Oil-water mutual driving microscopic simulation research on low permeability reservoir

Rongliang Cao *
No.7 Oil Production Plant of Daqing Oilfield Co. Ltd., PetroChina, Daqing, Heilongjiang, 163517, China.

*Corresponding author e-mail: caorongl8505@163.com

Abstract: Oil-water mutual driving microscopic characteristics of the low permeability reservoirs are analyzed for the example of the H area in Qaidam Basin. The reservoir lithology and pore characteristics are studied by thin section observation, scanning electron microscopy (sem), physical property analysis and mercury injection experiment, etc. Then oil-water mutual driving microscopic simulation is studied by the experiment system device. It indicate that it is poor reservoir property, strong heterogeneity, rock types are mainly lithic arkose and arkose, reservoir space is mainly primary intergranular pore, pore throat characteristics are wide distribution, poor sorted, there are many distribution types and dispersed. Flow of crude oil in the reservoir rocks is non-darcy seepage, start-up pressure gradient is reduced along with the increase of permeability, but the correlation is poor, increase pressure gradient can make the single phase oil seepage achieve linear flow. It is the non-uniform displacement process, the microscopic heterogeneity is strong and the original oil saturation is low; Water flooding breakthrough rapidly along one or two channels, water-free oil production period is short, the efficiency is low, it can increase the water displacement efficiency by increase the pressure, but the effect is not obvious. The residual oil are flow around oil, oil film and the residual oil at the edge of the corner, the formation mechanism is different.

Keywords: oil-water mutual driving; microcosmic experiment; residual oil; heterogeneity.

1. Introduction
Using core displacement experiment to study displacement efficiency and percolation characteristics is a routine method of low permeability reservoir development test. Starting from reservoir characteristics, this paper carries out micro-experiment simulation of oil-water mutual displacement, clarifies the percolation characteristics of single-phase fluid and oil-water mutual displacement characteristics of reservoir, explores the distribution law of residual oil, and provides scientific basis for remaining oil excavation in later stage of reservoir development and improves oil field development efficiency.
2. Micro-experiment of oil-water mutual displacement

2.1. Experimental analysis of single-phase fluid seepage

2.1.1. Percolation characteristics of single-phase oil in reservoir rocks. The relationship curve between seepage velocity and pressure gradient is not a straight line through the origin according to Darcy's law. When the abscissa is the pressure gradient, it is a slightly concave curve (Fig. 1).

![Single phase oil seepage curve of C # core](image)

By calculating the permeability of oil phase at each point on the relationship curve between seepage velocity and pressure gradient, the ratio of oil phase permeability to maximum oil phase permeability increases until it approaches 1, and the fitting has a good correlation with pressure gradient.

2.1.2. Analysis of Single-phase Oil/Water Flow Capability of Reservoir. The maximum and minimum permeability values of single phase oil are 16% and 0.29% of gas permeability respectively. Among them, sample A has the strongest single-phase oil flow ability, and the ratio of maximum oil permeability to gas permeability of other samples is less than 1%. In addition, the maximum atmospheric permeability is only 106 times of the minimum, but the maximum oil phase permeability is 2844 times of the minimum. Therefore, gas permeability can not reflect the oil-phase percolation ability. Permeability affects the oil-phase flow ability. The greater the heterogeneity of the flow, the greater the difference.

2.2. Experimental Analysis of Oil-Water Inter-Flooding

2.2.1. Analysis of oil displacement process. When the pressure is very low, the crude oil will advance rapidly along the main pore throat, and the front of the oil drive will advance along the dominant channel in the form of non-uniform inrush. With the continuous displacement, the crude oil will enter into small channels, thus reaching the original oil-bearing state of the bound water. Statistics show that the ultimate original oil saturation is 27.5%-30.8%, with an average of 26.9%. The comparison shows that the original oil saturation of the reservoir in this area is low, which is closely related to the strong heterogeneity of the reservoir in this area.
2.2.2. Analysis of water flooding process. The injected water rapidly advances along the dominant channel. Only when the front of water drive breaks through, the injected water enters the rest of the area, which makes the reservoir in the study area have a shorter period of waterless oil recovery. Statistical results show that the final water displacement efficiency of the experimental model is between 16.8% and 29.2%, with an average of 22.9%, and the residual oil saturation is between 18.1% and 26.3%, with an average of 21.2%. It is considered that the water displacement efficiency of reservoirs in the study area is low, and the water displacement efficiency can be improved by increasing injection pressure.

