Short research visit report: Viscous froth model applied to an arbitrary number of two-dimensional bubbles flowing in a channel

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Results:
The study of microfluidics has applications in industries such as pharmaceutical, medical treatment, food, cosmetic, oil recovery and soil remediation [1]. In particular, this SRV concerns the microfluidic rheological properties of a multiphase fluid, specifically liquid foam, which has been widely studied by Professor Simon Cox's research group in recent years [2]. The rich rheological properties of liquid foams can be captured by using a two-dimensional model known as the viscous froth model (VFM) [3]. The VFM balances the curvature of the foam film with the pressure difference across it, converting any mismatch between these forces into film motion, thereby leading to viscous drag forces [4]. During the SRV we developed two-dimensional foam flow simulations of an N bubble cluster applying VFM. Specifically we were able to obtain the equilibrium and non-equilibrium states for systems from low to high flow velocities using Surface Evolver software. We varied the number of bubbles N, to explore the effect of this parameter upon stability and interfacial energy. The results were benchmarked against an analytical approach developed during Torres-Ulloa's PhD, for equilibrium structures with $N = 3$ or $N = 5$, being the results convergent (see Figure 1).

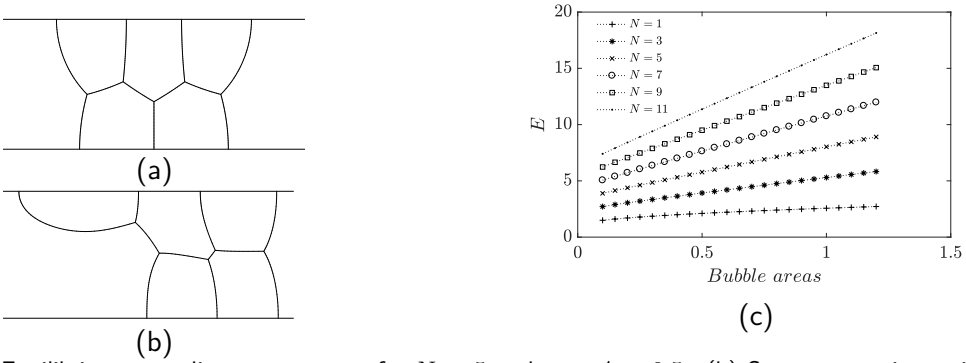

Figure 1: (a) Equilibrium monodisperse structure for $N = 5$ and area $A = 0.5$. (b) Structure set in motion at an apparent velocity $v = 5$ at time $t = 0.3843$. The structure has suffered a topological transformation or neighbour rearrangement. (c) Energy E as a function of the bubble areas for different N.

References

[1] W. Drenckhan, S. Cox, G. Delaney, H. Holste, D. Weaire, and N. Kern, "Rheology of ordered foams—on the way to discrete microfluidics," Colloids and Surfaces A: Physicochemical and Engineering Aspects, vol. 263, no. 1-3, pp. 52–64, 2005.

[2] D. Vitasari and S. Cox, "A viscous froth model adapted to wet foams," Colloids and Surfaces A: Physicochemical and Engineering Aspects, vol. 534, pp. 8–15, 2017.

[3] P. Grassia, G. Montes-Atenas, L. Lue, and T. Green, "A foam film propagating in a confined geometry: analysis via the viscous froth model," The European Physical Journal E, vol. 25, no. 1, pp. 39–49, 2008.

[4] T. Green, P. Grassia, L. Lue, and B. Embley, "Viscous froth model for a bubble staircase structure under rapid applied shear: An analysis of fast flowing foam," Colloids and Surfaces A: Physicochemical and Engineering Aspects, vol. 348, no. 1–3, pp. 49–58, 2009.