A missing link in blending?

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Introduction

Blend properties largely depend on flow history. CFD packages can predict this flow history and theories relating rheology with morphology exist. The link between flow history and morphology is still missing.

Objective

To investigate droplet behaviour in time-dependent flows by means of analytical, experimental and numerical methods.

Slender Body Model

Assumptions

- single, neutrally buoyant, Newtonian droplet
- axisymmetric elongational viscous Stokes flow
- droplet shape is a slender ellipsoid of revolution

Droplet elongation rate

The droplet elongation rate $\dot{\epsilon}_d = \dot{L}/L$ depends only on length L and capillary number $Ca = \eta_c R_0 \dot{\epsilon}_c/\sigma$ [1]:

$$\frac{\dot{\epsilon}_d}{\dot{\epsilon}_c} = \frac{L^3 + \frac{2}{3}\frac{\eta_c}{\eta_d} + \frac{5}{12} - \frac{\sigma g}{f \eta_c R_0 \dot{\epsilon}_c} - \frac{\sigma g}{4 \eta_d R_0 \dot{\epsilon}_c}}{L^3 + \frac{3}{4} + \frac{\eta_c}{2\eta_d} + \frac{4\eta_d}{3 f \eta_c} - \frac{2}{3f}}$$

- L droplet length
- $\dot{\epsilon}_c$ cont. phase elongation rate
- $\dot{\epsilon}_d$ droplet elongation rate
- σ interfacial tension
- η_d droplet viscosity
- η_c continuous phase viscosity
- R_0 equivalent droplet radius
- f, g shape functions $f(L), g(L)$

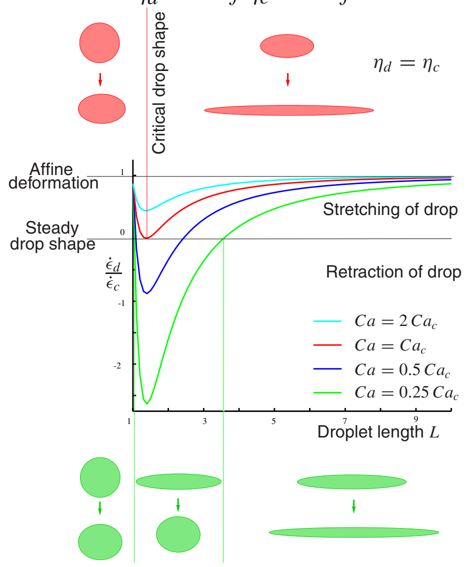

fig. 1 *Droplet elongation rate* $\dot{\epsilon}_d(L, \dot{\epsilon}_c, \sigma, \eta_d, \eta_c, R_0)$

By integrating $\dot{\epsilon}_d$ (figure 1), the droplet deformation L in any time-dependent flow can be predicted, relating morphology with flow history.

Results

Step in elongation rate $\dot{\epsilon}_c$

In figure 2, model predictions are compared with experimental results by Janssen [2]. The numbers denote the ratio between the imposed and the critical capillary number Ca_c (Ca_c: breakup in steady flow).

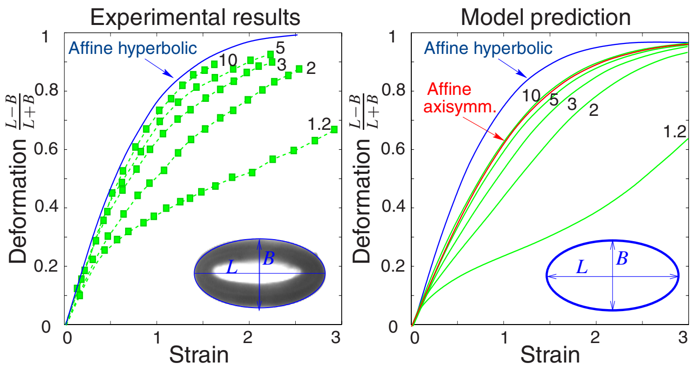

fig. 2 *Droplet response to a step in the capillary number.*

Triangular $\dot{\epsilon}_c$ - time profile

Predicted droplet response and experimental results obtained in a cross slot flow are shown in figure 3.

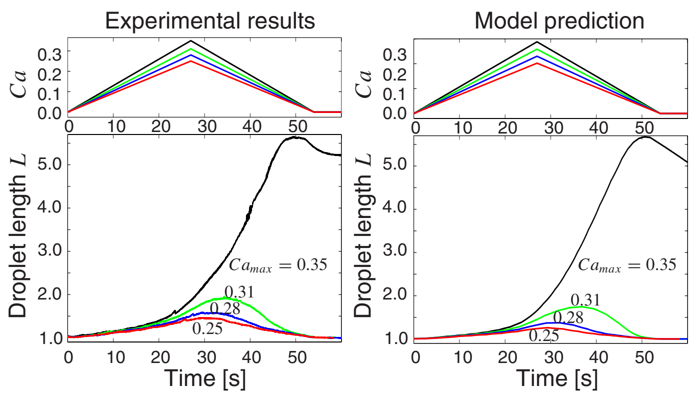

fig. 3 *Droplet response to a triangular Ca-time profile.*

Conclusions

The analytical model provides:

- adequate prediction of droplet deformation in time dependent flows
- link between morphology and flow history
- crucial input for CFD packages

Acknowledgement

This research is part of the FAIR project BioMix, funded by the European Community.

References:

[1] Y.W. Stegeman, A.K. Chesters, F.N. vd Vosse and H.E.H. Meijer, Proceedings PPS-15, 's-Hertogenbosch, 1999.

[2] J.M.H. Janssen, *Dynamics of Liquid-Liquid Mixing*, PhD-thesis, Eindhoven University of Technology, 1993.