A criterion to predict bridge break-up for engineers

Academic Year: 2026–2027
Supervisors: T. Gilet (Tristan.gilet@uliege.be), P. Lambert (Pierre.Lambert@ulb.be) and L. Tadrist (loic.tadrist@univ-amu.fr)
Host Laboratory: Institut des Sciences du Mouvement UMR7287, SBI Team
Location: Aix-en-Provence (IUT Aix campus)
Duration: 4 - 6 months
Salary: about 600€/month
Recommended Level: M1 or M2 in Mechanical Engineering / Physics
Required Skills: Physics of interfaces, Numerical physics.

Summary

Capillary adhesion makes possible to erect sand castles or that allows insects (such as certain beetles) to move on the ceiling [1]. For more concrete industrial problems, capillary bridges are used to move very small objects [2,3], perform efficient heat exchanges or may simply be harmful during industrial processes. Physical theories exist to determine the stability of a liquid bridge – when does a bridge break when the two plates linking the bridge are pulled apart? Two ways exist to answer this question: either pseudo-dynamics (fake vibrations) or by studying the second derivative of the energy. These stability studies are somehow advanced and have not precluded in engineering. Thus most engineers rely on simplified theories to predict the rupture of a capillary bridge which are not completely physically grounded such as Pepin's Criterion [4].

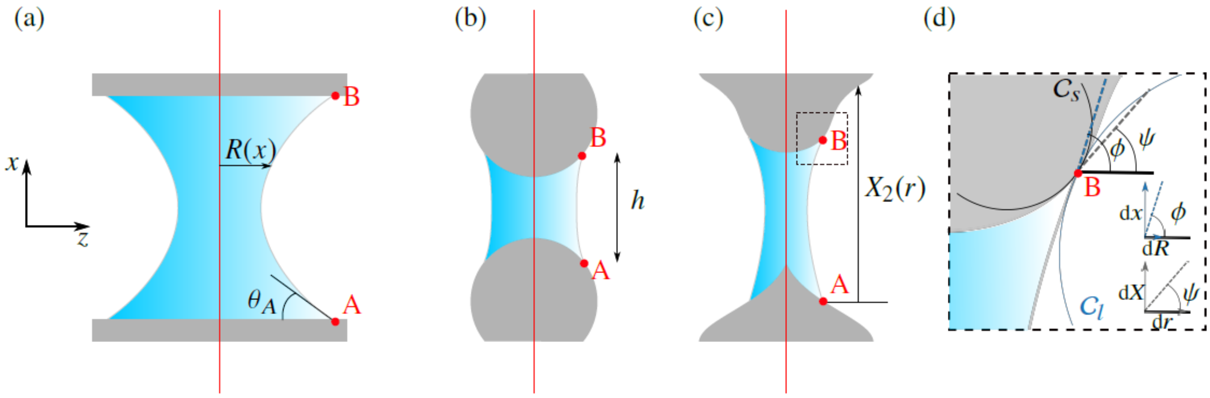

Figure 1 Examples of Axisymmetric liquid bridges and notations.

In this research project, we will solve numerically the stability of axisymmetric liquid bridges by determining the positivity of the second derivative of the energy (Sturm-Liouville analysis). A first work has been done considering the stability of liquid bridges between plates in micro-gravity (small Bond number). The first step is to complement this theoretical and numerical analysis with experiments. The second step is to extend this analysis to consider gravity. Finally, other shapes of substrate should be documented.

Internship Tasks:

1. Conduct a literature review on capillary bridge rupture from physical and engineering points of view.
2. Add gravity to the existing theory and complement the numerical analysis accordingly.
3. Make a table top experiment to measure the rupture of pinned capillary bridges either by quasi-static pulling of one plate or by evaporation. Check that both phenomena give the same rupture threshold.
4. Report experimental data points on the stability of capillary bridge;
5. Explore other shapes (beads) or boundary conditions (LIS surfaces)
6. Finish writing the scientific article for engineers.

Work Environment:

The Institut des Sciences du Mouvement (ISM) is a multidisciplinary research unit. The laboratory's research focuses on the study of locomotion in living organisms from various perspectives. The Bio-Inspired Systems (SBI) team at ISM aims to study principles and strategies derived from biological systems to inspire and design innovative technological systems.

References:

[1] P-G. de Gennes, F. Brochard Wyart and D. Quéré. Gouttes, bulles, perles et ondes. Belin, 2002.

[2] Iazzolino, A., Tourtit, Y., Chafaï, A., Gilet, T., Lambert, P., & Tadrist, L. (2020). Pick up and release of micro-objects: A motion-free method to change the conformity of a capillary contact. Soft Matter, 16(3), 754-763.

[3] Lambert, P., & Delchambre, A. (2005). Parameters ruling capillary forces at the submillimetric scale. Langmuir, 21(21), 9537-9543.

[4] Pepin, X., Rossetti, D., Iveson, S. M., & Simons, S. J. (2000). Modeling the evolution and rupture of pendular liquid bridges in the presence of large wetting hysteresis. Journal of colloid and interface science, 232(2), 289-297.

[5] Boleslaw Mielniczuk, Olivier Millet, Gérard Gagneux, Moulay Saïd El Youssoufi. Characterisation of pendular capillary bridges derived from experimental data using inverse problem method. Granular Matter, 2018, 20 (1), pp.14.