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Stable and Unstable Film Drainage Between Two Captive Drops

A.N.Zdravkov, G.W.M.Peters and H.E.H.Meijer
Eindhoven University of Technology, Department of Mechanical Engineering

Introduction

Drop coalescence occurs in many industrial and natural processes and its prediction and control is of great practical importance. The drainage of the film formed between coalescing drops is the time determining step. Observation of the film drainage behavior provides useful information on whether existing film drainage models can be applied.

Asymptotic models

In the present work two asymptotic laws for the evolution of film thickness, h (Fig.1), in the limiting cases of the immobile and the partially-mobile film drainage are used ([1]):

$$h = \left(\frac{0.36\mu_c}{\gamma}\right)^{1/2} \frac{R_{eq}^{1/2} a}{t^{1/2}}, \qquad \text{for} \qquad \lambda \to \infty$$

$$h = \left(\frac{0.32\mu_d}{\gamma}\right)^{2/3} \frac{R_{eq}^{1/3} a^{4/3}}{t^{2/3}}, \qquad \text{for} \qquad \lambda \to 0$$

where t denotes time, a the film radius, R_{eq} the equivalent drop radius, γ the interfacial tension, μ_d and μ_c represent the viscosity of dispersed and continuous phase, respectively, and $\lambda = \mu_d/\mu_c$.

Materials and Methods

Continuous phase: polydimethylsiloxane (PDMS). Dispersed phase: polyethylene oxide (PEO-$wt\%$ in water, molecular weight 8×10^6), polybutene (PB, molecular weight 635) and polybutadiene (PBD, molecular weight 1800) (see Table).

liquids	μ, $[Pa.s]$	γ, $[mN/m]$
PDMS	1	-
PEO-0.40	3	24.0
PEO-0.65	30	26.5
PEO-1.00	100	25.1
PB	3	2.0
PBD	0.72	4.0

The film deformation and drainage rate are determined with an interferometric technique:

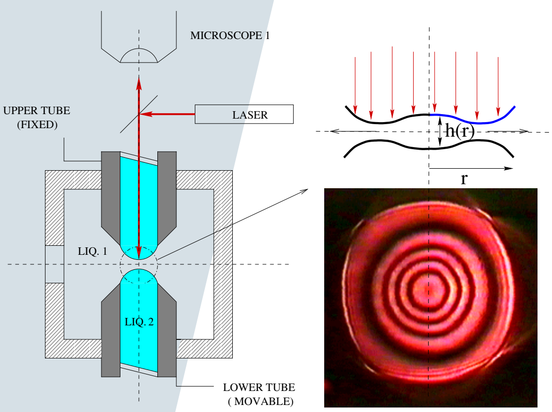

Figure 1. *The experimental set up and a resulting interference pattern.*

Experimental observations and Results

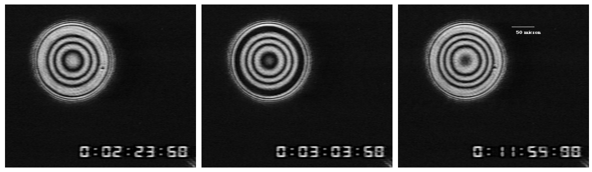

Figure 2. *Stable film drainage. PEO-0.40/PDMS system.*

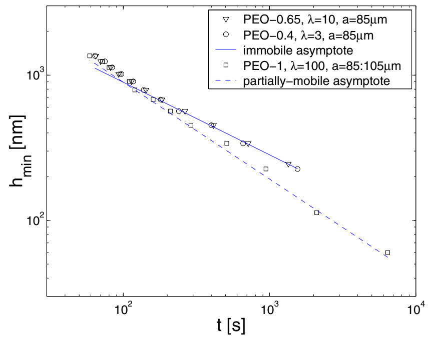

Figure 3. *The asymptotic models fit well the film thickness evolution curves obtained by counting the Newton rings at the periphery of the film backwards in time.*

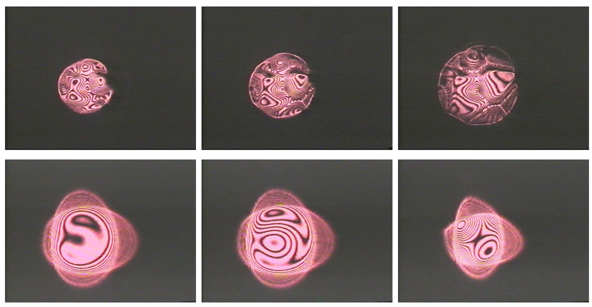

Figure 4. *Unstable film drainage. PB/PDMS system (top) and PBD/PDMS system (bottom).*

Conclusions

- ◇ PEO/PDMS systems have high interfacial tension, show stable axisymmetric film drainage and can be used to validate the existing film drainage models (Figs. 2 and 3).
- ◇ PB/PDMS and PBD/PDMS systems have relatively low interfacial tension compared with PEO/PDMS systems (see Table) and show unstable film drainage (Fig. 4).
- ◇ PBD/PDMS system has two times higher interfacial tension than PB/PDMS system and shows more stable film drainage (Fig. 4).
- ◇ The unstable film drainage can be attributed to mass transfer across the interface which is likely to occur in systems with low interfacial tension.

References:

[1] Bazhlekov,I.B., Chesters, A.K and van de Vosse, F.N.: *International Journal of Multiphase Flow*, 2000, 26, 445

PO Box 513, 5600 MB Eindhoven, the Netherlands