Study on the Relationship Between Pore Structure and Residual Oil in Low Permeability Reservoir

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Keywords: Pore Radius, Laryngeal Radius, Pore Throat Ratio, Plane Coordination Number, Plane Circuitous Degree, Shape Factor.

Abstract. At present, there is little research on the fundamental factor of pore structure affecting the recovery rate of low permeability oil layer at home and abroad, most of the research stays on the macroscopic seepage law and oilfield development scheme, seldom analyzes the intrinsic relationship between pore structure and fluid distribution from the microscopic point, studies the root cause of the influence of fluid distribution and residual oil formation, In order to find an effective method to improve the recovery rate of low permeability oil layer. Because of the different characteristics of pore structure, the seepage characteristics vary, from one class to five categories, the saturation of bound water increases, the permeability of oil phase changes rapidly, the coexistence area of oil and water decreases, the permeability of aqueous phase decreases, and the change of water content increases rapidly. The reservoir with good pore structure is more uniform, and the utilization degree of reservoir with poor pore structure becomes worse. This paper is a study on the relationship between pore structure and residual oil in low permeability reservoirs.

Introduction

In the early stage of oilfield development, the water in the oil layer exists in the form of bound water. Because of the low saturation of water, it is in a non-flowing state. In the later stage of oilfield development, especially after the special high water-cut period, the residual oil distribution in the oil layer is very complicated due to the influence of interfacial tension, wettability, heterogeneity, capillary force, oil flow ratio and pore structure.

With regard to the relationship between pore structure and oil displacement efficiency, many scholars have carried out research. Wang Yufu of Jianghan Petroleum Institute based on the data of capillary pressure curve of rock and the determination of pore structure eigenvalue of rock by moment method, the method of characteristic value function of pore structure is put forward, and the influence of pore structure characteristic parameters and pore structure composite characteristic parameters on the efficiency of water flooding oil is studied. In this paper, according to the microscopic anatomical experiment of core, the two modes of metallographic and fluorescence on the natural section of core were taken, and the pore radius, laryngeal radius, pore throat ratio, plane coordination number, plane circuitous degree and shape factor of each core were measured.

By studying the residual oil saturation corresponding to each pore, the relationship between pore radius, laryngeal radius, pore throat ratio, coordination number and circuitous degree and residual oil saturation is analyzed. The residual oil saturation in each pore is obtained by area method, and the pores with oil saturation greater than 15% in the core of rock are regarded as the pores with residual oil. The percentage of pore numbers containing residual oil in each rock's heart is called the pore ratio of residual oil.

Relationship between Pore Radius and Residual Oil

First, each pore radius and its corresponding residual oil saturation are classified according to the core number. For the data of pore radius and residual oil saturation of a certain core, according to the size of pore radius divided into several intervals, the number of pores in each interval and the number of pores with residual oil saturation greater than 15% are counted, and the relationship curve between pore radius and pore ratio of residual oil is plotted.
Figure 1 is the relationship curve between the pore radius of low permeability core and the pore ratio of residual oil, and it can be seen from figure 1-1 that the pore proportion of residual oil in wet core decreases with the decrease of pore radius, while the pore ratio of residual oil in the heart of oil-wet core and neutral wetting rock increases with the decrease of pore radius. In the heart of water-wet rock, capillary force is the driving force of oil displacement, the smaller the pore radius, the larger the capillary force, so the water first enters the pore with a smaller radius, then the crude oil in the small pores is easy to be driven out and not easy to form the remaining oil. For the oily wet core, the capillary force is the resistance of the oil displacement, the smaller the pore radius, the greater the resistance of the water flooding oil, the easy to form the remaining oil in the small pores.

Generally speaking, the capillary force is also the driving force of oil flooding in the large pores of the wet core, and the effect of oil displacement should also be better. However, due to the existence of microscopic heterogeneity, the oil in large pores is easy to remain. This reasoning can also be made in the heart of the oil-wet rock. It can be seen that the heterogeneity of the core microscopic makes the probability of the formation of the remaining oil greatly increased. Although the pore radius has a certain influence on the oil displacement effect, it is not the main reason for the low efficiency of low permeability core oil displacement because the pore radius distribution of each core is not very different.

![Figure 1](image1)

**Figure 1. Relationship between pore radius and ratio of contain remaining oil in low permeability cores.**

**Relationship between Pore Throat Ratio and Residual Oil**

Firstly, the residual oil saturation of each pore throat ratio and its corresponding pores is classified according to the core number. For the data of pore throat ratio and residual oil saturation of a certain core, according to the size of pore throat ratio, the number of pores in each interval and the number of pores with residual oil saturation greater than 15% are counted, and the relationship curve between pore throat ratio and pore ratio containing residual oil is plotted.

