Numerical Study of Owls’ Leading-edge Serrations

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Owls’ silent flight capability is commonly attributed to their special wing morphology and wingbeat kinematics. One of these special morphological adaptations is known as leading-edge serrations: rigid miniature hook-like patterns placed at the primaries of the leading edge of their wings. The connection between flow field alteration due to the presence of serration and subsequent noise signature alteration is not self-evident. It has been hypothesized that leading edge serrations function as a passive flow control mechanism, impact the aerodynamic performance and supposedly alter the boundary layer developed over the wing and subsequently the wake flow dynamics. To elucidate the flow physics associated with owls’ leading-edge serration, we investigate the flow field characteristic around an owl wing with serrated leading-edge geometry during gliding at an intermediate chord-based Reynolds number (Reₐ ~ 40,000). We use a direct numerical simulation (DNS) approach, where the Navier-Stokes equations for incompressible flow are solved on a Cartesian grid with sufficient resolution to resolve all the relevant flow scales, while the wing is represented with an immersed boundary method. We have simulated two wing planforms: with leading edge serrations and without (see Figure 1). Our findings suggest that serration improves suction surface flow by promoting sustained flow reattachment via streamwise vorticity generation at the shear layer, prompting weaker reverse flow, and thus augmenting stall resistance. It is also found that serration increases turbulence level in the downstream flow. Turbulent kinetic energy budget comparisons showed that whilst dissipation is not affected by the presence of serrations, the production terms change, thus demonstrating the impact of serrations on the turbulent scales. Flow scale reduction is also evident from the trailing edge noise spectra where spectral energy distribution is shifted towards multiple frequencies with low energy content as compared to the smooth leading-edge case.

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Figure 1: Iso-surface of Q-criterion coloured by streamwise vorticity for (left) smooth leading-edge wing and (right) serrated leading-edge wing.