Parametric Optimization and Discovery of a Low-Noise Toroidal Quadrotor Propeller With a Leading Blade Segment Height Offset for Responsible Wildlife Research

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Quadrotors, or drones, have the distinct potential to streamline wildlife observation research efforts, which, in turn, focus on improving the biodiversity and carbon sequestration of ecosystems. Yet, noise from the quadrotor propellers is harmful to the environments being studied. Recently, the toroidal propeller was developed, with its unique shape resulting in noise reduction. The current literature has limited analysis regarding geometrical variations of the toroidal propeller. This work computationally and experimentally investigates the effect of varying the following toroidal propeller design features on aerodynamic and acoustic performance to develop the quietest and most efficient model for utilization in wildlife observation: collective pitch angle, tip taper, chord length and taper, minor axis length, and camber. This work also identifies a novel design parameter, the leading segment height blade height offset, that further reduces the acoustic signature of the toroidal propeller by 1.9 dBA. The thrust and torque of computer-aided design (CAD) models of all variations were first simulated using the Reynolds-Averaged Navier Stokes equations in computational fluid dynamics (CFD) simulations. Candidate designs were 3D printed and experimentally tested with static thrust and torque test stand measurements, and the figure of merit (FM) efficiency and noise output were analyzed against a conventional propeller. Optimal values of all seven design parameters were identified, resulting in a 4.4 dBA quieter propeller that exhibits a 40.7% noise reduction in the mean sound pressure over the 1000 to 10000 Hz frequency range —where animals are most sensitive to sound—thereby enabling responsible environmental engagement.

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