Precise Identification of Water Flooded Degree and Oil-water properties of Reservoir Based on Logging Interpretation

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Abstract. The crude oil reserves are very rich in the peripheral tight oil-water layer. However, due to the lack of effective production technical means, reserves utilization is relatively low. Imbibition flooding is one of the critical technical measures for the efficient development of (weak) hydrophilic tight oil-water layer. To obtain high efficiency production technology for weak hydrophilic tight oil-water layer, we investigated the imbibition flooding effect of negative/non-ionic surfactant “HLX”, “SYH (petroleum sulfonate) + Na2CO3”, cationic surfactant “YANG” and non-ionic surfactant “DCY” on weak hydrophilic core with permeability of about 2.0×10⁻³µm². The study results suggest that the imbibition recovery rate and imbibition rate are affected not only by the interfacial tension of the oil-water layer but also by the rock pore wettability. The physical simulation experimental results indicate that the “YANG” and “DCY” imbibition can change the wettability of rock pore surface and reduce the interfacial tension. Hence, the imbibition flooding effect is relatively good, and the recovery rate is significantly increased.

1. Introduction
Fuyu reservoir has rich tight oil resources in the peripheral area. However, it has yet to be extensively developed due to the poor physical properties. According to the structure and combination of clay minerals, illite, the main clay mineral[1-2], stands on the surface of particles with bridging, wispy, or circular petal-like leaf crystals, which makes the pore throat tortuous, smaller and narrower. The minor clay mineral chlorite is closely arranged on the particle surface and between the pores, making the pore throat smaller and narrower[3-4]. The secondary enlargement of quartz in the pores is serious, resulting in poor physical properties of the reservoir[5-6].

In recent years, with its simple technology, low operating cost, and excellent oil increasing effect, seep water flooding technology has been highly valued by petroleum scientists and technicians and is expected to become one of the effective measures for tight oil-water development under the condition of low oil price. The mechanism analysis shows that when the wettability of the rock pore surface is hydrophilic or weakly hydrophilic, the capillary force will be the driving force. The process of displacement in the non-wetted phase by wetted phase is called imbibition process, and the process of displacement of oil phase by water phase is called imbibition water flooding. The existing tight oil permeability imbibition flooding technology mostly uses oil well (or water well) water injection (or surfactant injection) solution, through the effect of stewing well and oil-water infiltration, and finally achieves the purpose of enhancing oil recovery. In view of the geological characteristics and fluid properties of the peripheral Fuyu reservoir, this paper has carried out the research on the effect of imbibition and flooding and its impact factors through the three-dimensional physical model...
experiment.

2. Precise identification based on logging interpretation

Assuming that \(X \in \mathbb{R}^N\) represent a vector of reservoir flooding, \(Y \in \mathbb{R}^N\) a vector of scale reservoir composition, \(\hat{Y} \in \mathbb{R}^N\) a vector of identified reservoir composition, where, \(N\) is the number of reservoir pixels, the relationship between reservoir flooding degree and scale reservoir can be expressed as:

\[
Y = X + \nu
\]  

(1)

Where \(\nu\) represents the gaussian white scale of additive. The observation model represented by formula (1) shows that the \(Y\) of scale reservoir represents obtained by the degree of reservoir flooding \(X\) by adding scale, while the problem to be solved by reservoir identification represents how to recover from \(Y\) to \(X\).

In general, the vector corresponding to the reservoir block has scale properties under some dictionary. first, in the form of overlapping pixels in the scale reservoir \(Y\), the composition vector of the reservoir block with \(n\times n\) size is extracted \(x_i \in \mathbb{R}^n\), that is, the \(X = RY\), \(R \in \mathbb{R}^{n \times N}\) is the extraction matrix, then the scale vortex detection of the reservoir block is \(X = Da\), where the \(D\) is a dictionary and the \(a_i\) is a scale coefficient.

