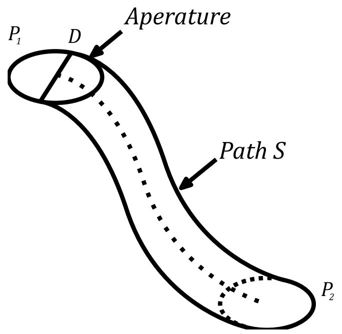
Why Does Puck Air-Locking Take Place

Finer grinds allow higher extraction, but if the grind size is too fine, the top layer can provide too much resistance to water, the **compressive back pressure force** will be too large, and the water channel aperture diameters, *D,* will also be too small. Let's examine this scenario in more detail. The bottom layer of a puck is full of narrow channels for the initially present CO_2 to squeeze through and create crema:



However, the force required to push and elongate an air pocket through the aperture passage is:

$$F_{required} = dW(s)/ds \quad \text{where,} \quad W(s) = \gamma_l \int_1^2 \pi D(s)\, ds$$

and where

$W(s)$ = work required to create a liquid surface,

γ_l = liquid surface tension,[1]

$D(s)$ = aperture's diameter and hence $\pi D(s)$ is just the circumference

ds = is an infinitesimal distance along the path.

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[1] Note: we do not need to consider, γ_s the solid surface free energy or γ_{sl} the solid-liquid interfacial free energy as we are considering a process after the initial wetting, i.e., the passage denoted by path *S*, is assumed to be prewetted. In fact we can probably safely assume $\gamma_s > \gamma_{sl}$, meaning it's energetically favourable for water to "wick" into the puck, although this would depend on the water content of the solid, as γ_s scales with increasing water content.

The **critical criteria** to allow a bubble front to elongate within the passage is:

$$\boldsymbol{A(s)\Delta P > dW(s)/ds} \quad \text{or} \quad \boldsymbol{F_{avaliable} > F_{required}}$$

(Note: for all sections along the path *S*)

where $A(s)$ is the cross-sectional area of the aperture, $\Delta P = P_1 - P_2$ the pressure differential across the passage.

But, here we see an issue; $F_{avaliable} \propto D^2$ while $F_{required} \propto D$

As our grind gets finer, the **compressive back pressure** gets larger and the apertures, D get smaller so that as $D \to 0$, $F_{avaliable}$ becomes smaller much faster then $F_{required}$, and at some point, we run into the problem that, for some, D_{min}, our required criteria will flip to $F_{avaliable} < F_{required}$.

Here, the force available to push CO_2 bubbles through the passage is smaller than that required!

Hence, we have an air-lock. If we have too many such air-locks across the ensemble of channels, we can have poor flow through sections of the puck and thin crema. This phenomenon limits us; else, we could grind finer and finer to get higher extraction. Further, we suspect the minimum aperture diameter, D_{min} could also be limited by the diameter required to pass colloidally suspended coffee particles that add to the body and flavour.