## The Role of Capillary Forces on the Strength of Rock: The Fracture Mechanics Approach

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The influence of drilling fluids on the mechanical strength of shale is already a well known phenomenon in the oil industry. It is well realized that the strength of shales depends on relative saturation of wetting and non-wetting fluids (e.g. water & gas or water & oil). The strength of shales drastically decreases with increase in saturation of a wetting fluid phase [**1**] due to changes in capillary pressure. Also the experimental data suggest that the strength of rocks is lower for higher values of interfacial tension between wetting and non-wetting fluids [**2**]. The influence of fluid salinity on the strength of shales is also well-documented [**3**]. Depending on salt concentration, the amount of water content (and pressure) in shales can either decrease or increase due to osmotic diffusion and cause the increase or decrease in the strength of shale, respectively. Using the fracture mechanics approach [**4 & 5**] and a published analytical solution [**6**], I have calculated the change in stress intensity factor, for the elliptical crack shown on Figure 1.

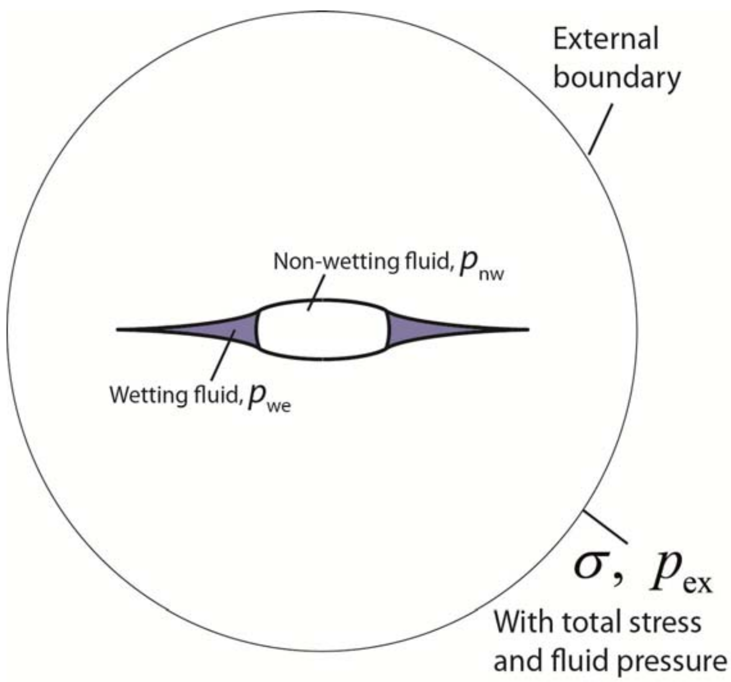


Figure 1. Partially saturated crack

Here the elliptical crack is partially saturated with two immiscible fluids, with the capillary pressure difference calculated as follows

$$p_c = p_{nw} - p_{we} = \frac{\gamma}{R}.$$

Here $\gamma$ is the surface tension between two fluids and $R$ is the curvature radius of the interface, $p_{nw}$ & $p_{we}$ are the fluid pressure in non-wetting and wetting fluids. Far-field total stress on the external boundary is denoted by $\sigma$ and $p_{ex}$ is the fluid pressure on the external boundary of the sample, with $p_{ex} \neq p_{we}$ due to the difference in salinity, i.e.

$$p_{ex} - p_{we} = -\alpha_m \frac{RT}{V} \ln \frac{a_{w,shale}}{a_{w,mud}}$$

with $\alpha_m$ = membrane efficiency, $R$ = universal gas constant, $T$ = temperature $V$ = molar volume of water, $a_{w,shale}$ = water activity of shale, $a_{w,mud}$ = water activity of mud.

Using results of a theoretical calculation I have predicted the strength of shale as function of saturation degree (for the whole range of saturations), fluid type and salinity. Results of the calculations are directly applicable for wellbore stability analysis and for hydraulic fracturing stimulation of tight gas shale reservoirs. The calculations demonstrate how the specific fluid can alter the strength of shale.

**References:**

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