Effect of dispersed phase viscoelasticity on drainage of Newtonian liquid films

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Introduction
Viscoelastic effects have an important contribution to the coalescence process during the polymer blending process. While the coalescence process in Newtonian systems is not completely understood the same process in viscoelastic polymer blends is even less understood.

Asymptotic theory
The coalescence process can be split into three coupled but individually manageable sub-processes:

- External flow
- Internal flow and drainage
- Film rupture

Collision frequency
Contact force, $F(t)$
Contact time, $t_1$

Flattening (film radius, $a$)
Flattening (film thickness, $h(t)$)

Film rupture at ($h_{min}=h_c$, $t_2$)
Confluence (coalescence)

Figure 1. Schematic representation of two liquid drops coalescing in an immiscible fluid [2].

The rate-determining step in the coalescence process (Fig.1) is usually the drainage up to critical thickness ($h_c$) of the matrix film separating the two droplets. Considering only this sub-process one can assume:

- axi-symmetry
- film radius $a \ll R$
- creeping flow in the viscoelastic drop phase
- film thickness $h \ll a$
  - lubrication in the film
  - inertia forces negligible.

Figure 2. Detailed sketch of the film drainage sub-process, where $\theta$ is the relaxation time, $\mu$ is the viscosity and $\lambda$ is the dispersed to continuous viscosity ratio.

Theoretical results

Figure 3. Comparison between the film thinning behavior in case of Newtonian ($\theta=0s$) and viscoelastic ($\theta=1.7s$) drop phase [1]. The other parameters (Fig.2) are kept the same.

Experimental observations

Figure 4. Comparison between observed interference pictures of dimpled thin liquid films: first row Newtonian (Glycerine) and second row viscoelastic (water solution of PEO, $M_0=8.10^6$, 0.36 wt%) drop phase.

Conclusions

- according to the theoretical model when the drop phase elasticity increases the dimple becomes less pronounced and the thinning rate increases (Fig.3).
- the experimental observations indicate when the drop phase elasticity increases the dimple remains more stable and the axi-symmetric thin liquid film drains until rupture (18 min., Fig.4).

References: