The mysteries of droplet birth in microfluidic cross junctions

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Introduction

• Experiments on droplet formation in symmetric cross junctions - the simplest geometry.
• With and without surfactant.
• Different production regimes are observed as Capillary number (Ca) and flow rate ratio (f) are varied in a large range.

Parameters

Fixed: H, W, μ, ρ, σ
Varied: Qp, Qc

Output: Lp, Fd

Ωd = QD / Fd W2/H

Phase diagrams

without surf., W* = 1.8  with surf., W* = 3.2

Stable dripping  Aperiodic dripping  Jetting
No drop  Spurious/no drop  Secondary droplets

Satellite droplets

Satellite droplet looping in the horizontal plane between two main droplets.

Time decomposition

Dripping in two steps: inflation (T1) and squeezing (T2).

Ω = (T1 + T2)QD / W2/H

Satellite droplet looping in the vertical plane between two main droplets.

Spatio-temporal diagram

Ω1, Ω2

Ω1 & Ω2 vs. Ca (resp. f) with fixed φ (resp. Ca).

Solid line - fit on the whole dataset. Dashed line - model of Chen et al. [1].

Inflation: dispersed volume

Superposition of two snapshots from the same experiment right after pinch-off and initial retraction (orange) and after T1 at the end of the inflation step (blue).

Prediction of Ω

without surf., W* = 1.8  with surf., W* = 3.2

Parity plot of measured dimensionless droplet volume Ω vs. empirical law:

Ω* = A1 - B1 log Ca - C1 log φ

Table: Prediction of Ω

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>Ω*</th>
<th>w/m</th>
<th>w/m</th>
<th>w/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without surf.</td>
<td>-0.25 ± 0.05</td>
<td>-2.21 ± 0.01</td>
<td>-0.25 ± 0.04</td>
<td>-0.9 ± 0.05</td>
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<tr>
<td>With surf.</td>
<td>0.05 ± 0.05</td>
<td>0.03 ± 0.03</td>
<td>0.06 ± 0.05</td>
<td>0.07 ± 0.05</td>
</tr>
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</table>

Conclusion

• Model valid for large range of Ca & φ (extended range compared to previous models - limits of Chen’s model)
• Influence of surfactant mainly on T1
• Aspect ratio W* determined from satellite droplets.

Acknowledgments

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References