



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS**

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SHORT ABSTRACT

The flapping flight, which is governed by the unsteady aerodynamics, deals with inherent complexities especially at low Reynolds number (Re). Understanding the low physics behind these intricacies may lead to a great chance of enhancing the aerodynamic performance of Flapping Wing Micro Air Vehicles (FW-MAVs). Nature provides a variety of small flying birds and insects to achieve this goal via biomimicry. However, direct copying of concepts available in nature may not lead to feasible solutions. The balance between engineering implementation and exploitation of concepts from nature may lead to successful designs. The work presented in this dissertation attempts at bringing this vision a little closer to realization.

In the first part of the work, a biomimetic wing is modelled by considering the *Passer Domesticus* wing as a reference. Initial investigations are carried out to analyse the aerodynamic characteristics of the biomimetic wing and its performance is compared with commercially available rectangular and elliptical wing planforms under fixed condition. From the present findings, it is observed that the elliptical planform offers less drag than that of other wing planforms. This indicates that the elliptical wing planform might be suitable for studies where the drag reduction is primary objective. It is also observed that the presence of the sharp edges in the rectangular wing planform encourages the flow separation and affects the overall aerodynamic performance of the wing. In the case of biomimetic wing, the change in wing profile allows to have a variable angle of attack along the span which delays the flow separation and improves the wing's aerodynamic performance. Due to this, a 57.9% increase in lift coefficient is observed for the biomimetic wing than that of elliptical wing. A 22.4% increase in lift to drag ratio of the biomimetic wing is observed than that of rectangular wing under same conditions. In the next part of the work, the kinematics of flapping flight of birds are discretised into three different motions, namely: pitching, plunging and flapping motion (combination of rotation about wing chord and span). The unsteady flow characteristics of the biomimetic wing subjected to these motions are numerically analysed.

When the wing is subjected to the pitching motion, it is observed that, the unsteady vortex shedding over the pressure side of the wing creates the negative suction at lower pitch amplitudes. This opposes the positive suction created over the suction side and affects the wing's performance. However the adverse effects of the oppositely signed circulation diminish with increase in the frequency due to substantial reduction in the growth of the vortex over the pressure side of the wing. This improves the instantaneous values of lift and thrust force coefficients at higher

frequencies in combination with lower pitch amplitudes. At higher mean angles of attack, a substantial diminution in the instantaneous force coefficients is observed due to large flow separation which makes it hard for the separated flow to reattach. From the flow investigations, it is also observed that the shifting of pitching axis away from the leading edge encourages the retardation of vortex coherence which has adverse impact on the thrust force generation of the wing.

The observations from the flow field investigations reveal a superior convection of the leading edge vortex along the axial core at smaller plunge amplitudes when the wing is subjected to the plunging motion. The presence of local peaks in the amplitude spectrum of instantaneous force coefficients confirms that there exist an adverse interaction between leading and trailing edge vortices at higher plunge amplitudes. With increase in the frequency, a more prominent vortex formation is observed near the leading edge and also closer to the wing's surface. As the cycle continues, this vortex roll-up and interacts with the trailing edge vortex which was formed closer to the wing's trailing edge. These vortices shed in the wake in the form of the alternating vortices. From the flow investigations, it is observed that the additional advantage of increasing the frequency is that, it remarkably increases the strength of these vortices which eventually roll-up over the suction side of the wing. Due to this, the instantaneous force coefficients of the wing rises towards higher values at higher frequencies.

The investigations are further carried out to analyse the unsteady flow characteristics of the biomimetic wing subjected to flapping motion. Asymmetric variation of instantaneous force coefficients despite of having symmetrical flapping kinematics reveals that the optimal aerodynamic performance of the biomimetic wing demands proper selection of operating conditions. It is observed that, at lower flapping amplitudes, the formation of Leading edge vortex (LEV) over the suction side happens farther away from the surface and roll up away from the wing at the beginning of the flapping cycle. As the cycle continues, this LEV convects farther downstream and affects the suction created due to the positive vortex circulation. Increasing the flapping amplitude increases the wing's influence over its surrounding fluid and vortex formation happens closer to the wing's surface. This enhances the positive suction and remarkably influences the thrust force generation of wing. The observations from the flow field Investigations reveals that the formation and the convection of the LEV not only influences the drag-thrust transition but also the wake pattern. The increase in the mean angle of attack has a significant impact on the wake pattern. Different types of transitional forms of wake are observed at different mean angles of attack due to shedding of multiple vortices per cycle. Especially at 16° , the alternating vortices exhibit irregular patterns in the wake region and form clusters due to adverse interference between the vortices shed between the previous cycle and next cycle. This impinges the wing's performance with increase in the mean angle of attack. From the flow investigations, it is also noticed that, increasing the flapping frequency not only increases the vortex strength but also ensures that the flow is attached during major portion of the flapping cycle.

In overall, it is observed that the proposed form of the biomimetic wing has shown a remarkable aerodynamic performance when subjected to different unsteady conditions at low Re. We hope the findings reported in this dissertation might be helpful in practical wing design applications.