

# Screening and Evaluation of Microorganism Species in Oil Recovery in Ji 45 Block

X Y Lei<sup>1</sup>, J You<sup>1</sup>, Y B Li<sup>1</sup>, R Wang<sup>1</sup>, X K Shan<sup>2</sup> and X Zhou<sup>3</sup>

<sup>1</sup> Research Institute of Oil Production Technology, Huabei Oilfield Company of PetroChina, Renqiu, He Bei Province, 062552, China

<sup>2</sup> Research Institute of Exploration and Development, Huabei Oilfield Company of PetroChina, Renqiu, He Bei Province, 062552, China

<sup>3</sup> Operation Division, Huabei Oilfield Company of PetroChina, Renqiu, He Bei Province, 062552, China

**Abstract:** In order to improve the development effect of Ji 45 block and slow down the nature decline, the bacteria evaluation experiment was carried out. Six strains were screened and their adaptability, emulsifying property and viscosity reduction were evaluated. The results showed that the strains of CYY0807 and CYY0810 have significant effect on the oil under reservoir conditions. The viscosity reduction rate reached 46.9% when the two strains were compounded. The gas chromatography results indicated that the compounded strains have good degradation effect on crude oil. The light components of crude oil increased and the heavy constituent reduced. According to the physical simulation experiment, the recovery was 9.2% under Ji 45 reservoir conditions by using the compounded strains.

## 1. Introduction

The water cut of Ji 45 block has increased rapidly since 1994. It is at super-high water-cut stage now. The controlling level of waterflooding decreased, the oil/water viscosity ratio is high. Appropriate tertiary technology is particularly necessary in order to improve the producing degree and oil recovery. The microbial enhanced oil recovery is that by using strains adapting for the formation environment, through the growth and metabolism of microorganisms in the formation, the physical properties of crude oil will be changed, for example, reducing the water/oil flow ratio, expanding swept volume, to achieve the purpose of improving oil recovery<sup>[1-4]</sup>. At the beginning of 2013, aiming at the geological characteristics and the development contradictions of Ji 45 block, the laboratory experiments of microbial strains was carried out.

## 2. Suitable bacteria screening

### 2.1 Enrichment medium selection

The demand for carbon, nitrogen, phosphorus and inorganic salts of different species of microorganisms is also different. For an unknown strain, it needs to be determined by experimentation. Therefore, during the screening process, several kinds of culture medium are used to ensure the growth of different strains in the sample, so as to select the target species. The culture medium used in the experiment ensures that the types and concentrations of carbon, nitrogen, phosphorus, growth factors and inorganic salts which are necessary for microbial growth and reproduction are different, so as to select more bacteria. The microorganisms in the samples were enriched and cultured by the



following four different media:

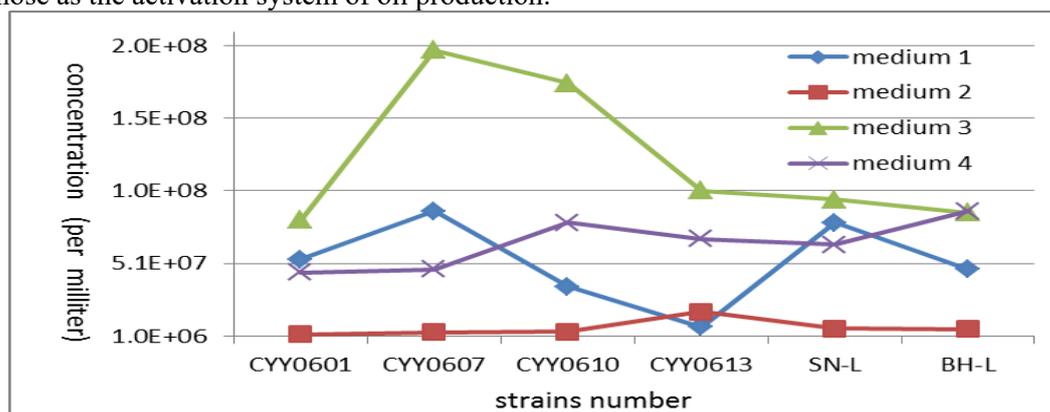
(1) Glucose 0.6%, peptone 0.1%, ammonium chloride 0.1%, microzyme 0.08%, dipotassium phosphate 0.02%, sodium dihydrogen phosphate 0.1%, pH 7~7.5.

