A New Method for Potential Evaluation of Compound Flooding of Tertiary Oil Recovery

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Abstract. Compound flooding and tertiary oil recovery is one of the leading methods to improve recovery efficiency in oil and gas development in China. Because there are certain requirements on the exploitation environment and technology in the process of petroleum exploitation, it is necessary to evaluate and analyze the reservoir potential in advance. Currently, our research team has integrated this method into the tertiary oil production potential evaluation software EORSYS3.0. In this paper, a new combined flooding potential prediction model is established to improve the accuracy of reservoir potential prediction results by changing the reservoir water cut of displacement front viscosity.

1. Introduction
The remaining amount of oil and gas resources in China decreases year by year, and the difficulty of crude oil extraction increases year by year[1]. New and efficient production methods are needed to gradually replace the original production methods[2,3]. China's oil fields have entered the stage of polymer flooding and other oil flooding, and the oil fields have significantly increased production[4].

After entering the stage of polymer flooding, inject new chemicals to increase reservoir so as to improve the effect of oil extraction, oil displacement effect to reduce residual oil saturation, oil field formed binary flooding alkali together table binary composite displacement technology such as asp flooding displacement in this paper[5], based on the theory of instantaneous distribution to establish a new composite flooding potential evaluation algorithm, to predict reservoir oil production and recovery degree.

2. Model Establishment
Due to the wide coverage and large workload of potential evaluation, potential prediction should ensure the accuracy and reliability of its potential evaluation results to a certain extent, grasp the main influencing factors and reflect its basic oil displacement mechanism, and the model should be simple and easy to realize.

2.1 Change of Residual Oil Saturation
In the iterative calculation process of combined flooding, the effect of early polymer flooding is the same as that of polymer flooding. When the concentration of flooding reaches the maximum concentration, the reservoir starts to inject chemical agents such as surfactant, and finally improves the overall recovery degree of the reservoir.

The analysis of a large number of examples shows that increasing the injection concentration of surfactant and alkali will lead to the reduction of residual oil saturation, and the degree of reduction is shown in table 1.
Table 1. Residual oil saturation remaining

| Surfactant | Alkali concentration (mg/L) | Residual oil saturation |
|------------|----------------------------|-------------------------|
| <=500      | <500                       | 100%                    |
|            | 5000-8000                  | 95%                     |
|            | >8000                      | 90%                     |
| 500-1000   | <500                       | 80%                     |
|            | 5000-8000                  | 75%                     |
|            | >8000                      | 70%                     |
| 1000-1500  | <500                       | 60%                     |
|            | 5000-8000                  | 55%                     |
|            | >8000                      | 50%                     |
| 1500-2000  | <500                       | 40%                     |
|            | 5000-8000                  | 35%                     |
|            | >8000                      | 30%                     |
| >2000      | <500                       | 20%                     |
|            | 5000-8000                  | 15%                     |
|            | >8000                      | 10%                     |

2.2 Correction of Phase Permeability Curve

In the process of combined flooding, with the decrease of residual oil saturation in the reservoir, the relative permeability of oil phase and water phase in the reservoir change, so that the permeability curve of the reservoir changes. The calculation formula of relative permeability of oil phase and water phase is shown in equation (1) and (2).

\[
K_{ro} = K_{row} \left( \frac{1 - Sw - Sor}{1 - Swi - Sor} \right)^x
\]

\[
K_{rw} = K_{row} \left( \frac{Sw - Swi}{1 - Swi - Sor} \right)^y
\]

where \(K_{ro}\) is the relative permeability of oil phase; \(K_{row}\) is the relative permeability of oil corresponding to irreducible water saturation; \(K_{rw}\) is the relative permeability of water phase; \(K_{row}\) is the relative permeability of water corresponding to residual oil saturation; \(Sw\) is water saturation; \(Swi\) is the irreducible water saturation; \(Sor\) is residual oil saturation; \(x, y\) is index.

According to the residual oil saturation and oil-water relative permeability value, the new phase permeability curve can be calculated, and its formula is as follows:

\[
\ln \frac{K_{ro}}{K_{rw}} = a + bS_w
\]

Through the fitting result of equation (3), the value of \(a\) and \(b\) at this time is calculated. The result can be substituted into equation (4) and equation (5) to calculate the size of \(m\) and \(n\) of oil-water phase permeability index at this time.

\[
m = -b
\]
According to \( m \) and \( n \) calculation results of oil-water phase permeability index in this period, the reduction of water content in this time step and the increase in oil recovery can be calculated iteratively.

3. Software Development and Effect Analysis
The research team developed the three-time oil potential evaluation software, named EORSYS3.0. This software has the main features of a friendly interface, flexible use, perfect function, fast batch operation, and so on. It can provide technical support and software tools for the comprehensive development of China’s third potential evaluation work. The main interface of the software is shown in Figure 1.

![Figure 1. Software for evaluating tertiary oil recovery potential](image)

This paper combines the evaluation method of ASP flooding with the software, integrates it into the technical potential evaluation part of the software through the program compilation, and directly inputs the relevant data into the software for calculation. The following is an example effect analysis.

Make the reservoir initial water saturation \( S_w = 0.25 \), bound water saturation \( S_{wi} = 0.25 \), residual oil saturation \( S_{or} = 0.35, 0.25, 0.15, 0.05 \), The relative permeability of oil and water under different speech saturation is calculated as shown in Figure 2.

![Figure 2. Variation of oil-water phase permeability curve under different residual oil saturation](image)
As can be seen from the figure 2, with the decrease of residual oil saturation (Sor). At the same water saturation, the relative permeability of oil phase increases and that of water phase decreases. At this time, with the decrease of residual oil saturation, the oil production of the reservoir is increased and the water cut of the reservoir is reduced. The variation rule of its moisture content is shown in figure 3.

![Figure 3. Variation law of water cut of reservoir under different residual oil saturation](image)

After the combined flooding enters the plateau stage, the oil field injects polymer and chemical agents at the same time to change the reservoir environment and affect the change of the overall oil production. With the change of time, the permeability index of reservoir oil and water becomes the focus of potential evaluation of composite flooding.

4. Conclusion

1. In the process of compound oil flooding, when the displacement polymer flooding concentration reaches the maximum concentration, with the injection of surfactant and other chemicals, the residual oil saturation of the reservoir gradually decreases, the overall phase permeability curve of the reservoir changes, the relative permeability of the oil phase increases, and the relative permeability of the water phase decreases.

2. According to the reduction of residual oil saturation after injection of surfactant and alkali, the new composite flooding potential evaluation model can change the parameters such as the reservoir water content of displacement front viscosity, and improve the accuracy of reservoir potential prediction results by using the instantaneous shunt theory.

5. Acknowledgement

This research was financially supported by 3 projects. First one is the National Science and Technology Major Project (No.2016ZX05010-005). Second one is CNPC science and technology project (NO.kt2018-11-06). The third one is also CNPC science and technology project (NO.2017E-04-06).

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