Aerodynamics of deformable flapping wings

Flapping wings are a possible alternative to fixed or rotating wings for the propulsion of very small aircraft (typically less than a centimeter) [1]. This mode of propulsion/lift inspired by the living world has been widely studied for about thirty years now [2,3], in conjunction with the advent of micro and nanotechnologies. The understanding of the physical mechanisms at the origin of the aerodynamic forces generated by the flapping wing has led to the recent development of prototypes miniaturized to the extreme, such as the RoboBee at Harvard University or the OVMI at IEMN (figure 1). Despite these important advances, the design of flapping wing aircraft is far from optimal. In particular, the wing shape is, at best, a simple copy of the shape observed in insects.

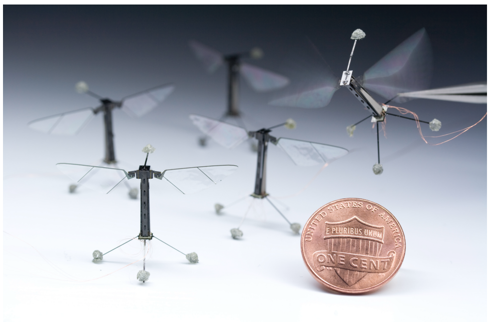

Figure 1 : The RoboBee prototype from Harvard University (weight: 60mg)

In this thesis, we propose to define an optimal wing shape for flapping flight propulsion/lift. The major difficulty here is that this mode of propulsion/lift is inherently unsteady, unlike the more conventional fixed or rotary wing modes. The shape of the wing must therefore evolve dynamically, in the sense that to be optimal it must vary during a flapping cycle. This dynamic depends directly on the flapping kinematics of the wing. The wing will therefore be controlled over time to obtain the highest lift forces.

The dynamic optimization of the flapping wing shape will be performed in two ways.

First, numerically, we will simulate the aerodynamics of a deformable wing whose deformation is imposed. The flow around the wing and the resulting aerodynamic forces will be obtained by direct resolution of the Navier-Stokes equations. The challenge here will be to implement an optimization process minimizing the number of Navier-Stokes simulations in order to obtain an optimal dynamic shape in terms of lift and efficiency. It will also highlight the physical phenomena at the origin of this optimality.

Then, in a second time, by experimental way, where we will seek to carry out measurements of the flow (PIV-3D) and of deformation (DIC) on a model of flapping wing deformed by piezo-electric actuators. The aim is to experimentally implement the optimal dynamics defined previously by numerical simulations. The challenge here will be to implement piezoelectric actuators for the deformation of structure in a highly unsteady context, as well as the realization of advanced optical measurements (DIC / PIV-3D coupling). The experimental results will finally be compared with the numerical results.
This thesis project will be carried out in partnership between the Pprime Institute in Poitiers and the ISAE-Supaero in Toulouse, which have a long-standing expertise in the subject [3-8] (figure 2).

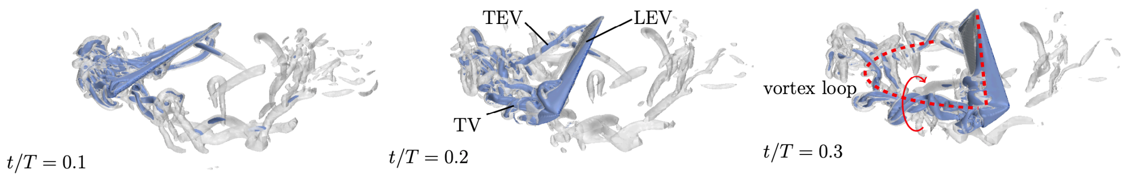

Figure 2 : example of numerical simulations carried out in the framework of the Pprime Institute/ISAE-Supaero partnership

Applicants with a good background in fluid mechanics are welcome to apply. Knowledge in numerical and/or experimental fluid mechanics and aerodynamics is a plus. Please send CV to thierry.jardin@isae.fr

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