(2) Glucose 0.2%, ammonium sulfate 0.5%, potassium chloride 0.11%, sodium chloride 0.11%, ferrous sulfate 0.0028%, potassium dihydrogen phosphate 0.15%, dipotassium phosphate 0.15%, magnesium sulfate 0.05%, microzyme 0.05%, microelement 0.5%, crude oil 2%, pH 7~7.5, zinc sulfate 0.029%, calcium chloride 0.024%, copper sulfate 0.025%, magnesium sulfate 0.017%.

(3) Glucose 0.6%, ammonium sulfate 0.1%, microzyme 0.01%, dipotassium phosphate 0.5%, potassium dihydrogen phosphate 0.15%, magnesium sulfate 0.02%, calcium chloride 0.01%, sodium citrate 0.05%, pH 7~7.5.

(4) Sucrose 2%, peptone 0.05%, microzyme 0.05%, carbamide 0.05%, ammonium sulfate 0.05%, potassium dihydrogen phosphate 0.5%, magnesium sulfate 0.02%, sodium chloride 0.01%, pH 7~7.5.

According to the performance evaluation method of microorganism for oil recovery<sup>[5-7]</sup>, 6 strains were evaluated for suitability. Figure 1 shows the growth conditions of six strains in the culture medium. The results showed that the growth and reproduction of the same strain in different nutrient solutions were very different. The low concentration of bacteria showed that the medium was not suitable for the growth of the microorganism. According to the growth of the every strain, medium 3 was chose as the activation system of oil production.



**Figure 1.** Growth of different strains in four kinds of culture medium

## 2.2 The emulsification performance of the strain

At the formation temperature of 47 °C, the formation water was added by nutrient system 3, and then cultured for 3 days after adding bacteria. According to the ratio of 5g /100ml, crude oil was added. After culturing for 3 days under the formation temperature, the emulsification properties of crude oil was observe, the emulsification level was assess. The emulsification assessment standard was in Table 1, the experimental results were shown in Table 2.

**Table 1.** emulsification standards for oil-producing bacteria

Emulsification grade	Emulsification description
5	Oil and water can be completely mixed, without oil and water boundary line, without stratification for a long time after standing.
4	Perfect results. Oil and water can be mostly mixed. The lower water layer is dark brown, oil phase is in spumescence. By shaking hard, oil and water can be basically miscible.
3	Good results. Oil and water can be partly mixed, The lower water layer is brown and oil phase is in bead, of which diameter is about 1 to 2 millimeter. By shaking hard, oil and water can be partially miscible, part of the oil beads is variable to be long or flattened
2	Better results. Oil and water can be partly mixed, the color of lower water phase is deepening and oil bead is smaller than the blank.
1	Effective. A small amount of oil and water is miscible, oil particle is smaller than the blank before the reaction
0	Invalid. Oil and water are significantly separated, oil bead is consistent with the blank before the reaction

