Lecture Nine: Channels and Fractures Permeability

9.1. Channels and Fractures

The various aspects of absolute permeability looked at so far were confined to the matrix permeability. However, petroleum reservoir rocks such as sandstones and carbonates frequently contain solution channels and natural or artificial fractures. Therefore, the key to understanding the flow of fluids in petroleum reservoir rocks is to account for flow in all the three permeability elements: the matrix, channel, and fracture. Channels and Fractures can add significantly to flow capacity.

1- Channels

Wormholes forms in the formations from acid stimulation.

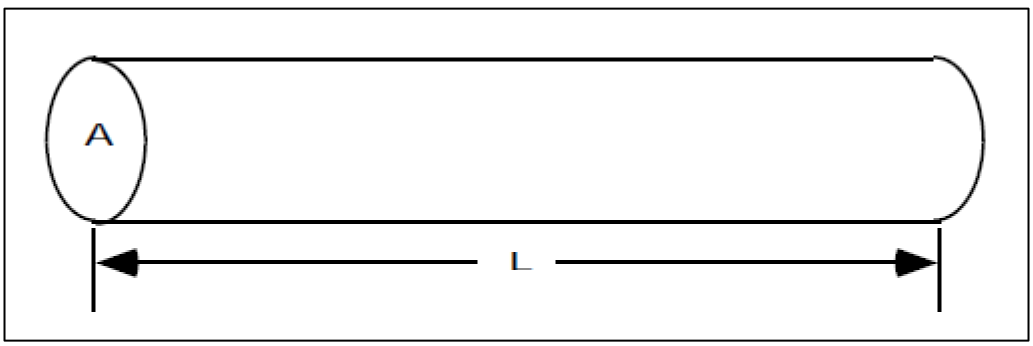

Fig. 9-1 flow through channels.

Poiseuille's Equation for viscous flow through capillary tubes is:

$$q = \frac{\pi r^4}{8\,\mu\,L}\,(p_1 - p_2) \qquad \text{....... (9-1)}$$

$A = \pi\, r^2$, therefore

$$q = \frac{A r^2}{8\,\mu\,L}\,(p_1 - p_2) \qquad \text{....... (9-2)}$$

Darcy's law for linear flow of liquids is:

$$q = \frac{K\,A}{\mu\,L}\,(p_1 - p_2) \qquad \text{....... (9-3)}$$

Equating Equation (9-2) with (9-3) and solving for the channel permeability gives:

$$k_c = \frac{d^2}{32} \qquad \text{[In any consistent system (SI)]} \qquad \text{....... (9-4)}$$

$$k_c = 2.0428\,x10^{10}\,d^2 \qquad \text{[k in md \&d in inches]} \qquad \text{....... (9-5)}$$

Example 1

A. Determine the permeability of a rock composed of closely packed capillaries 0.0001 inch in diameter.

B. If only 25 percent of the rock is pore channels (f = 0.25), what will the permeability be?

Solution:

A. $k = 20 \text{ x } 10^9 \, d^2$

$k = 20 \text{ x } 10^9 \, (0.0001 \text{ in})^2$

$k = 200$ md

B. $k = 0.25$ (200 md)

$k = 50$ md

2- Fractures

Fractures form in the formations from stimulation by hydraulic fracturing or naturally in naturally fractured reservoirs

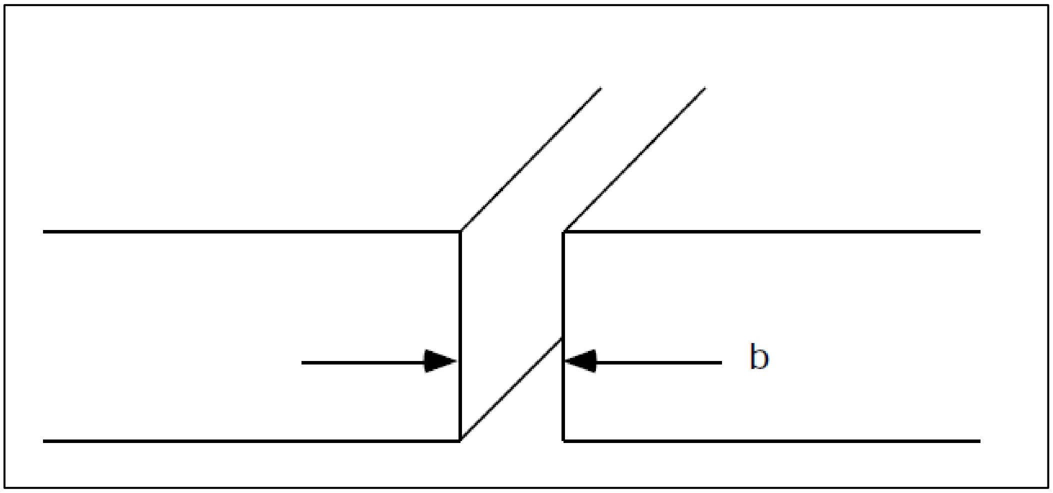

Fig. 9-2 flow through fracture.

Buckingham's Equation for flow in slots is:

$$q = \frac{A\, b^2\, \Delta P}{12\, \mu\, L} \quad \text{....... (9-6)}$$

$$A = b \times h$$

Setting this flow equation equal to Darcy's flow equation,

$$\frac{A\, b^2}{12\, \mu\, L}\, \Delta P = \frac{K\, A}{\mu\, L}\, \Delta P$$

Solve for permeability of a fracture:

$$K_f = \frac{b^2}{12} \qquad \text{[In Darcy units]} \qquad \text{....... (9-7)}$$

$$K_f = 5.4476 \times 10^{10}\, b^2 \qquad \text{[k in md \&b in inches]} \qquad \text{....... (9-8)}$$

where b= fracture width , h= fracture height

Example 2

Consider a rock of very low matrix permeability, 0.01 md, which contains on the average a fracture 0.005 inches wide and one foot in lateral extent per square foot of rock. Assuming the fracture is in the direction of flow, determine the average permeability using the equation for parallel flow.

Solution:

$$\bar{k} = \frac{\Sigma \; k_j A_j}{A} \text{, similar to horizontal, linear flow parallel to fracture}$$

$$\bar{k} = \frac{(\text{matrix k})(\text{matrix area}) + (\text{fracture k})(\text{fracture area})}{\text{total area}}$$

$$\bar{k} = \frac{(0.01)\left((12 \text{ in})^2 + (12 \text{ in})(0.005 \text{ in})\right)}{144 \text{ in}^2} +$$

$$\frac{(54 \text{ x } 10^9 \text{ x} (0.005)^2)(12 \text{ in x } (0.005 \text{ in}))}{144 \text{ in}^2}$$

$$\bar{k} = \frac{1.439 + 81{,}000}{144}$$

$$\bar{k} = 563 \text{ md}$$