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ORIGINAL ARTICLE

Study on distribution of reservoir endogenous microbe and oil displacement mechanism



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Abstract In order to research oil displacement mechanism by indigenous microbial communities under reservoir conditions, indigenous microbial flooding experiments using the endogenous mixed bacterium from Shengli Oilfield were carried out. Through microscopic simulation visual model, observation and analysis of distribution and flow of the remaining oil in the process of water flooding and microbial oil displacement were conducted under high temperature and high pressure conditions. Research has shown that compared with atmospheric conditions, the growth of the microorganism metabolism and attenuation is slowly under high pressure conditions, and the existence of the porous medium for microbial provides good adhesion, also makes its growth cycle extension. The microbial activities can effectively launch all kinds of residual oil, and can together with metabolites, enter the blind holes off which water flooding, polymer flooding and gas flooding can't sweep, then swap out remaining oil, increase liquidity of the crude oil and remarkably improve oil displacement effect.

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1. Introduction

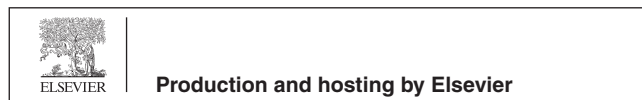
Endogenous microbial enhanced oil recovery (ASMR, activation of stratal microflora recovery) refers to the use of the original formation of microbial communities, activation underground beneficial microbial communities by adding activator to degrade crude oil viscosity, increased mobility of

crude oil to enhance oil recovery (Abdel-Waly, 1999; Lee et al., 1998; Zhang, 2005; Step et al., 1997; Wilhelms et al., 2001). Compared with exogenous microorganisms, endogenous microbes can adapt to extreme environmental reservoir, and has the advantages of high metabolic activity, no bacteria culture collections and production (Basso et al., 2005; Song et al., 2010; Li et al., 2006; Wang, 2002; Nazina et al., 2005; Ravin et al., 2009). However, the experimental study of microscopic microbial flooding currently defined at normal temperature and pressure conditions, most flooding during macro qualitative description of the process for the microbial enhanced oil reservoir simulation under high temperature and pressure conditions in porous media Microbial microscopic oil displacement experiments conducted have also been reported (Simpson et al., 2011; Borzenkov et al., 2004; Gray

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et al., 2009; Kaster et al., 2009), so many enhanced oil recovery mechanisms have not yet been identified and quantified. Therefore, based on the micro level, by simulating the reservoir temperature, high pressure environment, the use of micro-simulation models flooding experiment equipment and image acquisition system, using activated endogenous mixed microorganisms, microbial action on the various stages of the remaining oil in porous media changes in morphology and follow-up observations reveal microbial enhanced oil recovery characteristics under reservoir conditions, to clarify the mechanism of microbial microscopic flooding, provide reference for microbial enhanced oil field trials.

2. Material and methods

2.1. Materials and experimental reagents

Oil and water samples were taken from the Shengli oilfield wellhead of production and water injection station. The reservoir depth is 1240–1360 m, the temperature is 54–63 °C, formation water salinity 8900 mg/L, formation water pH value of 6.8, about 30% porosity and permeability of $800\text{--}1000 \times 10^{-3} \mu\text{m}^2$, average ground oil viscosity 1422 mPa·s, suitable endogenous microbial growth and reproduction. Activator formula is: 5% starch hydrolyzate, diammonium 0.05 g/L, urea, 1 g/L, ammonium nitrate 0.1 g/L.

Experiment Reagent: petroleum ether, ethanol, color gel, glucose, peptone, AR. Main experimental instruments: YZ15 peristaltic pump; UNICO2000 spectrophotometer; NDJ-1B viscometer; THZ-C Shaker; microscope; Canon digital camera.

2.2. Experimental method

2.2.1. Endogenous microbial culture

Formation water was added to the following nutrients: 5% of the starch hydrolyzate, diammonium phosphate 0.05 g/L, urea 1 g/L, ammonium nitrate 0.1 g/L. While taking 200 ml broth, were placed in the high-pressure, porous media, pressure and atmospheric pressure, porous media environment incubated at 60 °C for periodic sampling of bacteria under different culture conditions for microbiological staining observe the effects of different culture conditions on microbial growth; while applying surface tension measuring instrument to measure the surface tension of bacteria, microbial metabolites examine each case the growth period.