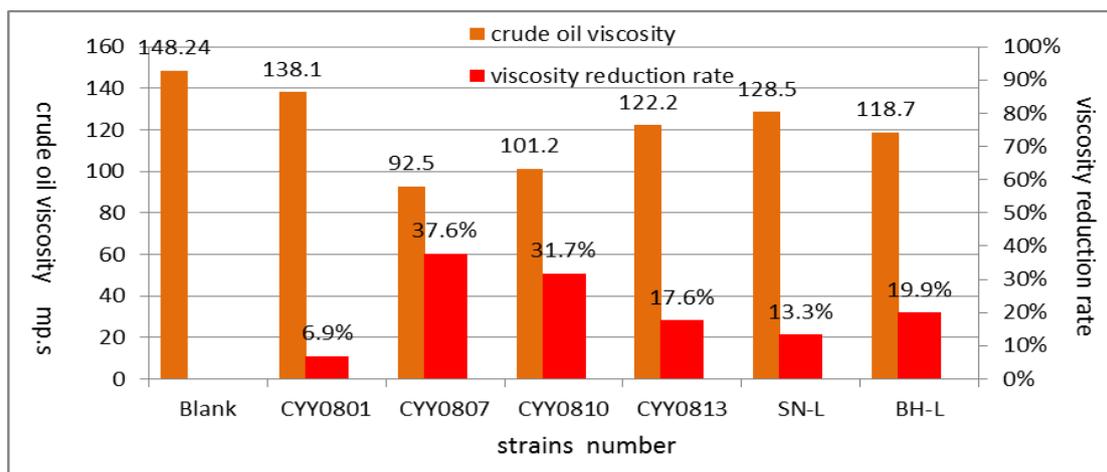
**Table 2.** emulsification effect of single strain on crude oil

Bacteria number	blank	CYY0801	CYY0807	CYY0810	CYY0813	SN-L	BH-L
Emulsification grade	0	3	5	5	3	3	4

It can be seen from Table 2 that the two strains of CYY0807 and CYY0810 have the best emulsification effect on crude oil, indicating that under the nutrient system 3, the two functional bacteria can be effectively activated with a good emulsifying effect.

### 2.3 Strain of the viscosity reduction test

The formation water was added by nutrient system 3, and then cultured for 3 days after adding 6 strains. Crude oil was added at a rate of 50 g / 50 ml and cultured for 7 days at the formation temperature. After centrifugation, the crude oil viscosity was tested using MARS rheometer. Compared with the initial viscosity, the crude oil viscosity reduction rate was calculated. The results were shown in Figure 2. The viscosity reduction effect of strains CYY0807 and CYY0810 for the well Ji 45-142 crude oil is significant and the viscosity reduction rate is more than 30%. The CYY0807 strain belongs to the hydrocarbon degrading bacteria. In its proper growth conditions, through its own metabolic action to produce decomposition enzymes, to crack heavy hydrocarbons and paraffin to improve the flow of crude oil [8-9]. CYY0810 was isolated and screened from output fluid in Huabei Oilfield Company, which belongs to the *luteimonas huabeiensis*. The surfactants metabolically produced had a good effect on the emulsification and dispersion of the crude oil [10].

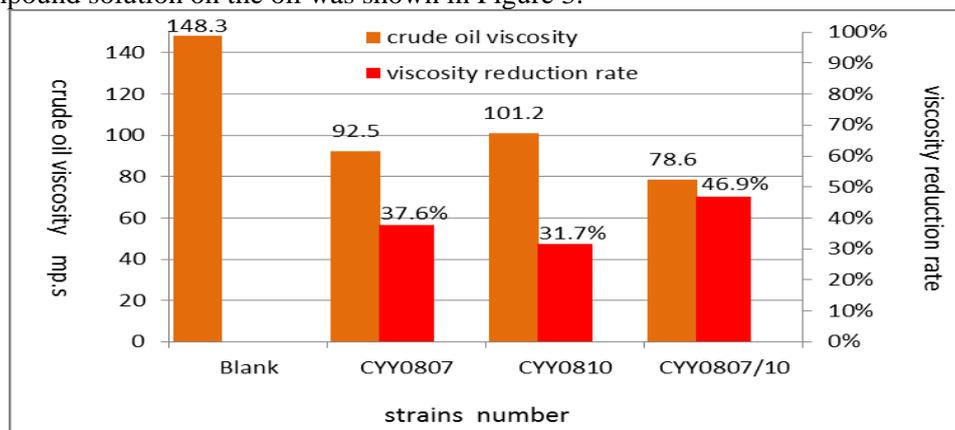


**Figure 2.** Ji 45-142 crude oil and bacteria viscosity reduction experiment

### 3. Effectiveness Evaluation of strains

#### 3.1 Compound strains and crude oil viscosity reduction experiments

According to the emulsification and viscosity reduction effect of the single strain on the crude oil, the strain CYY0807 and CYY0810 were selected to be compounded, marked as CYY0807 / 10. The effect of the compound solution on the oil was shown in Figure 3.



