Wing Optimization Report

LLM Analysis

July 27, 2025

1 Executive Summary

This report summarizes the results of an aerodynamic optimization performed on a wing design. The objective was to minimize drag at a lift coefficient of 0.5, with constraints on wing area (400 m^2) and span (60 m). The design variables included taper, dihedral, twist, and sweep. The optimization was conducted using the SLSQP algorithm. The analysis reveals a successful drag minimization, although some design variables reached their specified bounds. Further optimization and considerations are recommended to enhance the design.

2 Problem Formulation

The wing optimization problem was formulated to minimize drag, subject to a lift coefficient constraint of $C_L = 0.5$. The geometric constraints were a fixed wing area $S = 400$ m^2 and span $b = 60$ m. The design variables were taper ratio, dihedral angle, twist distribution, and sweep angle. The optimization algorithm employed was SLSQP.

3 Optimization Results

The optimization process converged in 17 iterations, achieving a final drag coefficient (C_D) of 0.01093787 while satisfying the lift coefficient constraint ($C_L = 0.5$). The design variables converged to the following values:

- Angle of attack (α): 3.94 degrees
- Taper ratio: 0.2 (lower bound)
- Dihedral angle: 2.64 degrees
- Twist: Values between 1.64 and 2.41 degrees
- Sweep angle: 30 degrees (upper bound)

4 Analysis of Results

The optimization successfully reduced the drag coefficient while meeting the lift constraint. However, the taper ratio and sweep angle converged to their lower and upper bounds, respectively, indicating that further drag reduction might be possible with expanded design space limits. The lift distribution, as shown in Figure 1, is close to elliptical, which is desirable for minimizing induced drag, but not perfectly elliptical, suggesting room for improvement.

5 Recommendations

Based on the optimization results and analysis, the following recommendations are made:

1. **Expand Design Space**: Increase the upper and lower bounds for the taper ratio and sweep angle, as these variables converged at their limits. This allows the optimizer to explore a broader design space.

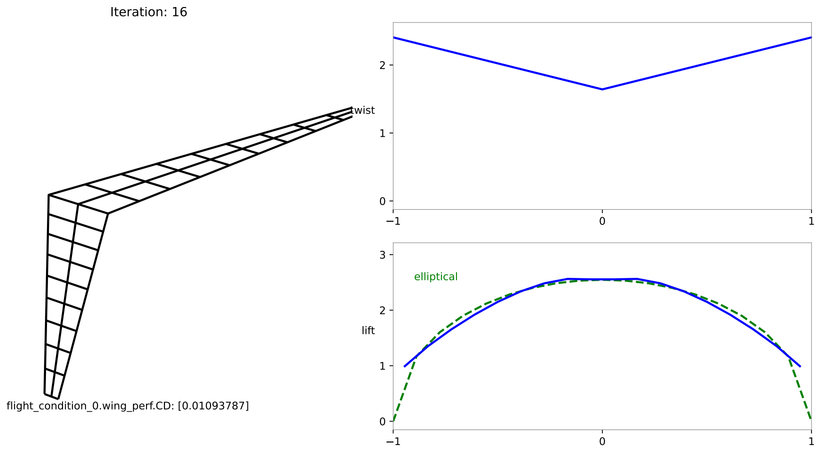

Figure 1: Optimized Wing Visualization: Elliptical Lift Distribution and Twist Distribution

2. **Mesh Refinement**: Refine the mesh used in the OpenAeroStruct model to more accurately capture the aerodynamic characteristics of the wing.

3. **Geometric Constraints**: Explicitly add constraints for wing area and span to ensure these geometric parameters are strictly enforced during optimization.

4. **Advanced Optimization Algorithms**: Consider using more advanced optimization algorithms, such as genetic algorithms or surrogate optimization, to potentially achieve further drag reduction.

5. **Aerostructural Optimization**: Extend the optimization to include structural considerations. This involves incorporating a structural model to account for the structural integrity and weight of the wing.

6 Additional Considerations

- **Manufacturability**: Evaluate the manufacturability of the optimized wing, considering the low taper ratio and specific twist distribution. Practical manufacturing constraints should be incorporated in future design iterations.

- **Multi-Point Optimization**: Conduct a more comprehensive design optimization that considers performance at multiple flight conditions (e.g., takeoff, landing, maneuver) and includes additional constraints related to stability and control.

- **Reynolds Number Effects**: Incorporate Reynolds number effects into the optimization, especially if the airfoil characteristics are sensitive to Reynolds number variations.

- **Airfoil Optimization**: Consider optimizing the airfoil shape as part of the design process. While constraining the airfoil is suitable for initial optimizations, allowing the optimizer to select an optimal airfoil can further improve performance.