

Numerical simulation of drop formation and dynamics in picoliter jetting technology

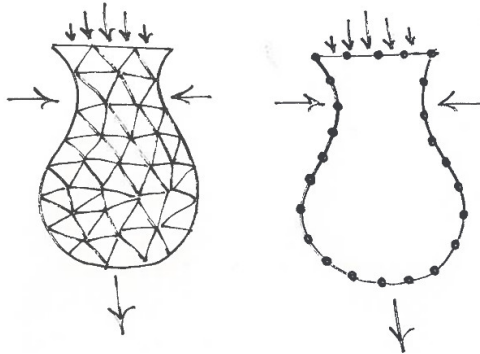
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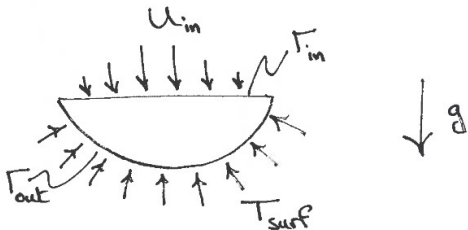
Why choose the boundary element method



Rationale:

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

Computational setting



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

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

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:

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

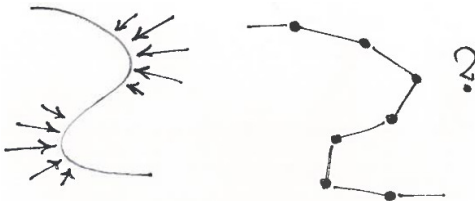


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Surface tension

Young-Laplace equation:

$$t = \gamma \kappa n \quad (4)$$



Surface divergence theorem:

$$\int_{\Gamma_{\text{out}}} \nu \kappa n = \int_{\Gamma_{\text{out}}} \nabla_{\Gamma} \cdot \nu + \int_{\partial \Gamma} \nu \cdot \tau \quad (5)$$

Remeshing

► Refinement



► Coarsening



Gravity

Inhomogeneous differential equation:

$$\nabla \cdot \sigma(u, p) = g \quad (6)$$

Splitting:

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

Particular solution:

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

Time stepping

$$\dot{\Gamma}_{\text{out}} = u \quad (9)$$

Explicit:

$$\Gamma_{\text{out}}^{n+1} = \Gamma_{\text{out}}^n + u\Delta t \quad (10)$$

Results