Confined flow of polymer blends

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Introduction

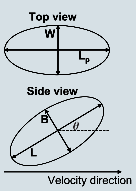
The trend toward miniaturization leads to processes in which the characteristic sizes of device and morphology are comparable. The goal is to study the influence of a confinement on the steady state morphology of two emulsions, differing in mutual miscibility and interfacial tension (Table 1).

Materials and Methods

$M_n^d/$ M_n^m	$(M_w/M_n)_d/$ $(M_w/M_n)_m$	η_d/η_m (p) $[Pa*s]$	σ_{steady} $[mN/m]$
PBD8K/PDMS60K	1.6/1.8	44.5/10.8	4.2
PB635/PDMS60K	2.1/1.8	3.75/10.8	2.2

Table 1. Selected model components.

Three weight concentrations (10%, 20%, 30%) are investigated. Samples were sheared between parallel plates (gap spacing H=40 μm) in a range of shear rates at which the transition from "bulk" behavior towards "confined" behavior was observed. Results are compared to the Maffettone-Minale model (MM model), as a function of the capillary number Ca, for bulk flows to detect deviations from bulk behavior.



L_p and W are measured; $r_p = L/B$ is calculated:
$L_p^2 = B^2 + (L^2 - B^2)\cos^2\theta$; $LBW = 8R^3$
θ predicted by MM model, and $\theta = 0$ are used.
$\theta_{MM} = \frac{1}{2}\arctan\left(\frac{f_1}{Ca}\right)$; $f_1 = \frac{40(p+1)}{(2p+3)(19p+16)}$
$Ca = \frac{\eta_m \dot{\gamma} R}{\sigma}$; R=drop radius

Figure 1. *Deformed droplet in simple shear flow.*

Results

Drop deformations (r_p) are fairly well predicted by the MM model for high enough shear rates. At lower shear rates (i.e. higher degree of confinements, $2R/H$), better agreement is found by considering $\theta = 0$ (Figure 2 and 3, r_p vs Ca curves).

The immiscible PBD/PDMS system

For degree of confinement larger than 0.3, deviations of measured width W from the MM predictions are found for all the three concentrations (Figure 2).

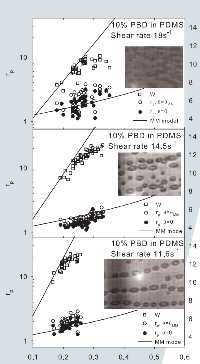


Figure 2. *PBD/PDMS system: drop deformation r_p and drop width W as a function of the capillary number Ca.*

The partially miscible PB/PDMS system

For the PB/PDMS system, W vs Ca becomes constant at concentrations higher than 10% and for a larger degree of confinement.

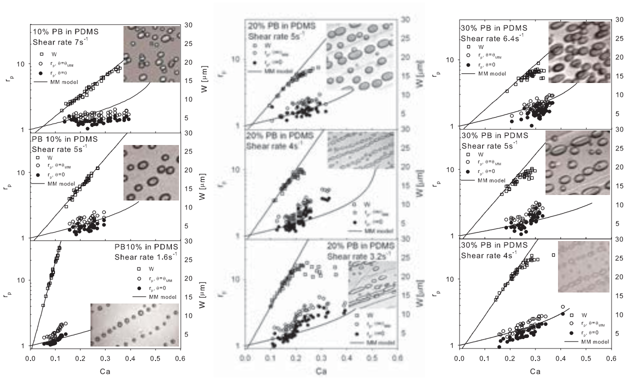


Figure 3. *PB/PDMS system: as Figure 2.*

Morphology: strings

The dependence of the length L and the width B of the drops on Ca was investigated for the 20 wt% systems by fitting the experimental data with $L \propto Ca^l$, $B \propto Ca^b$. The strong dependence of L/B on Ca is *unique* feature of strings in confined emulsions (Figure 4).

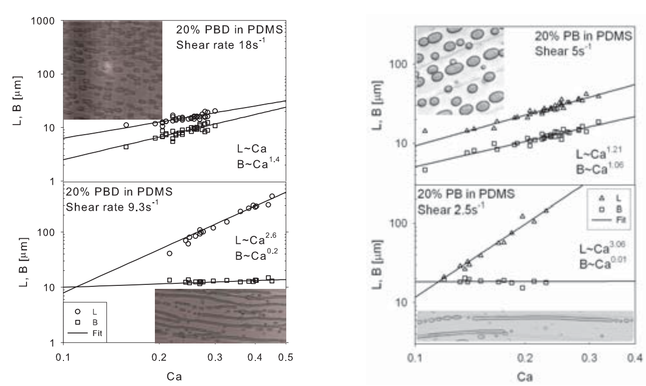


Figure 4. *Dependence of the two sizes of droplets (top) and strings (bottom) on the capillary number. Experimental data for L (circles) and B (squares), and the results of fitting (solid lines) are shown. The inserts show the steady morphologies.*

Conclusions

By decreasing the shear rate, for each blend the same morphology evolution is encountered:

- droplets arrange into two layers, move to a single layer at a critical degree of confinement lower than 0.5 and finally superstructures, like ordered pearl necklaces and strings, form.
- The MM model does not fully predict the morphology evolution in the confined geometries.
- An unique condition to identify strings is proposed.

P.L. Maffettone, M. Minale, *J. Non-Newtonian Fluid Mech.* 1998, 78, 227-241

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