2.2.3. Distribution characteristics of residual oil. (1) Residual oil formed by bypass flow. The residual oil after water flooding is mainly a micro-dead oil zone formed by micro-fingering and bypassing, which accounts for more than 80% of the residual oil. Its formation mechanism is that the micro-pore structure has strong heterogeneity, the pore with better connectivity and larger scale is flooded quickly, and the oil displacement efficiency is higher. On the contrary, the remaining small pore will selectively bypass during water flooding, thus forming a network and patchy. Residual oil.

(2). Residual oil of oil film. In the process of water flooding, the oil displacement efficiency of large channels is the highest, most of the crude oil is expelled quickly, but at the same time, because the hydraulic pressure of water flooding in large channels is small and the scouring ability is weak, the crude oil that was not expelled smoothly in the early stage is attached to the wall of channels, forming oil film-like residual oil. In addition, even when small holes roar, oil film will be formed. However, when the range is limited and the pressure reaches a certain value, the change of water displacement efficiency is weak (Table 1).

Table 1. The relationship between water flooding pressure and oil displacement efficiency

| Model number | Initial oil saturation /% | Oil displacement efficiency /% at different injection pressures (MPa) | Increase of final displacement efficiency /% |
|--------------|---------------------------|------------------------------------------------------|---------------------------------------------|
|              |                           | 0.004 | 0.006 | 0.008 | 0.010 |                              |                              |
| 1#           | 22.23                     | 6.21  | 12.62 | 15.53 | 17.57 | 11.67                          |                              |
| 2#           | 27.05                     | 8.59  | 14.81 | 20.46 | 24.36 | 16.36                          |                              |
| 3#           | 30.62                     | 5.75  | 9.26  | 12.16 | 14.91 | 9.73                           |                              |
| 4#           | 27.25                     | 9.68  | 16.71 | 20.22 | 22.98 | 13.12                          |                              |

(3). Residual oil in edge corner. This kind of residual oil mainly refers to the residual oil in blind or irregular channels, which is not easy to be washed into the area. The reason is that it is difficult to drive or there is no space to drive in the process of water flooding. This kind of residual oil is mainly distributed in low porosity and permeability reservoirs.

3. Conclusion

(1). Reservoir rock types in the study area are mainly lithic feldspar sandstone and feldspar sandstone, and primary intergranular pore is the main reservoir space.

(2). The relationship between oil-phase seepage velocity and pressure gradient is characterized by non-Darcy seepage. The starting pressure gradient decreases with the increase of permeability, but the correlation is poor. Permeability affects the oil-phase flow ability of reservoir, but gas permeability can not reflect the oil-phase seepage ability of reservoir.

(3). The process of oil displacement and water displacement are both non-uniform displacement. They advance rapidly along one or two dominant channels of macropore throat before roaring to the other channels.

References

[1] Bulova M, Nosova K, Willberg D. Benefits of the novel fiber-laden low-viscosity fluid system in
fracturing low-permeability tight gas formations [C]. SPE 102956, 2006: 1-8.

[2] Ren Xiaojuan, Wu Pingchang, Qu Zhihao, et al. Studying the scaling mechanism of low-permeability reservoirs using visual real-sand micromodel [C]. SPE 100452, 2006: 1-7.

[3] Block S, Lander and permeability R H, Bonnell I. Anomalously high porosity and permeability in deeply buried sandstone reservoirs: Origin and predictability [J]. AAPG Bulletin, 2002, 86 (2): 301-328.