2.2.2. Distribution and the influence of bacteria on crude oil

A certain amount of bacteria and oil poured into the flask of 500 ml capacity, while Shaker put it in at 60 °C, 120 r/min conditions of incubation 15 d, periodically sampled for significant oil state micro observation, see the impact of crude oil on microbial distribution, and change the oil viscosity is measured.

2.2.3. Microscopic model morphological changes in remaining oil

Vacuum microscopic model for saturate water → oil flooding water to make irreducible water → injection containing microorganisms and nutrients → remain 15 days at 60 °C, 10 MPa conditions → secondary water flooding experiments, observe and record the phenomena throughout the experiment.

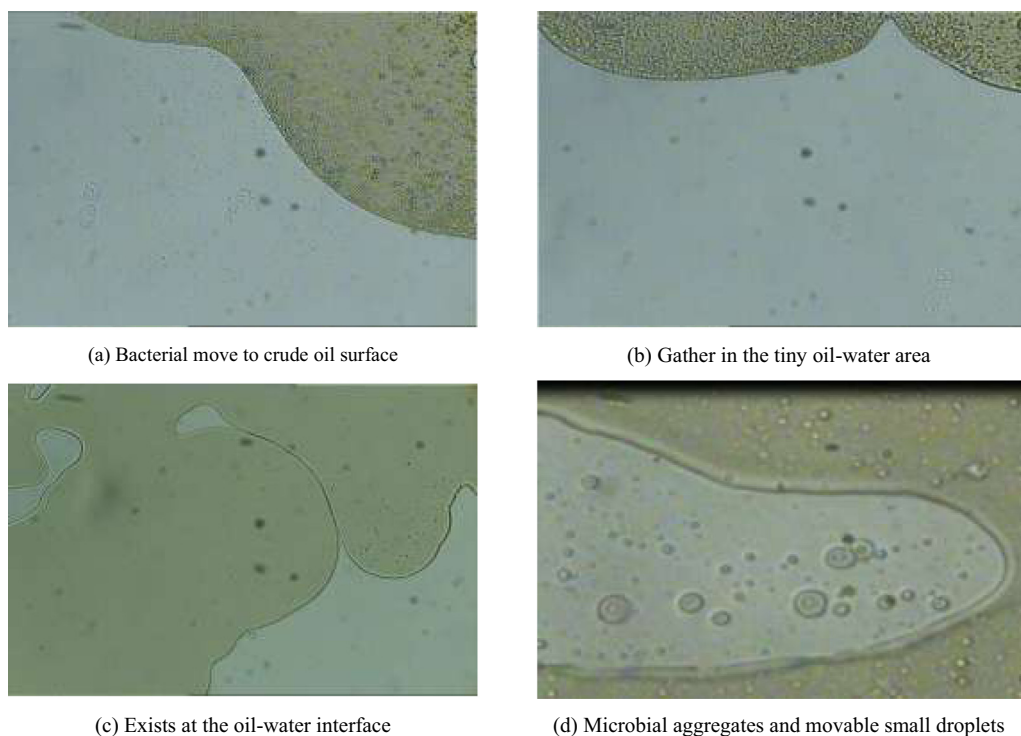


Figure 1 Microscopic observation of bacteria distribution.

3. Results and discussion

3.1. Bacteria distribution and the influence on the crude oil

Sampling of bacteria observed in the motion state of the biological cells microscope are shown in Fig. 1. The figure shows that the crude oil is used as a carbon source for microbial growth, microbial chemotaxis makes it gradually move to the oil film at the surface and be adsorbed. After one day, the aqueous phase carbon is gradually consumed and bacteria were mainly found in the microorganisms at the oil-water interface, simultaneously due to the action of microorganisms on the surface of the oil film, a lot of water with tiny droplets of movable and microbial aggregates was found in some water regions.