**Figure 3.** compound strains and crude oil viscosity reduction experiment of the well Ji 45-142

It can be seen from Figure 3, the viscosity reduction effect of compound strains is greater than that of a single strain, showing a greater degree of synergies. When the compound bacteria of CYY0807 and CYY0810 effects crude oil, the highest viscosity reduction rate can reach 46.9%.

#### 3.2 Analysis of Crude Oil Component Change after Microbial Action

The chromatography - mass spectrometry instrument, Agilent 6890, was used to detect crude oil composition before and after the microbial degradation for the well Ji 45-142. The gas chromatographic conditions [3] were as follows: the initial temperature of the oven was 40 °C, the heating rate was 2 °C / min, and when the temperature reached 200 °C, the heating rate changed to 6 °C / min until reaching 290 °C, and then temperature was constant until the peak, the carrier gas speed was 15ml / min. Mass spectrometry conditions were as follows: electron energy of EI source was 70eV, mass scanning range was from 30 to 50amu, quadrupole rods temperature was 150 °C. The change of mass fraction of C<sub>10</sub> ~ C<sub>32</sub> was analyzed by parameter change. The experimental results were shown in Figure 4, Figure 5 and Table 3.

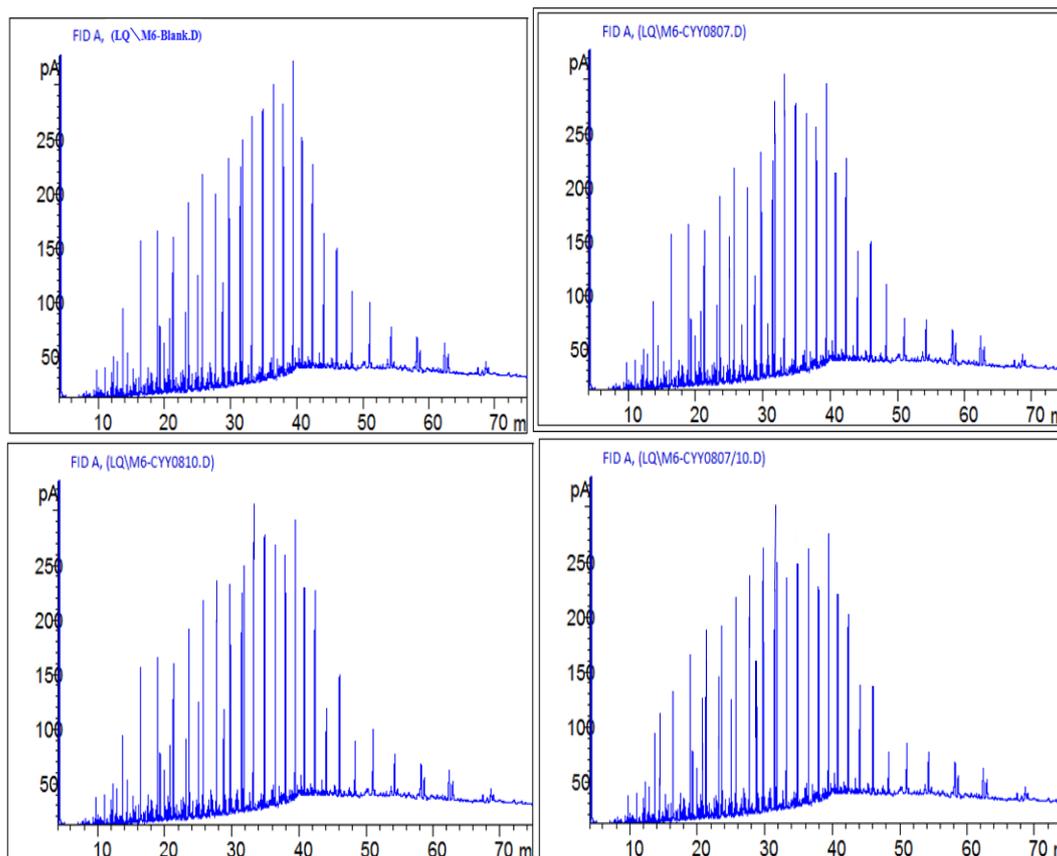


Figure 4. Gas chromatographic analysis of crude oil with different strains

Table 3. Changes in crude oil composition after the role of bacteria

Bacteria number	Carbon at peak value	nC21/nC22 <sup>+</sup>	Pr/nC17	Ph/nC18	CPI
blank	23	0.85	2.95	3.76	0.9