Figure 2 is the relationship between the inner hole laryngeal ratio of low permeability core and the pore ratio of residual oil. As can be seen from figure 2, whether it is water wet, oil wet or neutral wetting core, with the increase of pore throat ratio, the pore proportion of residual oil increases, that is, there is an increase in the probability of residual oil in the pores. For the pores with a certain pore radius, the increase of pore throat ratio means that the average laryngeal radius connected with it decreases, which indicates that the residual oil is more likely to be produced under the action of smaller larynx. As already known from the foregoing, the pore ratio is an important feature of the low permeability core, which is different from the medium and high permeability core, and the large pore throat accounts for a larger proportion than the orifice in the heart of the low permeability rock. Because the residual oil is easy to form in the pores of the macroporous laryngeal ratio, the large pore throat ratio is an important reason for the low efficiency of low permeability core flooding.
Relationship between Coordination Number and Residual Oil

Firstly, the residual oil saturation of each coordination number and its corresponding pores is classified according to the core number. For the coordination number and residual oil saturation data of a certain core, according to the size of the coordination number into several intervals, the number of pores in each interval and the number of pores with residual oil saturation greater than 15% are counted, and the relationship curve between the coordination number and the pore ratio of the remaining oil is plotted.

Figure 3 is a relationship curve between the number of core coordination of low permeability and the pore ratio of residual oil. As can be seen from figure 3, whether wet or wet core, with the reduction of the number of coordination, the proportion of pores containing residual oil increases, indicating that the number of low coordination is easy to form the remaining oil, and the increase in the number of coordination can make the probability of the formation of residual oil decline.

The number of coordination represents the degree of connection between the pore and other pores or larynx, and the larger the pore coordination number, indicates that the more pores connected to it, the greater the chance of crude oil being driven out.

The Relationship between Circuitous Degree and Residual Oil

First, each circuitous degree and its corresponding residual oil saturation are classified according to the core number. For the data of circuitous degree and residual oil saturation of a certain core, according to the size of circuitous, the number of pores in each interval and the number of pores with residual oil saturation greater than 15% are counted, and the relationship curve between the circuitous degree and the pore ratio of residual oil is plotted.

Figure 4 is a relationship curve between the core circuitous degree of low permeability and the pore ratio of residual oil. As can be seen from figure 4, whether it is wet core or oil wet core, with the increase of circuitous degree, the pore proportion of residual oil increases. This is because the larger the circuitous degree, the more complex the distribution shape of pores in space, easy to produce large seepage resistance, the formation of residual.
The Relationship between Shape Factor and Residual Oil

First, the shape factor of each pore and its corresponding residual oil saturation are classified according to the core number. For the shape factor and residual oil saturation data of a certain core, according to the size of the shape factor is divided into several intervals, the number of pores in each interval and the number of pores with residual oil saturation greater than 15% are counted, so as to draw the relationship curve between the shape factor and the pore ratio of the remaining oil.

Figure 5 is a relationship curve between the low permeability core shape factor and the pore ratio of the remaining oil. As can be seen from figure 5, for water-wet cores, with the reduction of shape factors, the proportion of pores containing residual oil increases. The smaller the shape factor, the more complex the pore shape, the larger the shape factor, the simpler the pore shape, which indicates that the complex pore shape is easy to form the remaining oil.

The smaller the shape factor in the heart of neutral wetting rock, the larger the pore proportion of the remaining oil. This is because, the smaller the shape factor, the more complex the shape of the pore cross section, the rougher the inner wall of the pore, the greater the resistance of fluid seepage, easy to form the remaining oil.

The small shape factor is the remarkable characteristic of low permeability core, at the same time, the wettability of low permeability core is mostly water wet and neutral wetting, even if the local speckle oily wetting, the proportion is not big. Therefore, the small shape factor is an important reason for the low oil displacement efficiency of low permeability oil layer.

Conclusion and Discussion

The core of different oilfields with the same permeability is very different from the microscopic parameters such as pore radius, pore throat ratio, coordination number, circuitous degree and shape factor. Permeability is only the embodiment of these microscopic parameter combinations on the fluid seepage capacity at the macroscopic level. The permeability is unique when the microscopic characteristics such as porosity, laryngeal tract, coordination number, circuitous degree, Shape
factor and mineral component of core are determined. It can be seen that permeability is the macroscopic reflection of microscopic parameter synthesis, and the microscopic parameters of pore throat are the determining conditions of permeability. Microscopic parameters are essential, and permeability is a phenomenon. With the same permeability of the core, the microscopic pore throat parameters may be very different, and the distribution characteristics of the fluid in it will also be very different.

It has been known from the results of core microscopic anatomy that the large pore throat ratio is the biggest characteristic of low permeability core difference and high permeability core. At the same time, we also know that the larger the pore throat ratio, the larger the porosity ratio of the remaining oil, the visible pore throat ratio has an important impact on the formation of the remaining oil.

References


