1. **Determination of drainage and imbibition relative permeability of two phase porous system**

OBJECTIVES

1. To calculate and plot the distribution of relative permeability of wetting and non-wetting phases during drainage scenario.
2. To calculate and plot the distribution of relative permeability of non-wetting phases during imbibition scenario.
3. To plot trapped non-wetting phase saturation along flow reversal saturation.

BACKGROUND THEORY

Relative permeability is the ease by which individual fluids flow through a porous formation, when two or more immiscible fluids flow coherently. Relative permeability is the fundamental petrophysical that governs the distribution of fluids in the formation. The dynamics of fluid flow varies with the type of fluid whether it is wetting fluid or non-wetting fluid which is being displaced in the pore spaces. For instance, when the non-wetting fluid is displacing the wetting fluid, then the porous medium is said to be under drainage scenario. Whereas, when wetting fluid is displacing the non-wetting fluid, then the porous medium is said to be under imbibition scenario. However, the distribution of relative permeability along saturation of wetting fluid is irreversible.

The analytical representation of relative permeability is most widely used in numerical models. In this experiment, Brooks Corey based relative permeability model is being used for computing the drainage relative permeability of the formation.

Wetting phase relative permeability: $$k_{r,w}^{Dr} = S_e^{\frac{2+3\lambda}{\lambda}}$$ (Eq. 1)

Non-wetting phase relative permeability: $$k_{r,nw}^{Dr} = (1 - S_e)^2 * \left[1 - S_e^{\frac{2+\lambda}{\lambda}}\right]$$ (Eq. 2)

The superscript (*Dr)* in Eq. 1 & 2 represents the drainage scenario. S_e is the effective saturation, $\left[S_e = \frac{S_w - S_{wr}}{1 - S_{wr} - S_{nwr}}\right]$. The parameter λ is related to the pore size distribution, which is taken as 2 in the present study. S_{wr} and S_{wnr} are the irreducible wetting phase saturation and residual non-wetting phase saturation, respectively.

The imbibition relative permeability of the non-wetting fluid is computed using the model presented in Killough (SPE 5016-PA, 1976).

$$k_{r,nw}^{Im}(S_{nw}) = k_{r,nw}^{Dr}(S_{nwi}) * \left[\frac{S_{nw}-S_{nwt}}{S_{nwi}-S_{nwt}}\right]^{\beta} \quad \text{(Eq. 3)}$$

Where,

$k_{r,nw}^{Im}(S_{nw})$ represents the relative permeability of non-wetting phase at S_{nw} during imbibition

$k_{r,w}^{Dr}(S_{nwi})$ represents the relative permeability of wetting phase at S_{nwi} during drainage

S_{nwi} represents the maximum saturation of non-wetting phase attained during drainage process or the saturation of non-wetting phase at which imbibition scenario take place.

S_{nwt} represents the trapped non-wetting phase saturation during imbibition, which is calculated using Land's trapping coefficient (C).

$$S_{nwt} = \frac{S_{nwi}}{1 + C * S_{nwi}}$$

Land's trapping coefficient is the property of the porous media which quantifies the fraction of non-wetting phase being trapped in the porous media during imbibition process. Land's trapping coefficient for a core sample is obtained using core flooding experiments.

β represents the curvature exponent, generally taken as 1.5.

INPUT

Parameters	Inputs
Irreducible wetting phase saturation, S_{wr}	0.3
Residual non-wetting phase saturation, S_{nwr}	0.05
λ	2
Land's trapping coefficient, C	1
β	1.5

PROCEDURE

In the present exercise, the relative permeability curves are calculated and plotted in Microsoft Excel.

Calculation of drainage relative permeability:

1. Calculate effective saturation, S_e corresponding to individual water saturation (S_w).
2. Calculate drainage relative permeability of the wetting phase using the equation 1, corresponding to individual water saturation (S_w), so that $S_{wr} \leq S_w \leq (1 - S_{nwr})$.
3. Calculate drainage relative permeability of the non-wetting phase using the equation 2, corresponding to individual water saturation (S_w).
4. Plot drainage relative permeability curves (in Y axis) along water saturation (in X axis), as in Figure 1. Provide axis title and legend for the curves.

Calculation of imbibition relative permeability:

1. Calculate trapped non-wetting phase saturation, S_{nwt}.
2.

RESULTS

OBSERVATION