The Study on Relative Permeability Curves of ASP Flooding in Daqing Oilfield

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Abstract

In order to determine the relative permeability curves of ASP flooding in Daqing Oilfield accurately, laboratory experiments were carried out by using natural cores with different permeability in this paper. The relative permeability curves under the condition of different permeability were measured by unsteady state method. The results showed that with the increase of core permeability, the relative permeability of water phase increased, the residual oil saturation decreased, the distance between the first isotonic point and the third isotonic point increased, and the oil recovery also increased. The conclusions of this paper can be used to guide the development of Daqing Oilfield

Keywords

Relative Permeability Curve, ASP Flooding, Laboratory experiment, Daqing Oilfield.

1. Introduction

Daqing Oilfield is a typical onshore sandstone oilfield, and the water cut has reached 90%. At present, Daqing Oilfield has entered the high water cut stage. In order to tap more remaining oil, many chemical flooding technology has been applied in Daqing Oilfield, including polymer flooding, polymer/surfactant/alkali (ASP) flooding, etc. In order to conduct reservoir engineering calculation and numerical simulation of ASP flooding, the seepage law of ASP system in reservoir need to be studied, and the relative permeability curve under the condition of actual reservoir also need to be determined.

Recently, there are many studies on the relative permeability curve of chemical flooding at home and abroad. For instance, P.H. Yang et al. [1] presented a Bayesian methodology for estimating relative permeability curves. Jinxun Wang et al. [2] proposed an investigation of the effect of oil viscosity on relative permeability curves for heavy oil-water systems. K.P. Abeysinghe et al. [3] investigated the effect of reducing the interfacial tension between oil and water on the relative permeability curves at different wettability conditions. Guangqin Lu et al. [4] determinated the oil-water relative permeability curve of surfactant system. Min Wei et al. [5] determinated the relative permeability curve of surfactant system and polymer system by using the unsteady method, and they also compared the curve with that of water flooding. Kun Xie et al. [6] studied the influence of core permeability, scouring effect and crude oil viscosity on relative permeability and displacement efficiency for polymer flooding in heavy oil reservoir. However, most researchers studied the relative permeability curve of polymer flooding, rarely involved ASP flooding. Based on the existing research, this paper studied the relative permeability curves of ASP flooding by using natural cores with different permeability.

2. Experimental section

2.1 Materials and equipment

The experimental materials are as follows: Partially hydrolyzed polyacrylamide with molecular weight being 1500×10^4 and concentration being 1000mg/L; Reinjection sewage of Daqing Oilfield; Alkylbenzene sulfonate with mass concentration being 0.3%; Na_2CO_3 with mass concentration being 1.2%; Simulated oil with viscosity being 8.5mPa•s at 45℃, which is made from the filtered oil and kerosene; Natural cores with different permeability, which are 1000mD, 600mD, 200mD, respectively.

The experimental equipment is as follows: Synder Constant-flux pump with flow precision being 1%; C80 Pressure sensor with measurement error being 0.4%; SG-83-1 Constant-temperature cabinet; Rotary vane vacuum pump; FA1604S Balance with measurement accuracy being 0.1%; Oil-water separator with division value being 0.1mL.

2.2 Experimental method

In this paper, oil-water relative permeability curves were measured through unsteady state method. According to the petroleum and natural gas industry standard SY/T 5345-2007, we carried out a series of laboratory experiments.

Specific steps are as follows:

1) Filter the reinjection sewage with filter paper.

2) Weigh the natural cores, saturate the cores with formation water, then weigh the cores again to calculate pore volume.

3) Place the saturated cores in the constant-temperature cabinet and heat them for 12 hours at 45℃.

4) Place the cores in the core holder and measure the permeability with formation water, then saturate the cores with simulated oil and calculate the initial oil saturation.

5) Conduct water flooding experiments by using the filtered reinjection sewage, inject 0.8PV ASP solution when water cut reaches 98%, then inject the reinjection sewage until water cut reaches 98%. Record the experiment data, for example, differential pressure, water production, oil production and the viscosity of produced fluid, etc.

6) The relative permeability curves and the water cut curves of different schemes are determined according to the results of experiments.

3. Results and discussion

3.1 Comparison between the relative permeability curves of cores with different permeability

The relative permeability curves determined by cores with different permeability are shown in Fig.1 to Fig.3, respectively. Through comparison of relative permeability curves, it can be seen that with the increase of core permeability, water-phase relative permeability gradually increased at water flooding stage, the residual oil saturation decreased, and the distance between the first isotonic point and the third isotonic point increased.

