Numerical Simulation of a Fixed-Wing UAV and the Effect of Blended Winglets

Toran Bahadur Niroula[1], Nikhil Bhamare[2], Tushar Chourushi[3], and Chandan Bose[4]

[1]Undergraduate student, Department of Mechanical and Aerospace Engineering, Pulchowk Campus
[2]CFD Engineer, CFD Baba
[3]Assistant Professor, Department of Aerospace Engineering, MIT Art, Design and Technology University, Pune, Maharashtra 412201, India
[4]Assistant Professor, Aerospace Engineering, College of Engineering and Physical Sciences, The University of Birmingham

May 2025

Synopsis

This research migration study aims to replicate and extend the work "Numerical Simulation of a Flow Around an Unmanned Aerial Vehicle", Mechanika, vol. 17, no. 2, pp. 193–196, 2011 by S.M.A. Meftah et al. using the open-source computational fluid dynamics (CFD) software OpenFOAM. The study investigates the aerodynamic performance of a small fixed-wing unmanned aerial vehicle (UAV) with an inverted V-tail, a configuration relevant for various civil and defence applications such as aerial surveillance and reconnaissance, environmental and disaster monitoring, and remote delivery. This makes it necessary to accurately model flow separation and tail-wing interactions, as well as assess the effect of geometric modifications like winglets while using validated and computationally affordable m odels. This study employs `simpleFoam`, a steady-state incompressible solver in OpenFOAM, and uses the Spalart–Allmaras (SA) turbulence model, which aligns with the reference study. The half-domain model is used, taking advantage of the longitudinal symmetry found in cruise to reduce computational cost. An unstructured mesh is generated using `snappyHexMesh`, with refinement and local surface feature resolution near the surface of the UAV. Mesh independence is verified using the lift coefficient, and results are validated against the experimentally validated numerical results of Meftah et al. Furthermore, the study examines the effect of blended winglets with cant angles of 90° and 45° at a constant sweep and taper ratio, revealing a maximum lift-to-drag ratio improvement of 14.95% at a 45° cant angle compared to the baseline design. These results confirm that the exploration of the winglet design can enhance aerodynamic performance without altering the geometry of the main wing. The work provides insight into effective design strategies for performance enhancement in small-scale UAVs, helping bridge the gap between academic CFD studies and practical UAV development.

Keywords: OpenFOAM, simpleFoam, UAV, RANS, turbulence modeling, winglets, cant angle