The reservoir identification model based on scale eddy detection can be expressed as follows:

\[
\hat{a} = \arg \min_a \left\{ \|Y - Da\|_2^2 + \lambda \|a\|_1 \right\}
\]

(2)

Where the first term is the fidelity term, which is used to constrain the error between the reconstructed reservoir and the scale reservoir, and the second term is the scale constraint of the reservoir. The regularization parameter controls the trade-off between the fidelity term and the regularization term

3. Precise interpretation process of water flooded degree and oil-water properties of reservoir based on logging interpretation

Surfactant: non-ionic surfactant (DCY) and cationic surfactant (YANG) provided by oilfield flooding Research Institute and anion/non-ionic surfactant produced by Heilongjiang Chemical Co., Ltd. (animal and vegetable oil are used as basic chemical raw materials, Tego type surfactant, which is synthesized by hydrolysis hydrogenation and amination reaction with polyvinyl polyamine, is referred to as “HLX” with an effective content of 50% and petroleum sulfonate (SYH) produced by refining company with an effective content of 40%. The effective content of Na2CO3 is 99.8%. The experimental oil is from Fuyu reservoir production well, and the viscosity of dehydrated and degassed crude oil is 4.2mPa·s (temperature 80 ℃). The experimental water is injection water from the mine and simulated formation water from Fuyu reservoir. The water quality analysis is shown in Table 1, in which displacement water is simulated formation water and distribution water is injection water.

| Water sample | Formation water | cation/(mg·L⁻¹) | anion/(mg·L⁻¹) | Salinity/(mg·L⁻¹) |
|--------------|-----------------|-----------------|----------------|-----------------|
| Injected water | 1763.8 | 42.1 | 20.1 | 2767.2 | 1008.6 | 0 | 198.1 | 5523.9 |
| water sample | 231.9 | 12.0 | 4.9 | 1064.2 | 57.6 | 15.3 | 389.0 | 817.1 |

The experimental core is quartz sand epoxy resin cemented artificial core [6,7], in which the relative wetting index is 0.15, the wettablity is weak hydrophilic, which is similar to the wettablity of the target reservoir rock. The core size is \(\phi 2.5\times10\) cm, and the permeability is about \(K_2 = 2.0\times10^{-3}\)µm2.

TX-500C spin drop interface tension meter (biaowi Industry Co., Ltd.); OCA20 video optical
contact angle meter (Data-physics company, Germany).

At oil-water temperature (80 °C), tx-500c rotating drop interfacial tension meter was used to measure the interfacial tension between the imbibition liquid and the crude oil, and the rotating speed was 5000 R/min. The contact angle of imbibition liquid on the core surface was measured by the oca20 video optical contact angle meter.

The volume method was selected to conduct the imbibition flooding experiment. The optimization measures were taken to improve the measurement accuracy of imbibition flooding volume as follows: ① Before the experiment, the imbibition bottle was immersed in the mixture of concentrated sulfuric acid and hydrogen peroxide (the volume ratio of concentrated sulfuric acid to hydrogen peroxide (40%) was 7:3. Hence, the inner wall of the glass had strong hydrophilicity, and the adhesion of oil droplets in the process of imbibition experiment was eliminated or reduced; ② Before the oil volume was recorded, the imbibition bottle was shaken gently to make the oil drop fall off from the core surface and the inner wall of the imbibition bottle. The specific experimental steps were as follows: ① The core was dried and weighted. The saturated formation water was vacuumized, the wet weight was obtained, and the pore volume was calculated; ② The core was put into the core holder to perform oil displacement at oil-water temperature (80 °C) until no water was observed, and the oil saturation was calculated; ③ The core was placed in a grinding bottle filled with experimental oil and allowed to stand for 24 h; ④ Prepare imbibition solution (0.1% 0.5% surfactant DCY or HLX\ SYH\ YANG solution) and vacuum for 23 h; ⑤ Take out the core from the grinding bottle, remove the oil film on the surface of the core with oil absorption paper, and then put it into the imbibition bottle for imbibition water flooding experiment, record the imbibition water flooding amount at different times, and calculate the imbibition recovery rate and imbibition rate (change of imbibition recovery rate in unit time). Unless otherwise specified, the experimental temperature was 80 °C

4. Experimental results and analysis
Table 2 shows the interfacial tension between DCY solution with different concentrations and crude oil, the contact angle on the core surface and the result of oil recovery interpretation for bedrock logging. Figure 1 shows the relationship between the oil recovery rate and the treatment time. Table 2 and Figure 1 suggest that surfactant solution can greatly improve oil recovery compared with injected water. With the increasing surfactant concentration, the recovery and imbibition rates increased accordingly. On the one hand, the surfactant can enhance the hydrophilicity of core pore surface, reduce the thickness of oil film on the pore surface, increase capillary force, and expand the swept volume of imbibition fluid; on the other hand, it can effectively reduce the interfacial tension between oil-water, reduce the size of oil drop on the pore surface of core and enhance the deformation ability of oil drop, so that the oil drop can smoothly pass through the pore throat and improve the efficiency of imbibition and oil displacement. From the technical and economic point of view, 0.3% DCY solution has the best technical and economic effect. It is recommended to be used as the surfactant concentration of the subsequent imbibition experiment.

