

# Estimation of displacement coefficient with due account for hydrophobization of reservoir using geophysical data of wells

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**Annotation.** The coefficient of oil displacement by water from productive reservoirs is one of the main parameters reflecting the efficiency of oil field development by maintaining reservoir pressure. This parameter is necessary for both calculation of reserves and composition of technological scheme and project for oil field development. The displacement coefficient is important information for localization of residual reserves of developed oil fields and for estimation of oil production dynamics and effectiveness of methods for intensification of oil field development and oil recovery. In reservoirs of Western Siberia, during the displacement of oil by water from voids of productive reservoirs, residual oil has two components: capillary trapped oil and adsorbed oil on the surface of clay aggregates as separate droplets and films. The work demonstrates that the fraction of capillary trapped oil can be estimated using the value of effective reservoir porosity, since it characterizes the correlation of the size of pores and inter pore narrowings. The content of adsorbed hydrocarbons on the active surface of pores depends on the clayiness and activity of clay, and on wetting ability of oil as well. The clayiness of reservoir is proportional to its residual water content and tightly connected with initial oil content of the productive reservoir. The present work shows the possibility of taking into account the effect of hydrophobization of a reservoir on the residual oil content using the value of initial reservoir charge. Noteworthy, the effective porosity and initial reservoir charge with practically useful accuracy can be estimated using the data of conventional complex of geophysical surveys of wells.

## 1. Motivation

Currently, there are no reliable methods of quantitative estimation of the oil displacement coefficient with due consideration of hydrophobization of the surface in pay zone voids. In this connection, increased accuracy and precision of quantitative assessment of residual oil content is necessary. Moreover, a forecasting method of this parameter directly in a well under conditions of natural occurrence is required. This is only possible using the data of geophysical well logging that allows assessing this parameter in any layer intersection both across section and along the area of the oil field.



## 2. Materials and Methods

The forecasting method of oil displacement coefficient using well logging data was developed on the basis of laboratory studies of the coefficient of oil displacement by water, theoretical studies of the structure of voids, and methods of mathematical statistics as well.

The forecasting method development involved data of laboratory studies of the reservoir properties, residual oil content and oil displacement coefficient of the core sample from productive reservoirs Yu<sub>2</sub> – Yu<sub>6</sub> of Lovinskoye oil field in Western Siberia.

## 3. Results

The displacement coefficient is also important information for localization of residual reserves of developed oil fields and for estimation of oil production dynamics and effectiveness of methods for intensification of oil field development and oil recovery [1–6].

In reservoirs of Western Siberia, during the displacement of oil from voids by water, residual oil has two components: capillary trapped oil and adsorbed oil on the surface of clay aggregates as films and separate droplets [7–13].

To reveal quantitative connection between storage capacity and filtration properties of reservoir rocks, the investigators use different structural models of voids [14]. Among them, the most widely used is the model of parallel capillaries of constant cross-section. Even such simple model in many cases yields satisfactory results.

The correlations between storage capacity and filtration properties obtained using this model are quite adequate, but not in all cases. For instance, the dependence of residual oil content on the productive reservoir parameters cannot be adequately justified.

Every pore channel of a real rock is known to be represented by intermittent pores and interpore narrowings. The pores determine capacity properties, while interpore channels determine filtration properties of a reservoir. This unquestionable fact is by no means considered in existing capillary models.

Our suggested dumbbell model models the voids of a natural reservoir by a combination of chains of pores and interpore narrowings, located along the filtration lines [15].

Due to electrohydrodynamic similarity during quantitative estimation of correlations between filtration and storage capacity properties of reservoirs, the main role is played by electric methods of well surveying.

In this connection, the dumbbell model was quantitatively described by porosity parameter  $P_v$  which characterizes the structure of voids.

Let a rock to be penetrated by a system of capillaries of variable cross-section. Every capillary is represented by a chain of pores with average cross-section  $S_p$  and interpore narrowings with average cross-section  $S_{ip}$ . Then the relation of cross-sections of pores and interpore narrowings is determined as follows [15]:

$$\frac{S_p}{S_{ip}} = 1 + \frac{P_p \cdot K_p - 1}{p(1-p)}, \quad (1)$$

where  $K_p$  is porosity coefficient.

$P_p$  is porosity parameter, according to the Archie-Dakhnov equation  $P_p = K_p^{-m}$ ,

where  $m$  is porosity exponent; in most cases  $m = 2$ ;

$p$  is total fraction of interpore narrowings on a unit length of a pore channel;

$(1-p)$  is total fraction of pores on a unit length of a pore channel.

According to a number of researchers, the volume of capillary trapped residual oil is determined by a relation of pore dimensions to interpore squeezes [16].

Obviously, in oil-saturated rock, both residual and movable oil are present in the effective part of a void. Hence, in eq. (1) instead of open porosity, one should use effective porosity ( $K_{ep}$ ). Consequently, the correlation of pore size and interpore narrowings is proportional to the inverse value of the effective porosity coefficient ( $K_{ep}^{-1}$ ).

Since the residual oil content is also determined by the relation of pore dimensions and interpore narrowings, between this parameter and inverse effective porosity, there should be a correlational relationship.

The reservoirs of Western Siberia are known to increase hydrophobization with the growth of clayiness [16].

Evidently, with increased clayiness, the residual water content also rises and, correspondingly, the initial oil content drops.

In this connection, to take into account the effect of hydrophobization, one may use initial oil content of the productive reservoir [17].

On this basis, the oil displacement coefficient  $K_{disp}$  can be calculated using a linear combination of parameters bound with separate components of residual oil content.

$$K_{disp} = a_1 + B_1 K_{ep}^{-1} + c_1 \ln K_c, \quad (2)$$

where  $a_1$ ,  $B_1$  and  $c_1$  are fixed multipliers for a given productive reservoir.