3.2. Analysis of microbial oil displacement mechanism

3.2.1. Distribution of oil remaining in model after the action of microorganisms

Reservoir temperature and pressure conditions were stimulated, using microscopic visualization photolithography simulation model, and the form of remaining oil after microorganisms was observed. After water-flooding, a lot of membranous and blind end remaining oil was found mainly in the large pores, while in column and clustered shape the remaining oil was found mainly in small pores. The model was fermented and cultured under the conditions of 60 °C 10 MPa for 15 days, due to the action of microbial growth and metabolites, various types of changes in the remaining

oil in the models occurred. Observation results were shown in Fig. 2.

Fig. 2 shows that after 15 days of the action of microorganisms, due to metabolic produce biosurfactants reduce the interfacial tension, oil-water interface stabilization system can destroy the initial case. Microbial degradation of crude oil takes place, the remaining oil makes the film surface becomes uneven, expanding the contact area of the surfactant provides a breaking point for membranous remaining oil, so film forms and the remaining oil gradually forms into small droplets to channel intermediate aggregates, such as (a). The remaining oil ends of the column suffered different degrees of wettability reversal phenomenon, it was found that the contact angle of the remaining oil column and wall increases, and increases with time, training, and gradually to the whole channel internal action, and finally conversion of the whole lipophilic surface wetting inversion channel into a hydrophilic surface, and thus was susceptible to flooding out, such as (b). Perpendicular to the main line at the opposite corners, and not because of the waves there are lots of clusters of remaining oil due to the role of surfactant gender groups, making clusters where the remaining oil pore wall wetting reversal occurs, so that the mobility enhancement tufted the remaining oil, such as (d).

3.2.2. Dynamic process of displacement by subsequent water flooding of the remaining oil

Subsequent to water flooding, various types of remaining oil start to be driven, the dynamic process of the remaining oil is shown in Fig. 3. Fig. 3 shows that, due to the action of

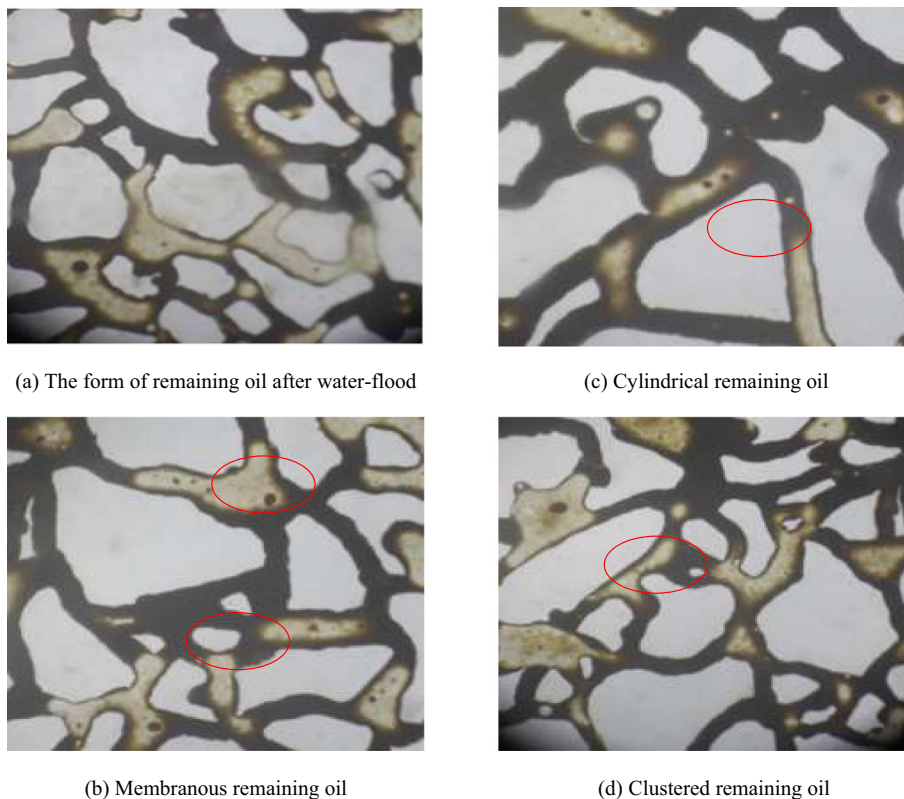
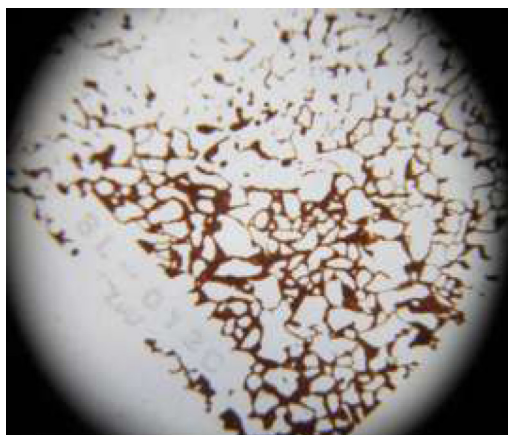