CYY0807	21	0.89	2.52	3.66	0.95
CYY0810	21	0.91	2.71	3.49	1.07
CYY0807/10	20	1.07	2.48	3.05	1.22

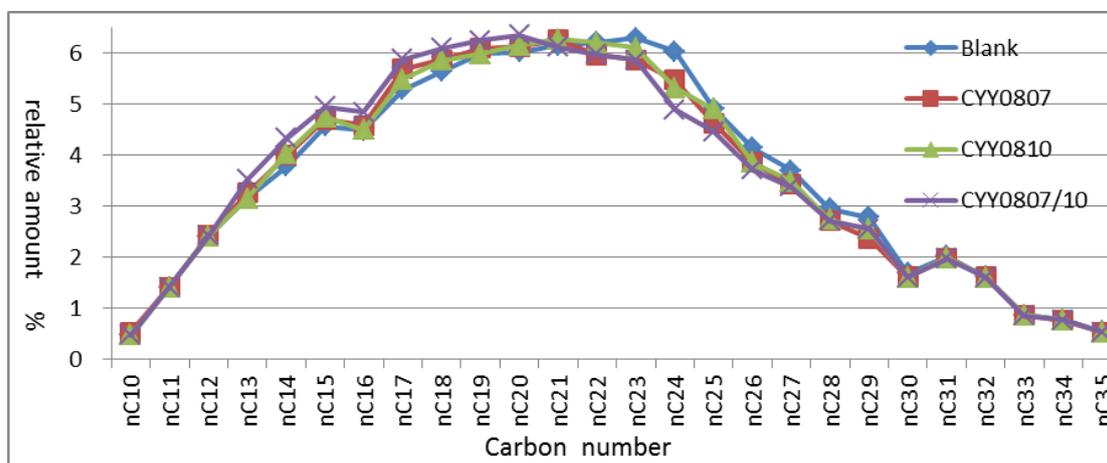


Figure 5. Analysis of all hydrocarbons gas chromatography on crude oil

The crude oil component changed after the effect of two kinds of bacteria, which the compound bacteria of CYY0807 and CYY0810 were the best. In the compound sample, the value of  $nC_{21-} / nC_{22+}$  increased from 0.85 to 1.07, carbon at peak value of crude oil changed from  $nC_{23}$  to  $nC_{20}$ , the value of  $Pr / nC_{17}$  and  $Ph / nC_{18}$  decreased to a certain extent, light component of  $nC_{10}$  to  $nC_{20}$  relatively increased and the heavy components decreased, the CPI value decreased from 0.9 to 1.22. All the data changes fully reflect the two experiment strains had a good degradation on crude oil. The light components of crude oil increased, heavy components decreased, n-alkane decreased, isoparaffin increased and the maturity of crude oil increased. On the macro level, crude oil flow performance increased and viscosity decreased <sup>[11]</sup>.

### 3.3 Physical modeling effect

Using long core physical modeling device of CMW-III, core saturated with oil was flooded with water until the watercut of export side reached 95% (1PV). Displacement solution of 0.5PV (pre-nutrient solution + compound bacteria liquid) is injected and cultured for 15 days in the formation temperature, continuing to water drive of 1 PV. The ultimate recovery was calculated, compared with the blank water flooding of 2.5 PV. The results were shown in Table 4.

