Boundary integral simulations of drop coalescence

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Boundary integral simulations of drop coalescence

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Introduction

Most numerical studies on drop coalescence use asymptotic thin film descriptions, since methods for full drop analysis lack accuracy to handle the small interfacial distances. Head-on viscous drop collisions driven by external flow or buoyancy are simulated using a full boundary-integral method (BIM), that can give accurate results for realistic length scales. Also the influence of an insoluble surfactant in shown.

Objective

To investigate the parameter space where asymptotic theories can be applied.

Method

- ☐ Axisymmteric BIM model.
- ☐ Contour-integration for single-layer potential [1].
- ☐ Near-singular subtraction for Marangoni contribution.
- ☐ Five-point FDM for solving surfactant convection-diffusion equation.

Results

Buoyancy

Our method can reproduce the partially-mobile asymptotes found with thin film descriptions [2] (Fig. 1 left).

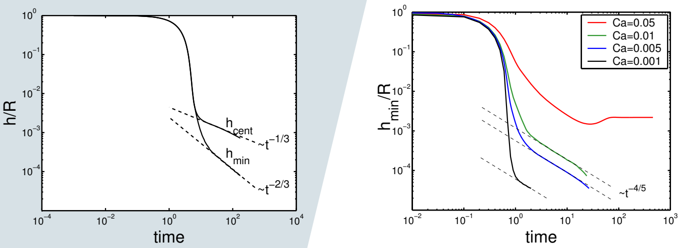

Figure 1 *Left: film drainage for a buoyancy driven collision (Bo $= 0.05$). Right: external flow driven collision.*

External flow

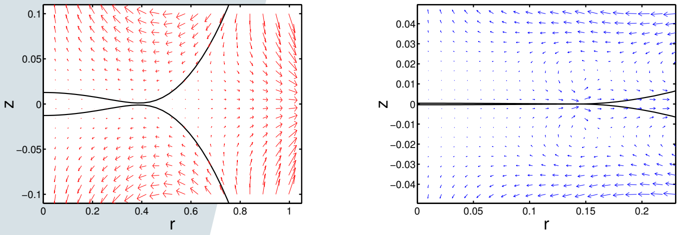

Figure 2 *The counter-rotating vortex disappears for Ca $= 0.05$ (left), while it remains for Ca $= 0.005$ (right).*

The film drains as $h \sim t^{-4/5}$ (Fig. 1). Constant approach force and constant approach velocity cases give other asymptotes. A vortex appears above the film, that is counter-rotating the large, external flow induced inside the drop. For high capillary numbers, the drainage stops altogether, and the vortex disappears (Fig. 2). Critical film thickness is the same as for asymptotic theory [2]. The drainage time scales as Ca$^{3/2}$ between 3.10^{-3} $<$ Ca $<$ 3.10^{-2} and is constant at lower values of the capillary number, which also experimentally is reported [2].

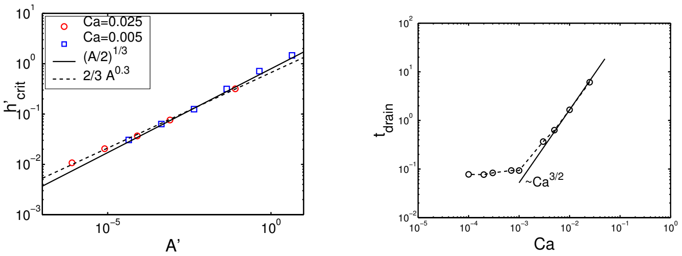

Figure 3 *Left: film rupture due to van der Waals forces (A') occurs for same h_{crit} as asymptotic theory [2]. Right: drainage time is similar to experiments [3].*

Surfactants

The main difference with asymptotic film descriptions is an increase in surfactant concentration, due to transport of surfactant from the drop tip into the film, which locally lowers the interfacial tension beyond the initial equilibrium situation and increases the film radius.

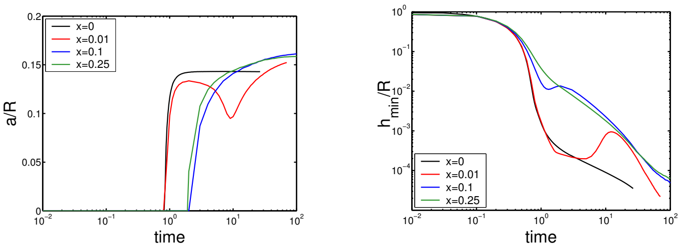

Figure 4 *Film radius a and h_{min} in time for multiple surfactant amounts, all for Ca=0.005.*

Conclusions

We can accurately simulate head-on collisions for small Ca and describe film thicknesses up to $1.10^{-4}R$, while retaining a full drop description. External flow proved to have a major influence on film drainage and is not simulated correctly in asymptotic theories.

Future work

- ☐ Non-unit viscosity ratios.
- ☐ Full range of capillary numbers for multiple surfactant coverages.
- ☐ Unequal drop radii.

References:

[1] I.B. Bazhlekov *et al.* *Phys.Fluids.* 16, pp 1064, 2004

[2] A.K. Chesters *et al.* *J.Coll.Int.Sci.* 230, pp 229, 2000

[3] L.G. Leal *Phys.Fluids.* 16, pp 1833, 2004