selected strains have good compatibility with the target reservoir. After the compound strains act with crude oil, miscible emulsification can occur in oil and water. The surface tension is reduced by 32.47%, the wax content is reduced by 40.1%, the viscosity of crude oil is reduced by 56.7%, and the fluidity of crude oil is improved.

2. The microbial recovery measures in block Q take effect significantly, which suggest that MEOR can improve oil displacement efficiency. This technology provides the theoretical and practical

support for MEOR of high waxy reservoir and can become one of the effective means to increase production in the late waterflood development.

REFERENCES

Cheng A.H., YU J., FANG X.X. (2004). Improvement of Qil Recovering Rate by Microbial Clearing and Preventing Was and Its Application in Field Test. J. Xinjiang Agricultural Sciences. 41: 70-72.

Liu W.G., Zhao B., Zhang H. (2001). Screening, Performance Evaluation And Site Application of Paraffin Thirsty Bacteria in Low Permeability Reservoir. J. Special Oil & Gas Reservoirs. 8: 52-92.

Qin F.L., Ke C.Y., Sun F.L., 2015, *Principles and Applied Techniques of Microbiology in Oil&gas Field*. Science Press Publishing.

Shi Y., Ji R.L., Wang S.J. (2008). Screening and Evaluation of Bacterial Species Using Petroleum Hydrocarbon as the Sole Carbon Source for Oil Recovery. J. Oilfield Chemistry. 25: 366-368.

Wang W.Q. Liu Y., Wang G.F. (2017). The Effect of a Wax Strain on the Wax-removal and Viscosity-reduction in Waxy Crude Oil. J. Journal of Engineering Thermophysics. 38: 1906-1910.

Wang W.Q., Li J., Wang G.F. (2017). The Selection of Paraffin-degrading Bacteria and Their Effects upon the Rheological Characteristics of Heavy Crude Oil. J. Journal of Southwest Petroleum University (Science & Technology Edition). 39: 176-181.

Yi S.J., Hu K., Li B. (2009). Field Application of the Technology of Microbial Paraffin Cleaning and Preventing in Well of High Temperature and Hyperhaline of Jianghan Oilfield. J. Journal of Oil and Gas Technology. 31: 146-148.