COMPARISON OF THE VORTEX METHOD AND THE IMMERSED BOUNDARY METHOD FOR 2D SIMULATIONS OF INSECT FLIGHT

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Painted lady butterflies are known to travel up-to 4000 miles during migration, from North Africa to Iceland. Sphinx Moths fly as fast as 33 m.p.h. A midge can beat it’s wings at a frequency as high as 62760 beats per minute (bpm), while a swallowtail butterfly is beats them as slow as 300 bpm. The highest altitude gained by any insect is noted to be about 20000 feet [1]. The diversity among insects is unfathomable and so are their acrobatic manoeuvres. They can fly forward, up, down and side-ways. They can hover, land upside down on the bottom of a leaf and even manage to fly with damaged wings. Insects are surprisingly resistant to environmental perturbations despite their small size and consequently small inertia. The mesmerizing brilliance of insect flight notwithstanding, understanding the unsteady aerodynamics and the lift generating mechanisms have practical applications to Micro Air Vehicles (MAV) [2].

The theory and numerical simulation of insect flight in general and the reduced problem of the heaving and pitching motion of airfoils has seen an evolution from the early Rankine-Froude momentum theories [3] [4], quasi-steady models on thin airfoil theory [5] [6] to unsteady models using the full Navier-Stokes equations and fluid-structure interactions [7] [8] [9] [10] [11]. While being essentially a 3D phenomenon, two dimensional models are often used as an effective tool to understanding the basic theories like the Wagner effect [12], Kramer effect [13] [12] and the clap and fling Mechanisms [5] [13] [14]. The extra lift generated by insects is believed to be due to the attachment of the leading edge vortex [15] [16] [17]. Though this mechanism is stable for a longer duration in 3D, the shedding of vortices after stroke reversal enables a comparable simulation in 2D.

In this work, we compare numerical simulations for the idealized clap and fling mechanism of insect flight using a Vortex Method (VM) [18] and the Immersed Boundary Method (IBM) [19] [20] [21]. Our motivation is both, the understanding of the vortex shedding patterns for clap and fling and the feasibility of these numerical techniques to resolve the
flow at various Reynold’s numbers in the presence of complex moving/deformable bodies. An example simulation of the heaving and pitching motion of an ellipse using the Vortex Method is shown in Fig. 1. Our comparison is based on the accuracy of the results and the ease with which the codes can be extended to three dimensions with the possibility of adding new physics. The results from this work would guide the development work for a 3-dimensional code for general insect flight.

![Figure 1. Heaving motion of an ellipse using a 2D Vortex Method.](image)

**References**


