Motivations:

1. From a fundamental perspective:

Gain a better insight into the transition from the capillary fingering to the stable displacement regime in the case of GDL. Particularly relevant for high current density i.e. high flow rates.

2. From the application:

How to explain the change in preferential path for liquid invasion in GDL?

Methodology:

1st step: Modelization of a pore network typically encountered in GDL into a 2 interconnected capillary tube system.

\[ \begin{align*}
\text{Poisson flow} & : \quad p_i = \frac{8\mu L}{\pi R^2} V^2 + \frac{4\gamma \cos \theta}{R} + p_0 \\
\text{Laplace law} & : \quad p_i = p_0 \\
Q & = V_i + V_2
\end{align*} \]

Once non-dimensionalized, it becomes:

\[ h_i(h_i + 1) - rh_j(h_j + 1) = \frac{1}{C_i} \left( \frac{h_i}{h_i^2 + 1} - \frac{h_j}{h_j^2 + 1} \right) \]

Problem driven by 3 parameters:

- \( f = L/R_1 \), pore aspect ratio
- \( R = R_1/R_2 \), pore radii ratio
- \( C_i = \frac{U_i^2}{\gamma} \), capillary number

The capillary regime: low value of \( f \cdot C_a \)

The meniscus/drop growth in the bigger pore does act upon the meniscus in the neighboring pore.

The mixed viscous/capillary regime: high value of \( f \cdot C_a \)

As the viscous effects get more important, a change of preferential path appears.

2D map of the duty cycle

The transition map

- Drops emitted from the smaller tube
- Drops emitted from the larger tube

Experimental conditions:

- Machined channels in teflon block
- Upper side in PDMS (for visualization)
- Inlet water flow rate: 50 µl/min
- \( R = 1.07 \) (hydraulic diameter ratio)
- \( \text{Ca} = 1.6 \times 10^{-4} \)

At first, only the larger tube is invaded, as predicted by the Invasion-Percolation mechanism.

But.....

As the time flows, due to the eruptive nature of the droplets emissions at the tube outlet, the smaller tube gets invaded....

To the point where the whole network is invaded. This is not predicted by the Invasion-Percolation mechanism.

Conclusion: The dynamic breakthrough alters the invaded pore networks. The transition from the capillary to the stable displacement regime depends on \( \text{Ca} \), the network geometry and viscous effects.