Drop deformation in confined geometries

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Introduction

With the ongoing miniaturization of various equipment, the understanding of the behaviour of blends in confined geometries has become increasingly important. In recent experiments, many interesting observations have been made for these systems, but lack a decent explanation [1,2].

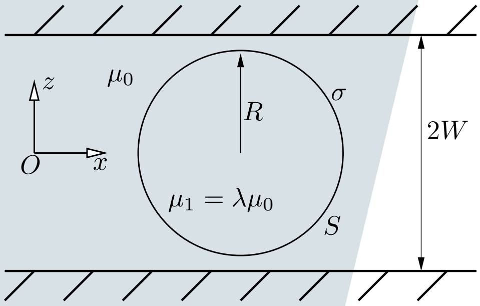

Figure 1 *A drop between two parallel plates.*

Objective

Develop a model to investigate how a drop deforms in shear flow between two parallel plates, and to explain of the observed phenomena.

Method

- ☐ Boundary integral method, that defines the velocity:

$$(\lambda+1)\mathbf{u} = 2\mathbf{u}_\infty - \frac{1}{4\pi}\int_S \mathbf{f}(\mathbf{x})\cdot\mathbf{G}(\mathbf{x},\mathbf{x}_0)\,dS - \frac{\lambda-1}{4\pi}\int_S \mathbf{u}\cdot\mathbf{T}(\mathbf{x},\mathbf{x}_0)\cdot\mathbf{n}(\mathbf{x})\;dS.$$

- ☐ Prescribed shear flow: $\mathbf{u}_\infty = (z,0,0)^T$.
- ☐ Green's functions $\mathbf{G}$ and $\mathbf{T}$ modified to obey the no-slip condition at the wall [3,4].
- ☐ Only capillary pressure included:

$$\mathbf{f}(\mathbf{x}) = \frac{1}{\text{Ca}} 2\kappa(\mathbf{x})\,\mathbf{n}(\mathbf{x}).$$

Results

Deformation

For shear flow, increasing the confinement ratio R/W leads to enhanced deformation (Fig. 2a) and a non-ellipsoidal drop shape (Fig. 2b). The effects are more pronounced at high Ca.

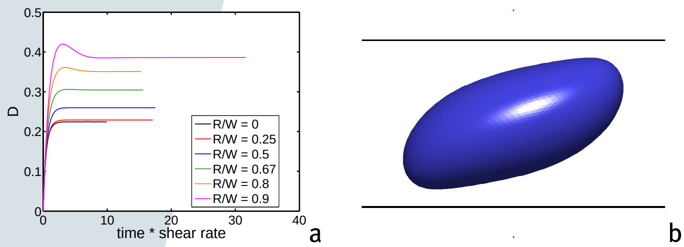

Figure 2 *Drop deformation for Ca = 0.2 as function of R/W (a) and the stationary drop shape for $R/W = 0.9$ (b).*

Breakup

One interesting aspect of the confinement is how it affects breakup behaviour. There is a minor influence on the critical capillary number, above which the drops breaks up (Fig. 3a). Remarkably, the breakup mode changes from binary into ternary (Fig. 3b). Breakup occurs as the drop is retracting. All these effects are also seen experimentally [1,2].

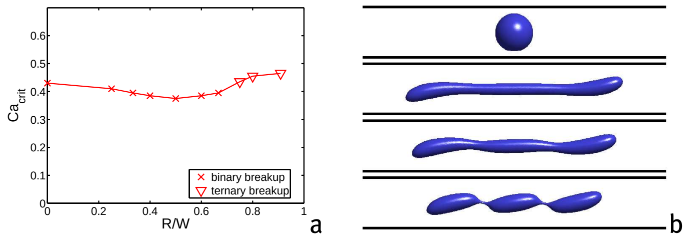

Figure 3 *Ca_{crit} as function of R/W (a) and the breakup behaviour for Ca=0.44 with $R/W = 0.75$ (b).*

Non-unit viscosity ratios

For viscosity ratios $\lambda > 1$, Ca_{crit} is significantly reduced with increasing R/W, and even highly viscous drops can be broken (Fig. 4), which is impossible under unconfined conditions.

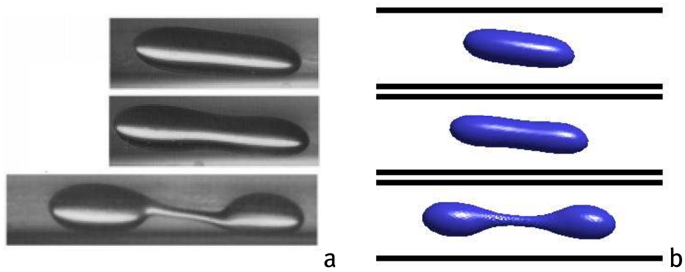

Figure 4 *Experimental data from [1] (a) and our simulation results (b) for Ca $= 0.6$, $\lambda = 10$, $R/W = 0.75$.*

Conclusions

- ☐ The presence of the walls significantly alters the drop shape and deformation.
- ☐ Ca_{crit} for $\lambda = 1$ only slightly affected, but a change in breakup mode. Breakup for $\lambda \gg 1$ enhanced.
- ☐ Numerical method available to simulate drop behaviour between parallel plates.

Future work

- ☐ Comparison with experiments from KU Leuven.
- ☐ Effects of surfactants.
- ☐ Theoretical analysis.

References:

[1] Vananroye *et al.*, Langmuir, 22, 3972, 2006
[2] Sibillo *et al.*, Phys. Rev. Lett., 97, 054502, 2006
[3] Jones, J. Chem. Phys., 121, 483, 2004
[4] Janssen *et al.*, Phys. Fluids, *submitted*

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