# Numerical simulation of drop formation and dynamics in picoliter jetting technology

Gertjan van Zwieten[1]
Harald van Brummelen[1]
Herman Wijshoff[2]

[1] TU Eindhoven, Department of Mechanical Engineering, Section Multiscale Engineering Fluid Dynamics

[2] Océ Technologies NV

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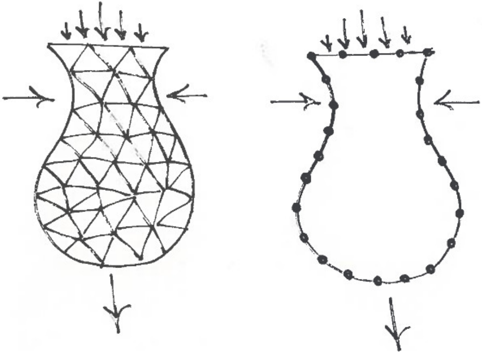
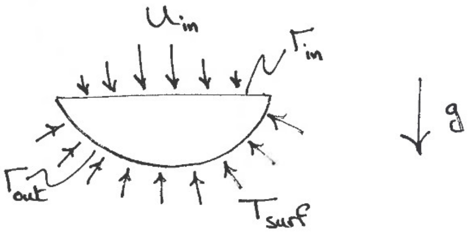
# Why choose the boundary element method



Rationale:

- Surface geometry is primary interest
- Focus on interaction interior, exterior flow and surface tension
- Simplicity; mainly meshing, remeshing

# Computational setting




$$\boxed{\begin{aligned} &\rho \frac{Du}{Dt} = \nabla \cdot \sigma(u, p) - g \\ &\nabla \cdot u = 0 \end{aligned}} \tag{1}$$

$$\text{Boundary conditions: } \begin{cases} u|_{\Gamma_{\mathrm{in}}} = U_{\mathrm{in}} \\ \sigma n|_{\Gamma_{\mathrm{out}}} = T_{\mathrm{surf}} = \gamma \kappa n \\ \dot{\Gamma}_{\mathrm{out}} = u|_{\Gamma_{\mathrm{out}}} \end{cases} \tag{2}$$

# Some aspects of the computation

- Flow regime
- Surface tension
- Remeshing
- Gravity
- Time stepping

# Flow regime

Problem: BEM limited to linear problems.

- Stokes flow: low Reynolds limit
- Potential flow: high Reynolds limit

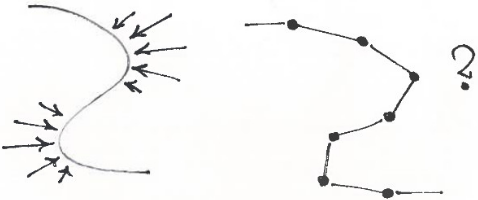
Stokes flow:

$$\boxed{\begin{aligned} \nabla \cdot \sigma(u, p) &= g \\ \nabla \cdot u &= 0 \end{aligned}} \quad (3)$$

# Surface tension

Young-Laplace equation:

$$t = \gamma \kappa n \tag{4}$$




Surface divergence theorem:

$$\int_{\Gamma_{\text{out}}} v \kappa n = \int_{\Gamma_{\text{out}}} \nabla_{\Gamma} \cdot v + \int_{\partial\Gamma} v \cdot \tau \tag{5}$$

# Remeshing

- Refinement

- Coarsening

# Gravity

Inhomogeneous differential equation:

$$\nabla \cdot \sigma(u, p) = g \tag{6}$$

Splitting:

$$\begin{aligned} u &= u_g + u_0 \\ p &= p_g + p_0 \end{aligned} \tag{7}$$

Particular solution:

$$\begin{aligned} u_g &= 0 \\ p_g &= gz \end{aligned} \Rightarrow \begin{cases} \nabla \cdot \sigma(u_0, p_0) = 0 \\ u_0|_{\Gamma_{\text{in}}} = U_{\text{in}} \\ \sigma(u_0, p_0) n|_{\Gamma_{\text{out}}} = \rho\kappa n + gz \end{cases} \tag{8}$$

# Time stepping

$$\dot{\Gamma}_{\mathrm{out}} = u \tag{9}$$

Explicit:

$$\Gamma_{\mathrm{out}}^{n+1} = \Gamma_{\mathrm{out}}^{n} + u\Delta t \tag{10}$$

# Results