Critical Velocities in Open Capillary Channel Flows (CCF): Groove

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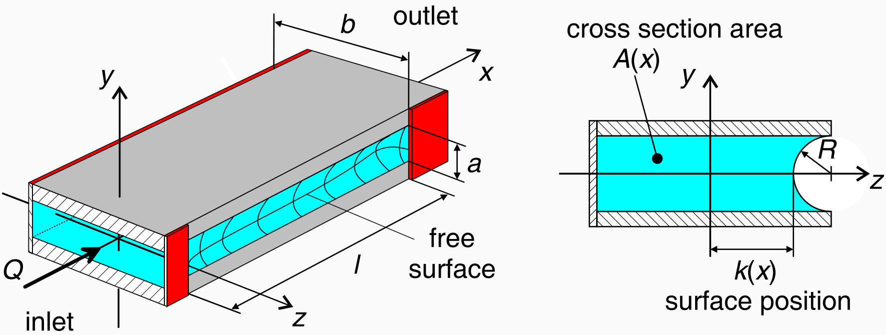


Bernoulli equation

- $dp + \rho v dv + dw_f = 0$

Conservation of mass

- $dA/A + dv/v = 0$

Scaling and Characteristic Numbers

- length with $d_h/4$, area with $A_0 = ab$ and velocity with $v_c = \sqrt{4\sigma/\rho d_h}$
- $\Lambda = b/a$; $d_h = \frac{4ab}{2b+a}$; $\mathrm{Oh} = \sqrt{\frac{\rho\nu^2}{\sigma d_h}}$ and $\tilde{l} = \frac{\mathrm{Oh}\, l}{2d_h}$

Non Dimensional Equations

- $2\frac{dh}{dx} + \frac{Q^2}{A^3}\frac{dA}{dk}\frac{dk}{dx} + \tilde{l}\frac{K_{pf}}{2}\frac{Q}{A} = 0$ (Bernoulli with frict. fact. K_{pf})
- $k_{xx} + \left(\frac{1}{R_1} - 2h\right)\left(1 + k_x^2\right)^{3/2} = 0$ (Curvature with $k_x = \frac{dk}{dx}$ ...)

Boundary Conditions

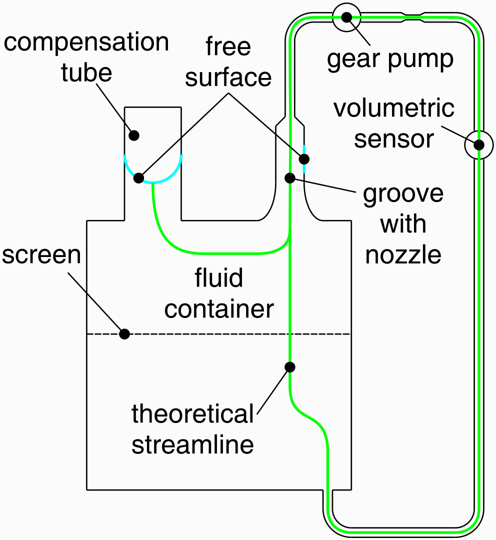
- $k(x=0) = k(x=l) = \frac{2\Lambda+1}{2}$; $2h(x=0) = 2h_0$

Seeking for Solution of

- $k(x) = f(\Lambda, \mathrm{Oh}, \tilde{l}, Q)$
- $Q_{krit} = g(\Lambda, \mathrm{Oh}, \tilde{l})$

Motivation

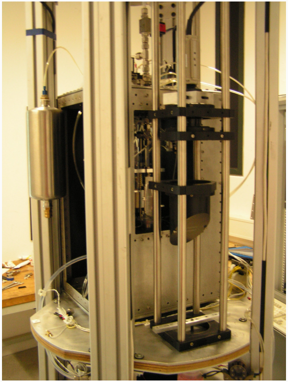
- Capillary vanes and grooves in surface tension tanks
- Withdrawal of propellants directly through the capillary channels
- Gas ingestion should be avoided

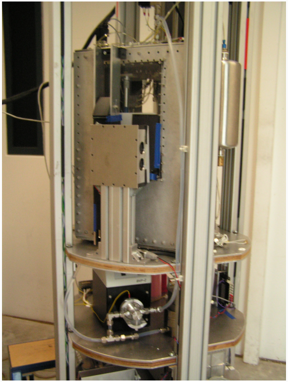


Fluid Loop

- from compensation tube
- through nozzle to the groove
- through the pump
- back in the fluid container
- through the screen

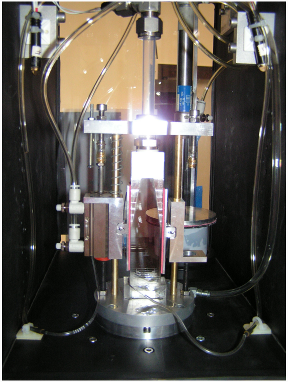
...

