Breaking up is easy, coalescence is hard


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Introduction
Drop break-up and coalescence are the two competing mechanisms that determine the microstructure of a blend. Break-up is unavoidable at a relatively large neck radius $d$ (see figure 1), while for coalescence the dimensions of the film between two drops can be many orders smaller than $R$ (figure 2), and still it is not sure if they merge. The extreme length scales involved ($h \ll a \ll R$) complicate studies on coalescence and therefore asymptotic theories are used that only model the film.

Method
- Boundary integral method [1], that gives the velocity:
  $$u(x_0) = u_\infty(x_0) - \frac{1}{8\pi} \int_S G(x_0,x) \cdot f(x)dS(x).$$
- Only capillary and disjoining pressure included:
  $$f(x) = \frac{1}{Ca} \left( \frac{A}{h^3(x)} - \frac{A}{h^3} \right) n(x).$$

Results

Objective
To determine the parameter space where asymptotic theories, that use lubrication theory for the film drainage, can be applied.

Film drainage
Coalescence occurs if van der Waals forces become dominant over capillary forces ($h_{\text{min}} < h_{\text{crit}}$) and rupture the film, thus the evolution of $h_{\text{min}}$ is one of the most important parameters to investigate (figure 3). Due to the external flow, a stationary profile can form (figures 3 and 4). The film drainage

For low capillary numbers is only in partial agreement with asymptotic theories [3].

Van der Waals forces
While the film drainage itself does not fully correspond, we find an excellent match for the critical film thickness (figure 4 left) with an asymptotic theory [4].

Drainage time
A new scaling is found for the drainage time (figure 4 right) [3], but, using a relatively simple model, we can find the drainage time as:

$$t_{\text{drain}} A^{-0.15} \sim Ca A^{-0.3}$$

for touching spherical drops, and

$$t_{\text{drain}} A^{-0.15} \sim (Ca A^{-0.3})^{3/2}$$

for a collision with a fully developed film.

Conclusions
- Numerical method available to simulate coalescence with realistic length scales for full parameter range.
- Parameter space determined where asymptotic theories are valid.

Future work
- Effects of surfactants.
- Effects of confined geometries on break-up.

References:

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