A Comprehensive Study on the Design, Analysis, and Practical Application of Elliptical Annular Wing Aircraft

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Crosswind poses a significant and unavoidable threat to flight safety. Aircraft with elliptical annular wings have been proposed to possess inherent advantages for operations in strong crosswind conditions. This study aims to comprehensively investigate this premise through the integrated analysis and design, and construction of an unmanned elliptical annular wing prototype testbed aeroplane. The research employed a recursive multi-fidelity approach. Initial aerodynamic characteristics of various elliptical annular wings were evaluated using a numerical Vortex Lattice Method (VLM) and wind tunnel tests. Subsequently, complete aircraft configurations were analysed under crosswind conditions using Navier-Stokes-based Computational Fluid Dynamics (CFD) and further physical wind tunnel tests. Based on these findings, an unmanned elliptical annular wing aeroplane prototype testbed was designed and constructed. Wind tunnel results showed that elliptical annular wings have a lift coefficient over twice that of rectangular planar wing of equivalent span at subsonic speeds. Crucially, aircraft models with elliptical annular wings demonstrated a 39% greater induced force along the transverse axis in crosswind during wind tunnel tests when compared to equivalent models with conventional rectangular planar wings. This study demonstrates the practical potential and design considerations for elliptical annular wing aircraft. The configuration offers a significant improvement in stability during crosswind operations, without incurring a weight penalty. Consequently, elliptical annular wings are a particularly advantageous option for aircraft operating in challenging wind environments, such as agricultural aircraft and propeller-driven aircraft servicing remote airfields.

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