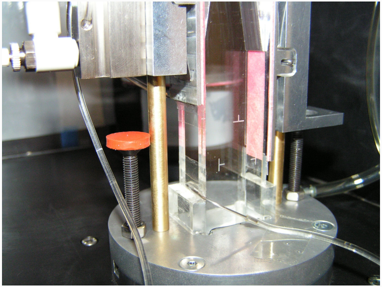




Experiment Overview

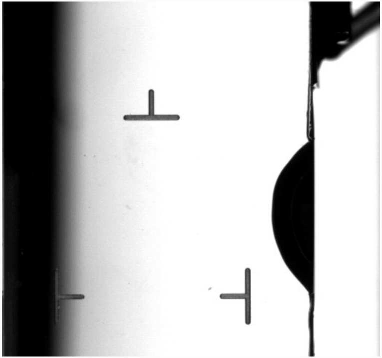
- CCD-camera and optics
- Illumination and pump

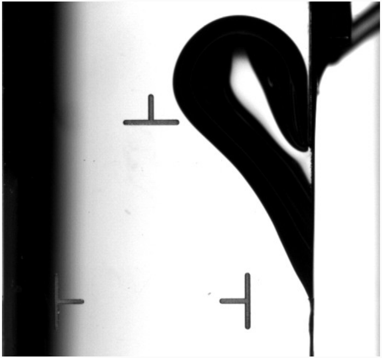




First Experiment Groove (convection dominated)

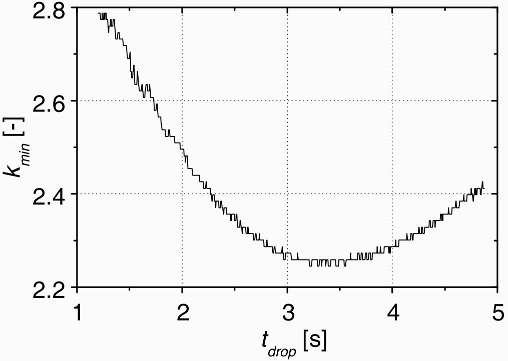
- $\Lambda = 2.5$
- $\mathrm{Oh} = 1.89 \cdot 10^{-3}$
- $\tilde{l} = 6.79 \cdot 10^{-4}$
- $\mathrm{Re}_c = \frac{d_h v_c}{\nu} = 1.06 \cdot 10^3$





Flowrate

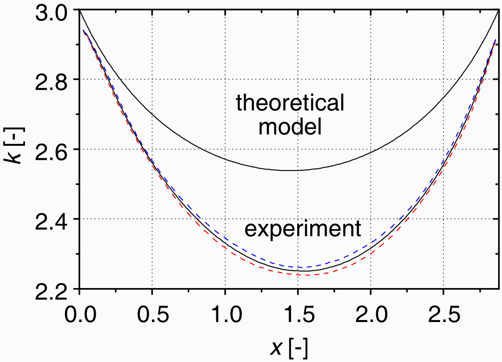
- Steady: $Q < Q_{krit}$
- Unsteady: $Q > Q_{krit}$



Time Depence of free Surface (steady)

- Flowrate: $Q = 0.74$
- t_{drop} is the experimental time
- k_{min} is the minimum of the surface position $k(x)$ at t_{drop}

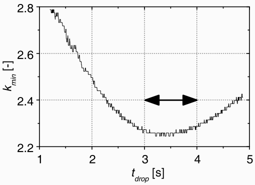
- Meniscus does not reach steady state



- Only qualitativ comparison possible
- Both show convection dominated behavior

Comparison of Surface Position

- Flowrate: $Q = 0.74$
- Experiment: Average surface position over a period of $3s \leq t_{drop} \leq 4s$



Critical Flowrate Q_{krit}

- Experiment: $0.74 < Q_{krit} < 0.77$
- Model: $Q_{krit} = 0.99$

Deviation of 25 %

- The pressure loss due to the profile change is not yet integrated
- Deviation of boundary condition h_0

- Theoretical model
- Experimental setup for the Drop Tower
- Experimental results for steady and unsteady flows
- Comparison of the experiment with the theoretical model