Breaking up is easy, coalescence is hard


Introduction
Drop break-up and coalescence are the two competing mechanisms that determine the microstructure of a blend. Breakup 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.

![Figure 1: A drop breaking up in shear flow.](image)

**Objective**

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

**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:
  \[
  f(x) = \frac{1}{Ca} \left( 2\kappa(x) - \frac{A}{h^3(x)} \right) n(x).
  \]

**Results**

![Figure 2: Two coalescing drops and the thin film that forms between them.](image)

**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].

![Figure 3: Film drainage for multiple Ca (left) and the stationary film thickness obtained, alongside two predictions from [2] (right).](image)

**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].

![Figure 4: Critical film thickness as function of Hamaker parameter \( A \) (left), and drainage time as function of \( Ca \) and \( A \) (right).](image)

**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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