Wing Optimization Report

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1 Executive Summary

This report details the optimization of a wing design with the objective of minimizing drag (C_D) while maintaining a lift coefficient (C_L) of 2.0. The optimization was performed using the SLSQP algorithm, with design variables including taper, twist, and sweep. Geometric constraints were set for the wing area (S = 100 m^2) and span (b = 10 m). The optimization converged successfully, resulting in a minimized drag coefficient of 0.01093787. The optimized design was analyzed, and recommendations are provided for further improvements.

2 Problem Formulation

The optimization problem was formulated as follows:

- Objective Function: Minimize drag (C_D)
- Trim Condition: $C_L = 2.0$
- Geometric Constraints: Wing area (S) = 100 m^2, Span (b) = 10 m
- Design Variables: Taper, Twist, Sweep

3 Optimization Results

The optimization process converged in 17 iterations using the SLSQP algorithm. The key results are summarized below:

- Minimized Drag Coefficient (C_D): 0.01093787
- Final Design Variable Values:
  - Angle of Attack (alpha): 3.94 deg
  - Taper Ratio: 0.2
  - Twist (at control points): Varying between -5 and 5 deg
  - Sweep: 30 deg

The lift distribution plot approximates an elliptical distribution, with some deviations observed near the wingtips.

4 Optimized Wing Visualization

Figure 1 presents the optimized wing design.

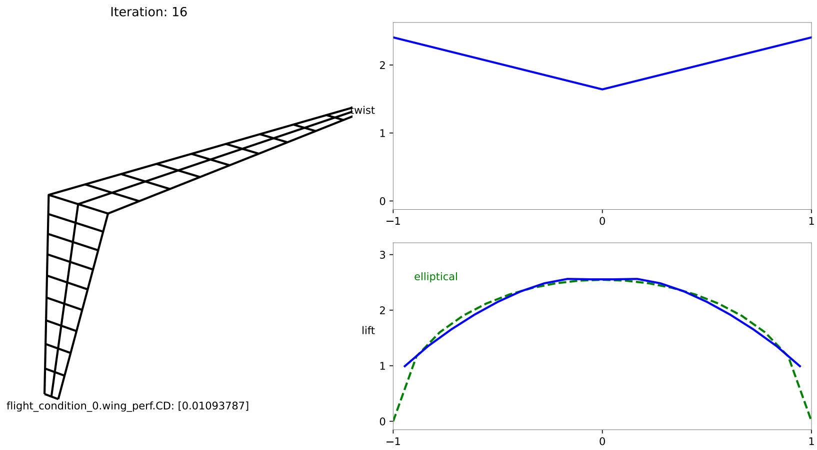

Figure 1: Optimized Wing Visualization

5 Analysis and Recommendations

5.1 Analysis

The optimization process effectively minimized drag while adhering to the specified lift constraint. The design variables converged within their defined bounds. The final optimized configuration presents a wing with a sweep of 30 degrees, a taper ratio of 0.2, and a twist distribution varying between -5 and 5 degrees. The lift distribution achieved is approximately elliptical, albeit with deviations observed towards the wingtips. The wall clock runtime was minimal, which indicates the process was efficient.

5.2 Recommendations

To further refine the design, the following recommendations are suggested:

- **Sensitivity Analysis:** Investigate the sensitivity of the solution to the design variable bounds, particularly for sweep and taper.
- **Twist Distribution Refinement:** Further optimize the twist distribution to more closely achieve an elliptical lift distribution. This might involve using more control points or a different parameterization for the twist.
- **Winglets:** Consider adding winglets to further reduce induced drag.
- **Structural Constraints:** Incorporate structural constraints and weight considerations into future optimizations to ensure a feasible and practical design.
- **Higher Fidelity Methods:** Recognize that the Vortex Lattice Method (VLM) has limitations, especially for stalled flows. Explore higher-fidelity methods for more accurate drag predictions.
- **Multiple Flight Conditions:** The optimization was conducted for a single flight condition. A more robust design should consider multiple flight conditions to ensure good performance across a range of operating points.
- **Manufacturability:** Evaluate the manufacturability of the optimized wing, particularly concerning the twist distribution and taper ratio.

6 Optimization Algorithm Performance

The SLSQP algorithm demonstrated suitable performance, converging in 17 iterations. Given the problem's simplicity and fast convergence, SLSQP appears adequate. For more complex scenarios with additional constraints or objectives, alternative algorithms like SNOPT or genetic algorithms could be considered.

7 Unrelated Observations

The rectangular wing mesh employed might introduce inaccuracies. Also, be mindful of potential issues with area and span constraints based on documentation. VLM is a lower-fidelity method, so absolute drag values should be interpreted with caution. Finally, manufacturability aspects of the optimized wing should be assessed, focusing on twist distribution and taper ratio.