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# Application of the Brooks-Corey model in the conditions of lower cretaceous deposits in terrigenous reservoirs of Western Siberia

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**Abstract.** The paper deals with the issues of determining Brooks-Corey model parameters in the approximation of capillary curves under the conditions of productive strata of Western Siberia. It was emphasized that in the conditions of reservoirs of Western Siberia, there are close correlations between current water saturation of capillary curves at fixed values of capillary pressure and reservoir properties (absolute permeability, residual water saturation). Using these correlations, the approximation model parameters (initial capillary pressure and capillary curve steepness) were accurately assessed.

## 1. Introduction

Extraction capabilities of an object are characterized by the following parameters: porosity, permeability, and initial oil saturation [1–6].

When calculating reserves and designing the development of any field, it is necessary to determine the nature of relationship between individual parameters of the reservoir.

It turns out that the data on the capillary pressure values of the rock connect all these three main parameters. Therefore, the study of capillary characteristics as well as determination of reservoir properties of productive layers are a laboratory analysis.

According to the capillarity data of core samples of a specific field, the following main tasks are solved:

- quantitative assessment of the size distribution of pore channels and development of a mathematical model for determining absolute permeability of oil and gas reservoirs;
- plotting the relative permeability curve for oil and water. The curves of capillary pressure can determine the position of boundary points, as well as the steepness of the curves of relative permeability for oil and water. Assessment of the curve steepness is carried out using the size distribution function of pore channels of rock samples estimated based on the capillary data.

Therefore, the problem of developing a mathematical model for approximation of the entire set of capillary curves of the reservoir, is important and relevant.



## 2. Methods and materials

To substantiate the parameters, laboratory materials for capillary characterization of core samples obtained for the BV<sub>6</sub> formation of the Las-Eganskoye field were used.

Statistically processing of capillary data was used to obtain dependences of the approximation model parameters on reservoir properties.

## 3. Results and discussion

It is known that when approximating the capillary curves of the primary drainage, the Brooks-Corey model is often used [7–11]:

$$K_{cw} = K_{rw} + (1 - K_{rw}) \left( \frac{P_{ip}}{P_{cp}} \right)^\alpha, \quad (1)$$

where  $K_{cw}$  is current water saturation;  $K_{rw}$  is residual water saturation;  $P_{ip}$  is initial capillary pressure;  $P_{cp}$  is current capillary pressure;  $\alpha$  is steepness of the capillary curve.

Formula (1) with fixed  $\alpha$  describes the plateau-shaped portion of the capillary curve of the primary drainage (the right branch of the capillary curve).

Formula (1) can also be used to approximate the left branch of the capillary curve. However, parameter  $\alpha$  should be considered function  $\alpha$  depending on the capillary pressure.

Let us consider the issues of determining the parameters of the Brusk-Kori model on the example of the capillary curves of the BV<sub>6</sub> formation of the Las-Eganskoye field in Western Siberia.

The following experimental studies were carried out using core samples from the BV<sub>6</sub> reservoir of the Las-Eganskoye field: porosity, absolute permeability, residual and current water saturation of the samples at different capillary pressures were determined (0.028; 0.056; 0.105; 0.246; 0.352; 0.492 MPa).

Let us substantiate parameters  $\alpha$  and  $P_{ip}$  of the approximation model for the BV<sub>6</sub> formation.

Our studies showed that the plateau-shaped portion of capillary curves corresponds to the range of relatively low capillary pressures in the range from the initial value of  $P_{ip}$  to  $P_{cp} \approx 0.1$  MPa.

The position of the plateau-shaped portion of the capillary curve in the coordinate system  $P_{cp}$ - $K_{cw}$  is determined by parameters  $\alpha$  and  $P_{ip}$ , and by the reservoir properties of the rock: absolute permeability, residual water saturation.

It should be noted that outside the plateau area, behavior of the capillary curve is independent of the reservoir properties of the rock.

Let us rewrite formula (1) as

$$\frac{K_{cw} - K_{rw}}{1 - K_{rw}} = \left( \frac{P_{ip}}{P_{cp}} \right)^\alpha. \quad (2)$$

If we have two values of current water saturation for the corresponding values of capillary pressure within the plateau area, then using formula (2), we can estimate the values of parameters  $\alpha$  and  $P_{ip}$ .

Further, the values of current water saturations  $K_{cw1}$  and  $K_{cw2}$ , corresponding to capillary pressures  $P_{cp1} = 0.028$  MPa и  $P_{cp2} = 0.105$  MPa were used.

The formulas used to calculate the parameters of the capillary curve are as follows.

$$\alpha = \frac{\ln\left(\frac{K_{cw1} - K_{rw}}{K_{cw2} - K_{rw}}\right)}{\ln\left(\frac{P_{cp2}}{P_{cp1}}\right)}; \quad (3)$$

$$P_{ip} = P_{cp2} \left( \frac{K_{cw2} - K_{rw}}{1 - K_{rw}} \right)^{\frac{1}{\alpha}}. \quad (4)$$

Analysis of the capillary data from the BV<sub>6</sub> reservoir of the Las-Eganskoye field showed that the current water saturation values of the capillary curves for fixed capillary pressure values correlate with the logarithm of the absolute permeability coefficient in accordance with the following formula:

$$K_{cw} = \ln\left(\frac{m}{C_{perm}^n}\right), \quad (5)$$

where  $m$  and  $n$  are the coefficients depending only on capillary pressure;  $C_{perm}$  is the absolute permeability coefficient.