**Table 4.** Microbial core flooding experiment

Core number	Permeability ( $10^{-3} \mu m^2$ )	Displacement solution	Primary water flooding recovery factor	Secondary water flooding recovery factor
1	128	—	—	63.7%
2	143	0.1PV pre-nutrient solution +0.4PV bacteria liquid	59.6%	71.2%
3	109	0.1PV pre-nutrient solution +0.4PV bacteria liquid	57.9%	72.9%
4	135	0.1PV pre-nutrient solution +0.4PV bacteria liquid	59.3%	72.1%

It can be seen from Table 4 that the recovery rate of secondary waterflooding recovery rate was improved compared to blank water flooding when the core injected into nutrient solution and bacterial liquid were cultured. The maximum increase of recovery efficiency is 9.2%. The results showed that under the condition of this reservoir, the compound strains named CYY0807 and CYY0810 had the potential to improve the recovery rate under this activation system.

## 4. Conclusion

(1) Two strains of bacteria selected from Ji 45 block crude oil had good degradation effect on crude oil after culturing in specific medium culture. When the strain No. CYY0807 and CYY0810 were compounded, the degradation effect of crude oil was achieved best and viscosity reduction rate of crude oil is 46.9%.

(2) Gas chromatographic analysis showed that the light composition of crude oil increased, the heavy component decreased, n-alkane decreased, isoparaffin increased and the maturity of crude oil increased after the effect of compound strain.

(3) Microbial flooding experiments showed that the compound strains named CYY0807 and CYY0810 could effectively improve the waterflooding recovery rate up to 9.2%, and the oil displacement effect was obvious.

## Acknowledgement

Fund program: Key S&T Special Projects of PetroChina Company Ltd. (Project number 2014-35-07).  
Biography: Lei Xiaoyang, born in 1988, engineer, graduated from Yangtze University in 2014,

majored in oil& gas field development engineering, worked on the tertiary oil recovery research, Tel: 18631777057. E-mail: cyy\_lxy @petrochina.com.cn.

### References

- [1] Dong L, Zhang B B and Liu Y J 2014 Application of Microbial Enhanced Oil Recovery Technology *J. Wuhan Inst. Tech.* **36** 32-37
- [2] Li G Q and Li L 2006 Discuss on Microbial Enhanced Oil Recovery Technology *Petroleum Geology and Engineering* **20** 75~77
- [3] Liu B L, Dong H P and Yu L 2011 Displacement Characteristics Analysis of Bacterial Microscopic Profile Control in Reservoir *Journal of Shenzhen University Science and Engineering* **28** 356-359
- [4] Dou Q L, Chen J F and Wang J 2004 Advances in Researches and Outlook for Microbial Enhanced Oil Recovery *Natural Gas Geoscience* **15** 560-562
- [5] Bai X Y and Hao N N 2008 The Experiment Evaluation Method of Microbial Species for Oil Recovery [J]. *Laboratory Science* 149-151
- [6] Wang J, Sun Y M and Wang P Z 2011 Screening and Characteristics of Biosurfactant-producing Bacteria *Journal of Dalian Polytechnic University* **30** 34-38
- [7] Lu M S, Liu Z C and Tang S H 2012 Experimental Selection Method and Effect Evaluation of Microbial Enhanced Oil Recovery *Drilling & Production Technology* **35** 90-93
- [8] Zheng C G, Li Y and Xu H C 2009 Study on Microcosmic Mechanism of Microbial Enhanced Oil Recovery by Hydrocarbon Oxidizing Bacteria *Science & Technology Review* **27** 28-31
- [9] Che X W, Xu C J and Diao L T 2014 Applied Potentials and Living Characters of Hydrocarbon Degradation Bacteria in High-Temperature and High-Salinity Environment *Oil&gas Field Environment Protect* **14** 23-25
- [10] You J, Li Q and Liu Y 2013 Activities of an Oil Degrading Bacterial Strain HB-2 *Biotechnology Bulletin* **11** 170-174
- [11] Zhang Y S and Xu S 2009 *Oil Microbial Recovery Technology* (Beijing Chemical Industry Press) p 112-115