Aerodynamic Design Optimization Workshop: Multimodal Subsonic Inviscid Optimization Problem

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Summary: Participants will perform a lift-constrained drag minimization of a wing under subsonic flow conditions ($M_\infty = 0.5$) governed by the Euler equations. This case is intended to admit multiple local minima. The optimization problem can be stated as

$$\min_{\mathbf{v}} \quad C_D(\mathbf{v}, \mathbf{q}),$$

$$\text{such that} \quad C_L(\mathbf{v}, \mathbf{q}) = 0.375$$

where C_D and C_L are the coefficients of drag and lift, respectively, $\mathbf{v}$ is the vector of geometric design variables, and $\mathbf{q}$ are the flow variables. The discrete flow equations also provide a constraint, and there are additional geometric constraints which are discussed below.

Geometry: As shown in Fig. 1, the baseline geometry uses NACA0012 sections with a sharp trailing edge. The semispan is 3.06 units, where the unit of length is defined by the chord length of the baseline geometry. The geometry is rectangular and planar, with no twist, taper, sweep, or dihedral, and has a pinched wingtip cap over the last 0.06 of span, as shown in the figure.

Design Variables: A high degree of geometric freedom is allowed in this case. The root of the wing is fixed in all three dimensions - though sectional control and chord changes are permitted. Either an angle-of-attack or root twist design variable should be used. At all other points all DOF are permitted: twist, taper (chord), sectional, sweep, span, and dihedral, though these are subject to linear and nonlinear constraints described below.

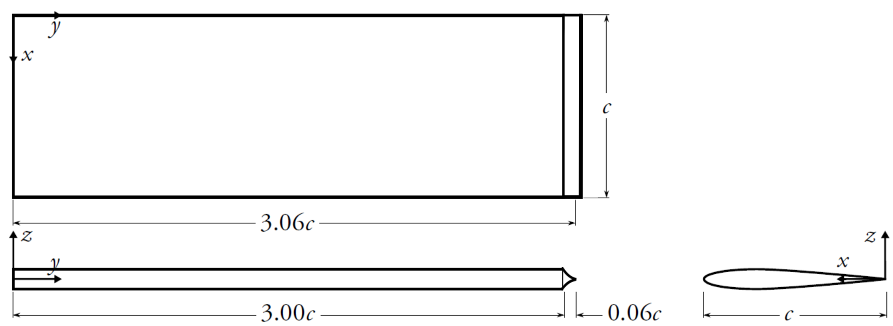

Figure 1: Three-view of baseline geometry for multimodal case

Constraints: A lift coefficient of 0.375 must be maintained. All values are nondimensionalized by the projected area S, which is constrained to the initial value of 3.06. Total volume is constrained to be no less than the volume of the baseline shape, approximately 0.245 square units. This includes the contribution from both the body and the wingtip cap. A root bending moment constraint is applied, limiting the maximum root bending moment to ??? nondimensionalized in a manner consistent with the lift coefficient, i.e. based on the projected area and the unit of length. Twist is limited to ± 2.0 degrees, chord may only vary between 0.450 and 1.550, and the cross-sectional thickness may not vary by more than $\pm$ 50%. Sweep is achieved by shearing the wing while maintaining the span such that the quarter chord location at the tip is no more than $\pm$ 1 chord length from its original position, span may vary between 2.46 and 3.67, and dihedral may not take a value such that the vertical position of the quarter chord lies more than 0.45 chord lengths above or below its initial position.
Grid: Although the grids used for optimization can be selected by the participants, analysis of optimized geometries should include some sort of an attempt to determine grid converged lift and drag coefficient values, such as a grid refinement study with Richardson extrapolation.
Suggested Results: The following results should be reported:

1. Number of optima
2. Geometric configuration and other relevant design variables (i.e. AOA) for each optimum
3. Some evidence of convergence for each optimum
4. Performance values for each local optimum, preferably eb^2,[1] where b is the final span and e is the span efficiency, defined as:

$$e = \frac{C_L^2}{2\pi S C_D} \tag{1}$$

[1]This enables comparison at slightly different lift coefficient values resulting from different meshes.