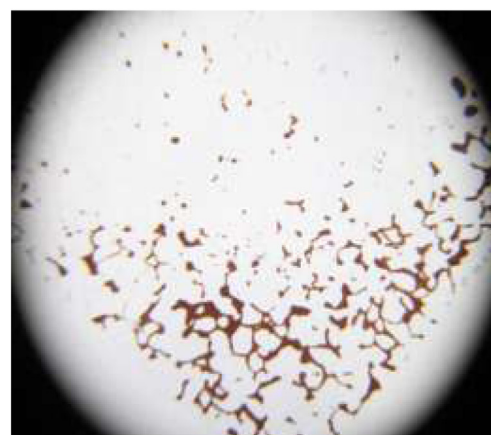
Figure 2 Different types of oil remaining after the action of microorganisms.



Figure 3 Dynamic process of displacement of remaining oil.



(a) Before the action of microorganisms



(b) after the action of microorganisms

Figure 4 Swept volume expansion phenomenon.

microorganisms, reducing the oil-water interfacial tension, softening the oil-water interfacial film. When subsequent water flooding begins, with the carrying effect of displacing fluid, and film edge deformation being gradually stretched, broken into small droplets, and eventually carried out from the porous medium took place, the displacement process is repeated continuously until movable remaining oil in the model was flooded cleanly.

3.2.3. Swept volume expansion with subsequent water flooding

As seen in Fig. 4, the phenomenon of swept volume expansion in the model appears with subsequent water flooding. Due to the similarity of bacterial solution viscosity and water solution viscosity, water can't sweep the area, neither bacterial solution, and therefore, swept volume expansion phenomenon after the role of microorganisms is mainly caused by the characteristic both of the displacement fluid viscosity increasing by biosurfactants produced by microbial metabolism and the microbial migration of the remaining oil at the diagonal line.

4. Conclusion

- (1) Under high pressure conditions, endogenous microbial grows slowly, less bacteria can adapt to the environment; under conditions of porous media, microbial growth, metabolism can be promoted, and its growth cycle is extended; the size of surface tension of bacterial

solution associated with the concentration of microorganisms, higher surfactant concentration of microbial metabolism, more quickly as the surface tension of the bacteria decreases.

- (2) Microbial chemotaxis makes itself gradually move toward the oil surface and present in the oil-water interface, provides nutrition in crude oil as carbon source for themselves, while degrades crude oil, the properties come out, such as "lower the viscosity of crude oil", "thinning the shear" and so on; after action of the microbe, emulsification of crude oil takes place significantly, showing an initial viscosity increase.
- (3) Microbial enhanced oil recovery is mainly to change and enhance liquidity of remaining oil by biosurfactant produced by microbial degradation and metabolization, effectively starting all kinds of residual oil, with the influence of subsequent water drive, the remaining oil is withdrawn, truncated, breaks away from the block, and eventually carried out in porous media, simultaneously appears the phenomenon of swept volume expansion that remarkably improves the oil displacement effect.

Acknowledgement

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