Impact of Toroidal Propeller Design on Unmanned Aerial Vehicle Acoustic Signature and Aerodynamic Performance

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Unmanned aerial vehicles (UAVs) are increasingly used for many applications across a range of industries. Increased UAV usage poses a public health and environmental threat due to the annoying and potentially harmful noise they produce. This research examined the potential for toroidal propellers to decrease drone noise while maintaining or improving thrust. Using Computational Fluid Dynamics (CFD), this study assessed how variations in toroidal propeller blade minor axis length and blade count affected thrust, benchmarked against a control. CFD simulations and physical tests were conducted on custom-designed and manufactured toroidal propellers of nine varying configurations at two different operational speeds in a custom-designed testing apparatus. A less than 5% difference was observed in CFD versus measured results for 16 of 18 tests. Longer minor axis lengths improved thrust for two- and three-blade toroidal propellers at the lower speed, but impact was negligible at the higher speed. All toroidal propeller designs demonstrated more thrust over the stock propeller at the lower speed, while three- and four-blade designs demonstrated thrust capabilities that matched or surpassed the stock propeller at the higher speed. At 10,000 RPM, all toroidal propeller designs were quieter than the stock propeller. This study confirmed reliability of CFD in propeller performance prediction and identified toroidal propellers as viable alternatives to the traditional designs due to their reduced noise levels and ability to produce equal or greater thrust. Future directions include CFD analysis at higher speeds, refinement of the testing apparatus, and evaluation of toroidal propellers in real-world UAV operations.