Integrating CFD, Experiments, and Bayesian Inference for Aerodynamic Analysis of a Serrated Delta Wing

S.K. Maharana[a], Anand M. Raikar[b], N. Chikkanna[b]

[a]*Dept. of Aerospace and Automotive Engineering, MSRUAS, Bangalore, India*
[b]*Dept. of Aerospace Engg., Visvesvaraya Tech. University, Muddenahalli, Karnataka, India*
Corresponding Author, Email: skmaha123@gmail.com

Background

Bayesian inference has emerged as a transformative statistical framework for aerospace engineering, particularly for aerodynamic studies where uncertainty plays a critical role. Unlike traditional deterministic methods that rely exclusively on computational fluid dynamics (CFD) or experimental testing, Bayesian approaches combine prior knowledge with observed data to produce robust probabilistic predictions. This study applies Bayesian inference to investigate the aerodynamic performance of a serrated double delta wing—a configuration known for generating strong leading-edge vortices that enhance lift and maneuverability at high angles of attack. The incorporation of serrations along the leading edge is hypothesized to manipulate vortex behavior, delay separation, and improve aerodynamic efficiency, yet these effects remain complex and highly nonlinear.

Methods

A comparative framework is developed between serrated and non-serrated double delta wings using both CFD simulations and wind tunnel experiments. Bayesian updating is employed to merge these datasets, accounting for turbulence modeling uncertainties, mesh sensitivity, and experimental noise. Lift, drag, and lift-to-drag ratios are analyzed alongside vortex strength, treated as random variables within the Bayesian model.

Results

The Bayesian framework demonstrates that serrated configurations yield statistically significant increases in vortex strength compared to non-serrated wings, particularly at moderate to high angles of attack. Posterior distributions confirm enhanced lift generation and delayed stall behavior in the serrated wing. The probabilistic model provides credible intervals for aerodynamic coefficients, ensuring predictions remain robust under uncertainty.

Significance

This research highlights the novelty of applying Bayesian inference to a complex aerodynamic configuration. By bridging CFD predictions, experimental data, and statistical learning, the study provides not only improved predictive accuracy but also deeper physical insights into vortex-dominated flows. The work demonstrates the potential of Bayesian reasoning to guide design optimization under uncertainty, thereby contributing to safer, more reliable, and performance-driven aerodynamic solutions.

Conclusion

The study establishes Bayesian inference as a powerful methodology for aerodynamic performance assessment and design optimization of serrated double delta wings. Its probabilistic nature ensures robustness and reliability—key requirements in aerospace engineering—while its ability to extract insights under uncertainty paves the way for integrating unconventional aerodynamic concepts into next-generation aircraft.