The expression for current water saturation at capillary pressure  $P_{cp} = 0.1$  MPa is as follows

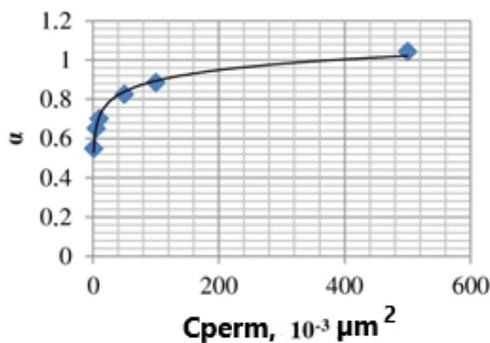
$$K_{cw} = \ln \left( \frac{1.15}{C_{perm}^{0,114}} \right) \tag{6}$$

The correlation coefficient is:  $R = 0.96$ .

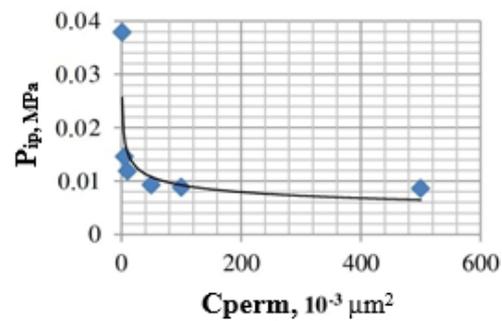
Thus, if we know the value of absolute permeability of the rock, it is possible to accurately estimate current water saturation for fixed values of capillary pressure.

By substituting the values of current water saturation for the values of capillary pressure in formulas (3) and (4), one can estimate the parameters of the Brooks-Corey model:  $\alpha$  and  $P_{ip}$ .

Figures 1 and 2 show the graphs of the dependences of  $\alpha$  and  $P_{ip}$  on the absolute permeability coefficient for the  $B_{V6}$  formation of the Las-Eganskoye field.



**Figure 1.** Dependence of parameter  $\alpha$  on the permeability coefficient

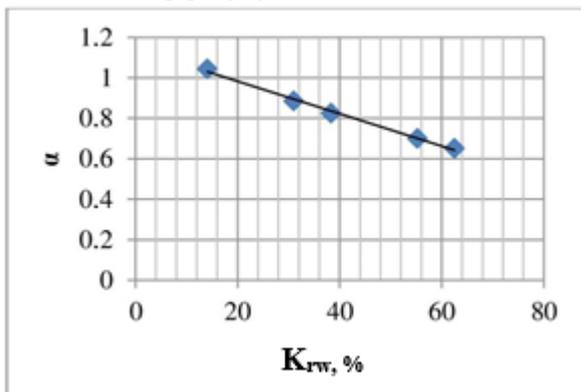


**Figure 2.** Dependence of parameter  $P_{ip}$  on the permeability coefficient

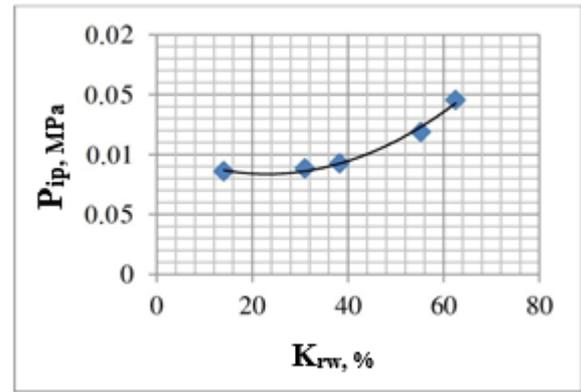
Therefore, to determine the parameters of the Brooks-Corey model, it is necessary to determine absolute permeability values [12, 13].

However, the calculation of absolute permeability of productive formations is a complex task. Therefore, to estimate the parameters of the capillary model, it is desirable to use residual water saturation rather than the permeability coefficient. Figures 3 and 4 show the dependences of the Brooks-Corey model parameters on the residual water saturation.

The value of residual water saturation (initial oil saturation) in extremely saturated reservoirs can be determined using geophysical data on the wells.



**Figure 3.** Dependence of parameter  $\alpha$  on residual water saturation



**Figure 4.** Dependence of parameter  $P_{ip}$  on residual water saturation

#### 4. Conclusion

The Brooks-Corey model describes a plateau-shaped section of the capillary curve whose position is completely determined by the reservoir properties (absolute permeability, residual water saturation). To justify the parameters of the Brooks-Corey model for a specific reservoir, it is recommended to use correlations between current water saturation and absolute permeability or residual water saturation at fixed capillary pressures.

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