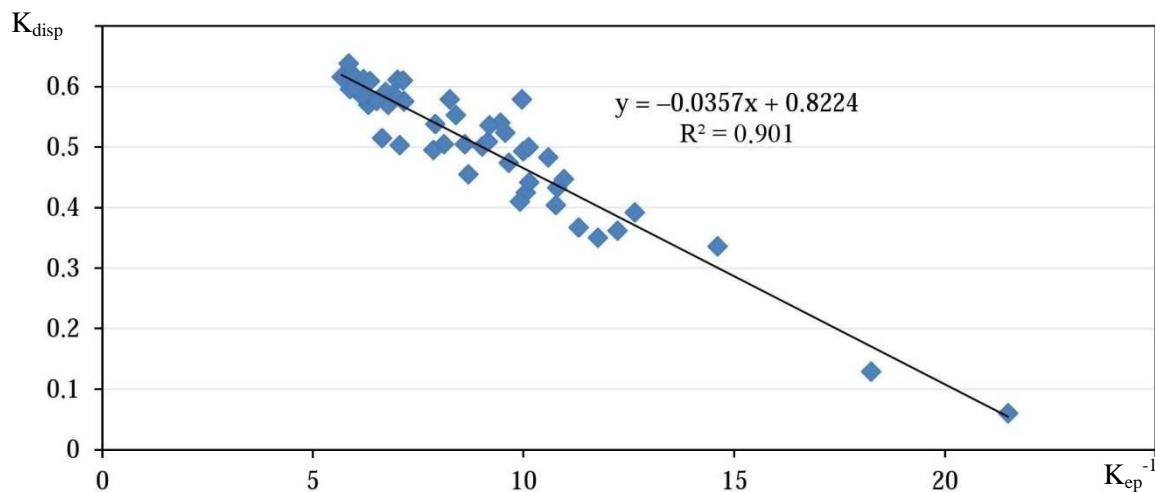
$K_c$  is initial oil content coefficient.

Fig. 1 depicts the plot of correlation of oil displacement coefficient with inverse effective porosity for reservoirs of productive formations Yu<sub>2</sub>–Yu<sub>6</sub> of Lovinskoye oil field in Western Siberia. The plot is based on experimental results on determination of reservoir properties, residual oil content coefficient and oil displacement coefficient by water for reservoir rocks of productive deposits.

According to Fig. 1, the indicated parameters are tightly correlatively bound. The regressional equation is:

$$K_{disp} = 0.8224 - 3.571 K_{ep}^{-1}, \quad (3)$$

correlation coefficient R equals 0.949. This equation allows considering only trapped residual oil.

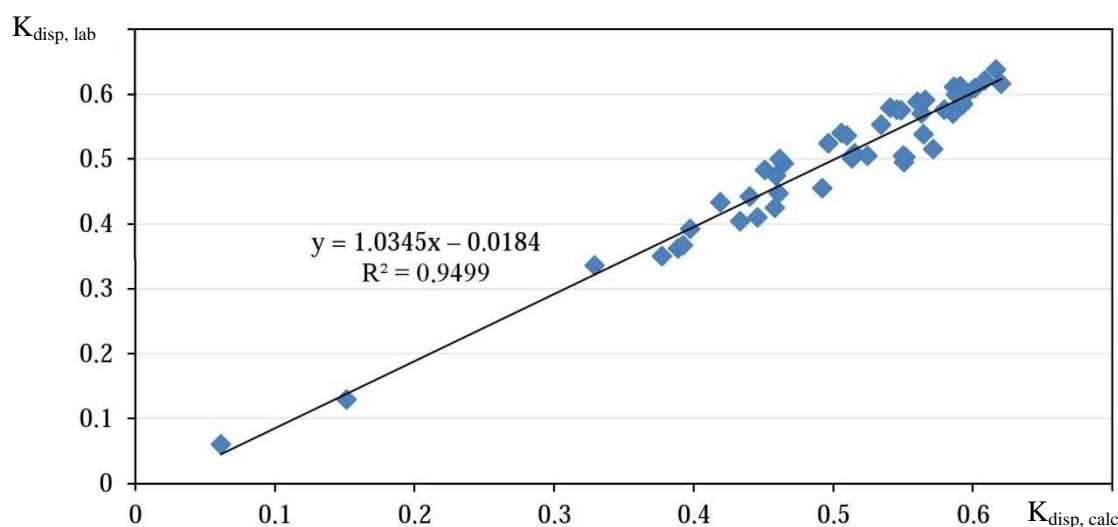


**Figure 1.** Comparison of the oil displacement coefficient with inverse porosity coefficient.

With due consideration of the void surface hydrophobization for Lovinskoye oil field in Western Siberia by statistical processing of laboratory data for core sample from pay zones Yu<sub>2</sub>–Yu<sub>6</sub> for oil displacement coefficient, we have received the following expression:

$$K_{disp} = 0.8135 + 0.0175 K_{ep}^{-1} + 0.311 \ln K_c. \quad (4)$$

Fig. 2 illustrates the plot of comparison of oil displacement coefficients obtained in laboratory conditions and those calculated using suggested equation for pay zones Yu<sub>2</sub>–Yu<sub>6</sub> of Lovinskoye oil field.



**Figure 2.** Comparison of laboratory-obtained and calculated coefficients.

According to the plot, the calculated and experimental values of the oil displacement coefficient are tightly bound; the correlation coefficient equals 0.975/ The mean square deviation of calculated and experimental values does not exceed 0.02 (absolute).

#### 4. Conclusions

1. The volume of capillary-trapped oil can be estimated by effective porosity of the reservoir.
2. The effect of reservoir hydrophobization on residual oil content should be taken into account using the value of initial oil of the reservoir.

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