INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:
Analysing the Effect of Reynolds Number and Aspect Ratio on the Wing Performance with Bio-inspired Passive Flow Control Devices

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SHORT ABSTRACT

Micro air vehicles (MAVs) are a special form of unmanned aircraft that are evolving rapidly every year due to their vast applications in civil and military sectors. Such vehicles have limited wing dimensions and power unit, due to which they operate under a low Reynolds number (*Re*) range of 10×10^3 to 100×10^3. Within this *Re* range, conventional airfoils experience a significant decline in performance as the *Re* decreases below 100×10^3. Apart from this, the wing design of such vehicles relies majorly on the use of wings with an aspect ratio (*AR*) lower than 2.0. These wings face a significant challenge of producing lower lift values at low *AoA* due to the presence of strong wingtip vortices. In this context, the present study is focused on investigating the aerodynamic characteristics of wings with an $AR \leq 2.0$, both in the presence and absence of bio-inspired passive flow control devices. The aim is to contribute to the advancement of MAV technology.

Two low-speed airfoils, S5010 and E214, have been chosen for the fabrication of rectangular wing models. The preliminary stage of investigation involves exploring the aerodynamic performance and wake field characteristics of these airfoil models within the *Re* range of $40 \times 10^3 \leq Re \leq 100 \times 10^3$. Subsequently, the effect of *Re* and *AR* on the aerodynamic performance of the wings associated with the S5010 and E214 sections is investigated in the next phase of the work. In this regard, the *AR* and *Re* have been chosen in the range of $2.0 \leq AR \leq 1.0$ and $60 \times 10^3 \leq Re \leq 150 \times 10^3$, respectively. The analysis exhibited that wings based on the E214 section demonstrate better aerodynamic performance compared to the S5010 airfoil for the tested *Re* and *AR* ranges. Consequently, in an effort to enhance the performance of the S5010 wing, bio-inspired passively acting devices have been implemented on the wing. These flow control devices are tested, targeting two different flow modes, specifically flow separation over the surface and flow of vortices through the wingtip.

In the first scenario, the self-actuating flaps, which are evolved by emulating the covert feathers on the upper wing of a bird, are tested for wings of $AR = 2.0$ and 1.0 to control flow separation over the surface. Focus has also been given for exploring flap effectiveness in various aspects, including flap span, chord length, and chord-wise placement within a *Re* range of 60×10^3 to 120×10^3. The flap does not impact pre-stall wing performance, but it significantly improves post-stall lift and drag characteristics over the clean wing. The optimal chord-wise position of the flap for better performance enhancement is near the mid-chord for both models. Finally, the effectiveness of various bio-inspired wingtip devices is also examined to reduce the effect of wingtip vortices for wings of $AR = 1.0$ and 0.5 in the *Re* range from 80×10^3 to 150×10^3. The concept of slotted wingtips is inspired by structural features observed in primary feathers located at the tips of bird wings. Two different wingtip attachment shapes, viz., tapered and conical, have been chosen for this study and added in a planar manner to the wingtips to create tapered or conical slotted winglet configurations. The incorporation of tapered slotted winglets has proven to be beneficial for enhancing the performance of low *AR* wings. Overall, the present findings provide valuable insights for optimizing wing design and improving the aerodynamic efficiency of MAVs.