Effect of surfactants on drop coalescence

Effect of surfactants on drop coalescence

I.B. Bazhlekov, F.N. van de Vosse and A.K. Chesters

Eindhoven University of Technology,
Faculty of Mechanical Engineering,
Section Materials Technology,
P.O. Box 513, 5600 MB Eindhoven, the Netherlands

Introduction

Most practically interesting dispersions contain surface-active materials, either by accident or by design. Surfactants can strongly affect coalescence and especially the film drainage by immobilizing the interfaces.

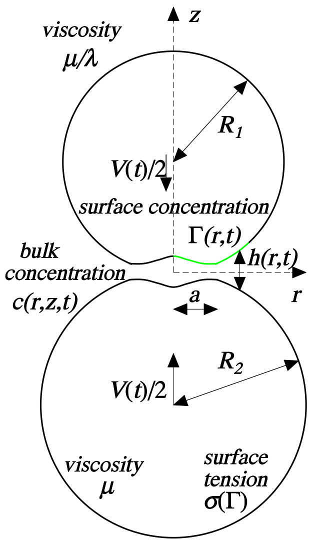
Objectives

- ☐ develop a model for numerical simulation of film drainage in the presence of surfactants;
- ☐ investigate the influence of surfactants on film drainage and rupture.

Film drainage model

hydrodynamic part

- ☐ $a << R_{eq}$, where: $R_{eq}^{-1} = \frac{1}{2}(R_1^{-1} + R_2^{-1})$
- ☐ $h << a$, hence: lubrication approximations in the film solved by FDM;
- ☐ Stokes equations in the drop phase solved by BIM.



surfactant transport

- ☐ surface equation of state: $\sigma = \sigma_s - \Gamma R_G T$;
- ☐ isothermal adsorption: $\Gamma(r,t) = k.c(r,z,t)|_{interface}$
- ☐ convection-diffusion of the surface concentration $\Gamma(r,t)$ on the interfaces solved by FDM;
- ☐ convection-diffusion of the bulk concentration $c(r,z,t)$ in the film solved by FDM.

boundary conditions

- ☐ continuity of the velocity and tangential stress, taking into account Marangoni effect - $\partial\sigma/\partial r$;
- ☐ continuity of the normal stress, neglecting the normal stress variation in the drop;
- ☐ constant interaction force: $F = 2\pi a^2 \sigma / R_{eq}$.

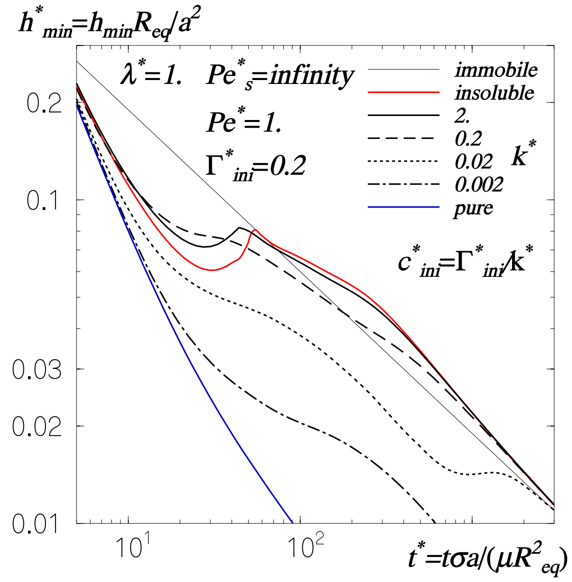
Results

dimensionless groups

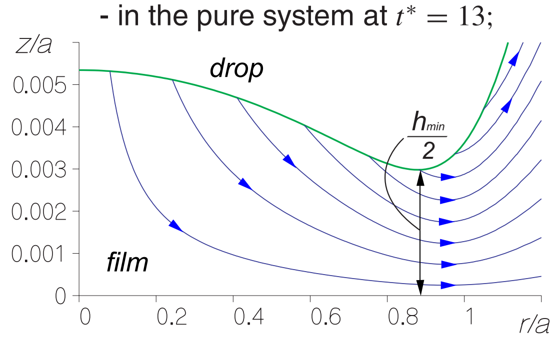
viscosity ratio $\lambda^* = \lambda a / R_{eq}$;
initial surface concentration $\Gamma^*_{ini} = \Gamma_{ini} R_G T R_{eq}^2 / (\sigma_s a^2)$;
surface Peclet number $Pe^*_s = \sigma_s a^3 / (D_s R_{eq}^2 \mu)$;
initial bulk concentration $c^*_{ini} = c_{ini} R_G T R_{eq} / \sigma_s$;
bulk Peclet number $Pe^* = \sigma_s a^5 / (D R_{eq}^4 \mu)$;
adsorption isoterm parameter $k^* = k R_{eq} / a^2$.

film drainage and minimal film thickness

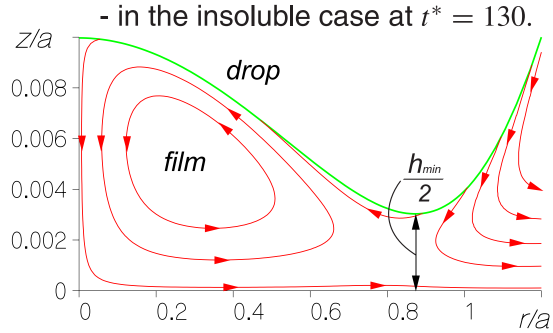
- ☐ evolution of the minimal film thickness h_{min}



- ☐ streamlines for $R_{eq}/a = 10$.
  - in the pure system at $t^* = 13$;



  - in the insoluble case at $t^* = 130$.



- ☐ The following effects were encountered:

- oscillatory behaviour of the minimal film thickness;
- spontaneous dimple growth;
- reversed flow in the film (anti-drainage).

Conclusion

- ☐ The main effect of the surfactants on film drainage is the immobilization of the interfaces, which can significantly slow down the film drainage.