The results of 0.3% DCY solution at different temperatures are shown in Table 3. The relationship between imbibition recovery rate and imbibition speed and treatment time is shown in Figure 2. Figure 2 suggests that with the increase of temperature, the imbibition rate increases and the imbibition recovery rate increases. On the one hand, the increase of temperature reduces the viscosity and enhances the fluidity of crude oil; on the other hand, it reduces the interfacial tension between oil-water and improves the oil washing efficiency. The increase of temperature is beneficial to the interaction between crude oil and imbibition fluid in core pores, and then to the improvement of imbibition flooding effect.
Table 4 shows the interfacial tension between different concentration and different types of imbibition agent solution and crude oil, contact angle on the core surface and the result of oil recovery interpretation for bedrock logging, and see Fig. 1 for the relationship between imbibition recovery rate and imbibition speed and time. Under the same surfactant concentration, compared with “HLX” and “SYH+Na2CO3”, the “DCY” and “YANG” have better flooding effect and larger recovery increase. Although “HLX” and “SYH+Na2CO3” can significantly reduce the interfacial tension between oil-water, too low interfacial tension is not conducive to increase capillary force, and thus is not conducive to improve the effect of water flooding. In addition, the ability of “HLX” and “SYH+Na2CO3” imbibitions to change the rock pore wettability is weaker than that of “DCY” and “Yang”, which is not conducive to improving the imbibition effect. Therefore, among the four kinds of imbibitions, “DCY” and “YANG” have the best imbibition flooding effect and the largest increase in oil recovery. Considering that “YANG” is a cationic surfactant, and its adsorption capacity is large in the pores of reservoir rocks, the effect of water flooding will be reduced, so “DCY” is the best one.

5. Conclusions

Compared with aqueous solution, surfactant solutions can improve the effect of imbibition and flooding by changing the rock pore surface wettability and reducing the interfacial tension in the oil-water interface. On the one hand, the increased temperature can reduce the viscosity of crude oil and enhance the flow capacity. On the other hand, it can reduce the interfacial tension in the oil-water interface and increase the capillary force. Their joint action is conducive to improving the oil-water interaction in the core pores and finally lead to the increase in recovery and permeability.

References

[1] Wei Yangqing, Wei Feilong, He Haoyang, Liu Feng, & Jiang Jun. (2013). A new method for the mud logging identification of reservoir fluids: a case study from the xujiahe reservoirs in the western sichuan basin. Natural Gas Industry, 29(s 1–2), 251-254.
[2] Qi Baoquan, Ran Zhibing, Wang Xueqin, & Su Xiaoyong. (2010). Identification of limestone reservoirs and prediction of their fluid properties in the amu darya right bank block, turkmenistan. Natural Gas Industry, 30(5), 21-25.
[3] Scott A. Elias. (2014). Environmental interpretation of fossil insect assemblages from mis 5 at ziegler reservoir, snowmass village, colorado. Quaternary Research, 82(3), 592-603..
[4] Reza Falahat, Asghar Shams, & Colin MacBeth. (2013). Adaptive scaling for an enhanced dynamic interpretation of 4d seismic data. Geophysical Prospecting, 61(s1), 231-247.
[5] A. Yu. Lein, A. S. Savvichev, & M. V. Ivanov. (2011). Reservoir of dissolved methane in the water column of the seas of the russia arctic region. Doklady Earth Sciences, 441(1), 1576-1578.
[6] Jianwei Dong, Xinghui Xia, Minghu Wang, Yunjia Lai, & Jiaojiao Wen. (2015). Effect of water-sediment regulation of the xiaolangdi reservoir on the concentrations, bioavailability, and fluxes of pahs in the middle and lower reaches of the yellow river. Journal of Hydrology, 527, 101-112.