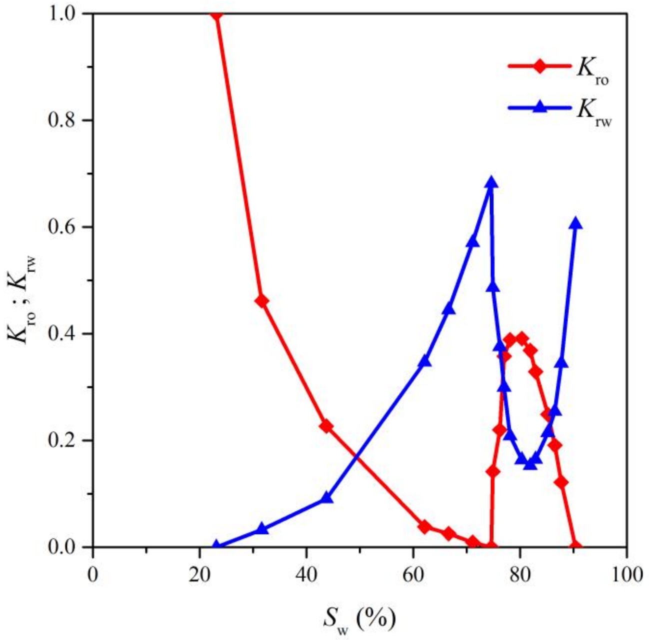

Fig.1 Relative permeability curve of high permeability core G-36

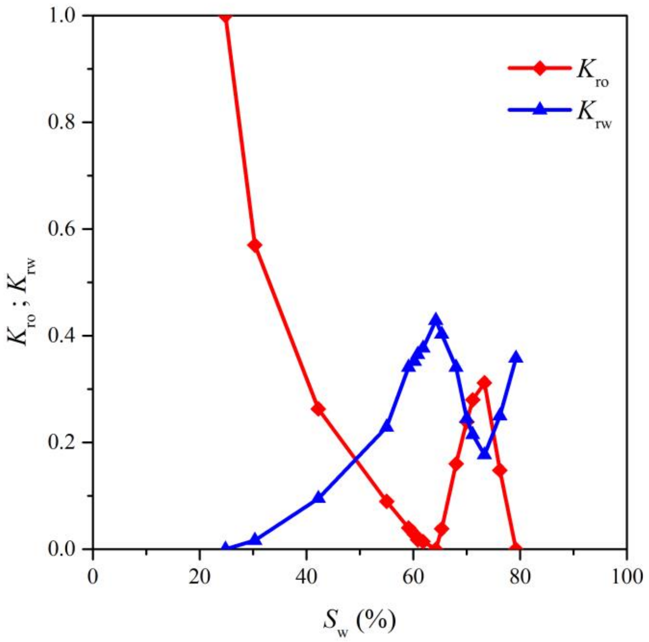

Fig.2 Relative permeability curve of medium permeability core Z-16

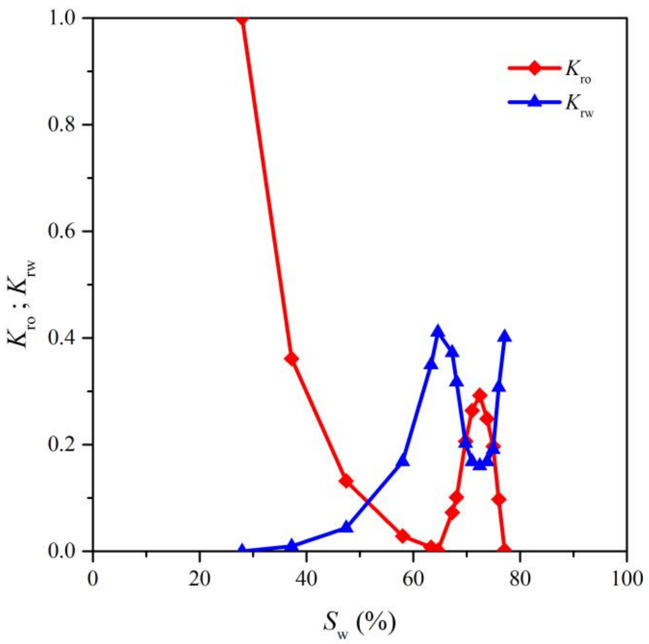

Fig.3 Relative permeability curve of low permeability core D-7

The related data data in the experimental process is shown in Table 1.

