Role of Aeroelastic Flutter in the Thermal Balance of a Tree Leaf Subject to Wind: Experimental and Numerical Study

Academic Year: 2025–2026
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Host Laboratory: Institut des Sciences du Mouvement UMR7287, SBI Team
Location: Aix-en-Provence (IUT Aix campus)
Duration: 4 - 6 months
Salary: Yes
Recommended Level: BAC+5 (Engineering or Master's 2nd year)
Required Skills: Computational fluid mechanics, Aeroelasticity, Thermodynamics, Heat transfers

Summary

Tree leaves share the common characteristic of having a flat blade to maximize photosynthetic efficiency: a large surface area to intercept solar radiation and exchange the gases required for the chemical reaction. However, the attachment of the leaf to the branch—the petiole—varies greatly in shape depending on the tree species. Some petioles are short and stout, promoting rigid foliage, while others are flexible with an oval cross-section, favouring flutter (e.g., poplar, *Populus tremuloides*).

Previous studies have shown that classical aeroelastic theories used in aviation (e.g., Den Hartog criterion) effectively describe the flutter thresholds of tree leaves. Since leaf motion amplitude models are nonlinear, numerical simulation is a powerful tool for characterizing these movements. While it seems clear that natural selection has favoured flutter in certain species, the biological benefits remain unclear.

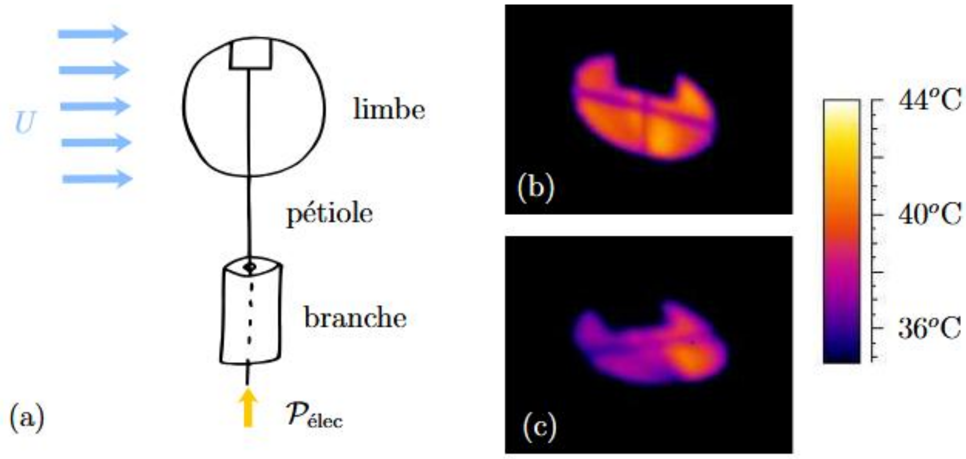

Figure 1 Surface temperature of a rigid leaf (b) and a fluttering leaf (c).

In this research project, we will model the thermal exchanges of a tree leaf, hypothesizing that flutter helps limit temperature rise in highly illuminated leaves and prevents a collapse in photosynthetic efficiency at high temperatures (>40°C). A preliminary experiment (L. Tadrist) demonstrated the concept: a fluttering leaf exchanges more energy with its surroundings than a rigid leaf (see Figure 1). However, these results need to be validated by varying wind speeds, input power, and surface roughness.

Internship Tasks:

1. Conduct a literature review on leaf flutter, flutter criteria and energy balance of a leaf.
2. Create a CFD model of the wind around a fluttering leaf (prescribed leaf motion).
3. Design and fabricate a pair of biomimetic tree leaves (one fluttering and one rigid);
4. Develop a plan for numerical and experimental exploration;
5. Numerically simulate the flow around the rigid leaf and perform thermal balance analyses;
6. Numerically simulate the flow around the fluttering leaf and perform thermal balance analyses;
7. Analyze and compare numerical and experimental results.

This internship may be fully numerical or numerical(50%)/experimental (50%). This internship may give potential PhD opportunity.

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] Tadrist, L., Julio, K., Saudreau, M., & de Langre, E. (2015). Leaf flutter by torsional galloping: experiments and model. *Journal of Fluids and Structures*, *56*, 1-10.

[2] Roden, J. S., & Pearcy, R. W. (1993). The effect of flutter on the temperature of poplar leaves and its implications for carbon gain. *Plant, cell & environment*, *16*(5), 571-577.