

Exercise 7 - Fractured reservoir calculations

Part 1

A fractured reservoir consists of a fracture-matrix system with matrix blocks surrounded by a network of fractures, as shown at right. Matrix permeability is measured in the laboratory to be

$$k_m = 1 \text{ mD},$$

and well test permeability is

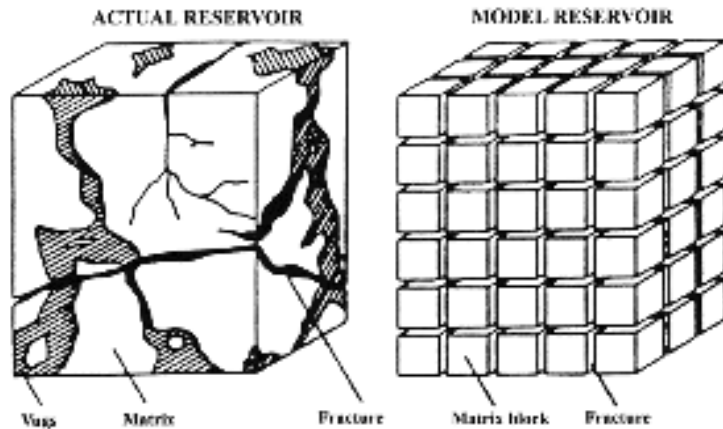
$$k_t = 100 \text{ mD}$$

The permeability of a channel (fracture) is given by the formula

$$k_f = 0.844 \cdot 10^7 w^2 \text{ mD}$$

where w is the fracture width in cm, determine following:

- If the side dimension of the cubical matrix blocks is 50 cm, compute the fracture opening (w).
- If the fracture opening is 0.01 cm, what is the matrix block dimension?



Part 2

The total thickness of a fractured reservoir is 100 m, the matrix block height is 1 m, and the initial oil saturation is 1.0. The reservoir is being gas flooded. The gas-oil drainage capillary pressure curve (rock curve) for the rock-fluid system is given by (in bar)

$$P_{cog} = P_{cd} - \ln \left(\frac{S_o - S_{or}}{1 - S_{or}} \right)$$

where

$$P_{cd} = 0.02$$

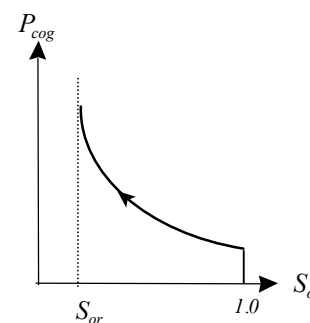
$$S_{or} = 0.2$$

The hydrostatic pressure difference between gas and oil in hydrostatic equilibrium is given by:

$$P_g - P_o = 0.05z$$

where z is the vertical distance (m) from the GOC. Initially, the GOC is at the top of the reservoir. Then, by gas injection, the GOC in the fractures is moved to the bottom of the reservoir and maintained at a constant level.

- Compute the theoretical oil recovery for no capillary contact between matrix blocks
- Compute the theoretical oil recovery for capillary contact between matrix blocks.



Part 3

The fractured reservoir above is being water flooded. The initial oil saturation is 0.8. Assume that the fluid-rock system is strongly water wet, and the water-oil imbibition capillary pressure curve (rock curve) for the system is given by

$$P_{cow} = -2 \cdot \ln \left(\frac{S_w - S_{wir}}{1 - S_{wir} - S_{or}} \right),$$

where

$$S_{wir} = 0.20$$

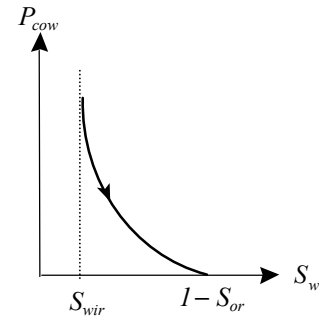
$$S_{or} = 0.20$$

The hydrostatic pressure difference (*bar*) between gas and oil in hydrostatic equilibrium is given by:

$$P_o - P_w = 0.02z,$$

where z is the vertical distance (m) from the water-oil contact (WOC). Initially, the WOC is at the bottom of the reservoir. Then, by water injection, the WOC in the fractures is moved to the top of the reservoir and maintained at a constant level.

- Compute the theoretical oil recovery for no capillary contact between matrix blocks
- Compute the theoretical oil recovery for capillary contact between matrix blocks.



Part 4

Now we will assume that the fluid-rock system is mixed wet, and that the water-oil imbibition capillary pressure curve (rock curve) for the system is given by

$$P_{cow} = -2 \cdot \ln \left(\frac{S_w - S_{wir}}{1 - S_{wir} - S_{or}^s} \right) \quad (S_{wir} \leq S_w \leq 1 - S_{or}^s),$$

and

$$P_{cow} = 2 \cdot \ln \left(\frac{1 - S_w - S_{or}}{1 - S_{wir} - S_{or}^s} \right) \quad (1 - S_{or}^s < S_w \leq 1 - S_{or}),$$

where

$$S_{wir} = 0.20$$

$$S_{or} = 0.20$$

$$S_{or}^s = 0.50$$

Again, the hydrostatic pressure difference (in *bar*) between water and oil in hydrostatic equilibrium is given by:

$$P_o - P_w = 0.02z,$$

where z is the vertical distance (m) from the water-oil contact (WOC). Initially, the WOC is at the bottom of the reservoir. Then, by water injection, the WOC in the fractures is moved to the top of the reservoir and maintained at a constant level.

- Compute the theoretical oil recovery for no capillary contact between matrix blocks
- Compute the theoretical oil recovery for capillary contact between matrix blocks.
- What are the recovery factors due to forced imbibition only for the two cases