Table 1 Experimental data

Core Number	Permeability(mD)	Oil Recovery(%)	S_{wr}(%)	S_{or}(%)
G-36	1148	88.3	23.1	10.1
Z-16	594	75.2	25.3	20.6
D-7	189	68.1	28.1	23.2

According to the experimental results, it can be seen that water-phase relative permeability increased after decreased at ASP flooding stage, while oil-phase relative permeability changed in the opposite trend. Compared with water flooding stage, there were two isotonic points in the relative permeability curves. In addition, the higher the core permeability, the lower the residual oil saturation, and the greater the distance between the first isotonic point and the third isotonic point.

Polymer molecules in ASP system are adsorbed and stuck in pores and throats after being injected into the formation, which narrowed the flow channel and reduced the flow ability of water phase. Therefore, the water-phase relative permeability curve decreased first. However, the polymer molecules were viscoelastic, which can improve the micro displacement efficiency. With the continuous injection of ASP system, there was synergetic action between alkali and surfactant, which altered the rock wettability and reduced the interfacial tension between oil and water phase. Therefore, the adsorption of polymer molecules and surfactant molecules on the rock surface is reduced, which resulted in an increase of the water- phase relative permeability curve. The higher the core permeability, the higher the micro displacement efficiency, the lower the residual oil saturation, and the higher the oil recovery.

3.2 Comparison between the water cut and the recovery of cores with different permeability

The water cut and the recovery determined by cores with different permeability is shown in Fig.4.

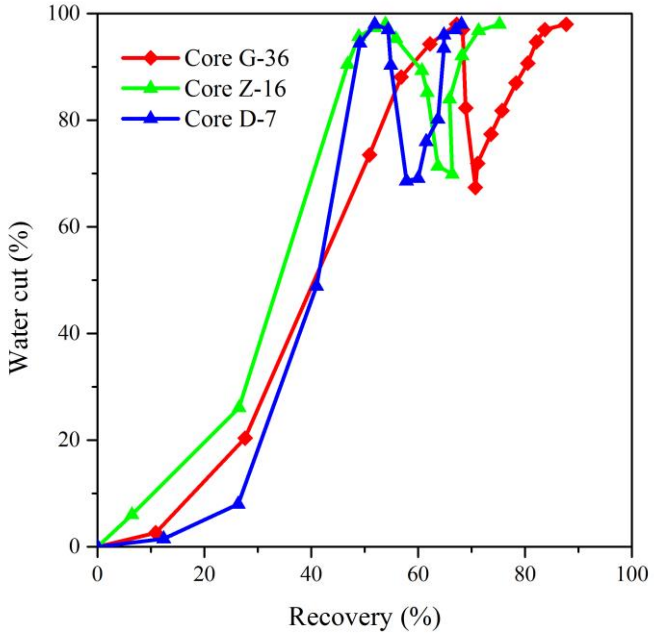

Fig.4 Water cut and recovery of different cores

As shown in Fig.4, with the increase of core permeability, the increasing trend of water cut became slower and the recovery increased gradually. Polymer improved the mobility ratio of displacement agent and the macro sweep efficiency at ASP flooding stage. Surfactant reduced the interfacial tension between oil and displacement agent, altered the rock wettability, and improved the sweep efficiency of displacement agent. In addition, alkali reacted with petroleum acid to form surface-active substance, which can not only reduce the interfacial tension, but also emulsify the crude oil to improve displacement efficiency. As a consequence, water cut presented a downward trend. Then the dominant channel formed with the continuous injection of ASP system, and the subsequent injected water flowed along the dominant channel, which led to an increase of water cut.

4. Conclusion

(1) At the water flooding stage, with the increase of core permeability, the relative permeability of water phase increased, the residual oil saturation decreased, and the distance between the first isotonic point and the third isotonic point increased.

(2) At the ASP flooding stage, the water-phase relative permeability increased after decreased, while oil-phase relative permeability changed in the opposite trend. In addition, there were two isotonic points in the relative permeability curves. The higher the core permeability, the greater the distance between the first isotonic point and the third isotonic point, and the higher the micro displacement efficiency.

(3) With the increase of core permeability, the increasing trend of water cut became slower and the recovery increased gradually.

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