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On the application of panel methods for shape optimization of aircraft wings

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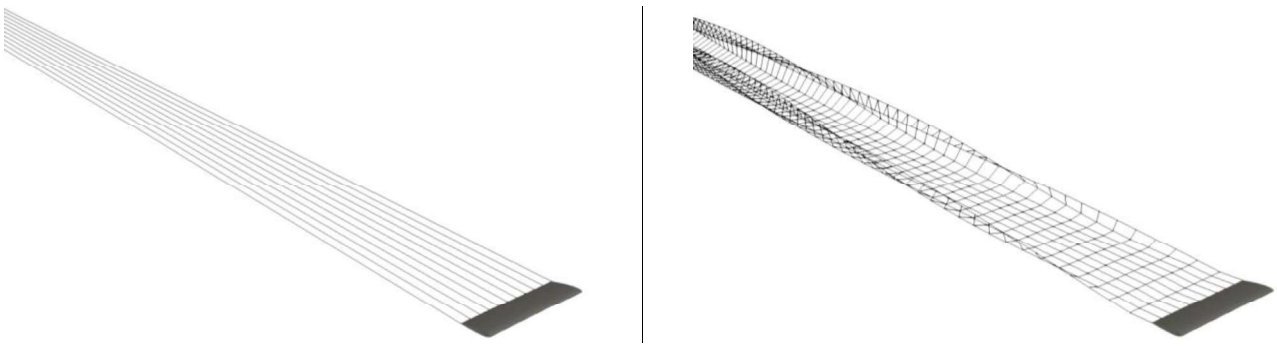
Abstract Panel methods are commonly used to study external flow problems as they can be applied to arbitrary geometries and have fast turnaround times as only surface mesh is required. These advantages make panel methods perfect for design optimization problems where geometry can be unpredictable during intermediate optimization steps, and the physics problem must be solved on each iteration. In this work we will discuss some of the main considerations in applying panel methods to shape optimization of aircraft wings. More specifically the discussion points will focus on (a) boundary conditions, (b) parametrization methods, and (c) the wake model.

(a) A Neumann or Dirichlet boundary condition (BC) can be used to satisfy the no penetration condition. The Neumann BC is appealing as it is the more intuitive of the two, however it can be shown that there are substantial time savings in solving the Dirichlet BC especially when applied to optimization routines.

(b) It is tempting to parameterize the wing geometry using global variables such as taper ratio or standard airfoils. However, design optimization generally requires large changes in the geometry and as such these standard methods create limitations on the design space. To avoid these limitations we implement a versatile paratermization method that allows large changes in the geometry using local variables. These variables are then subject to filtering in order to avoid numerical artefacts such as clustering/isolation of design points and saw-tooth geometries.

(c) Low-fidelity wake models (such as planar wakes) are desirable as the computational cost is low, however if the design is pushed to more complex geometries these methods cannot accurately capture the aerodynamic performance. Iterative models allow the wake to develop in time, offering a higher fidelity alternative which can maintain sufficient accuracy throughout the optimization procedure.

Our 3D panel method utilizes a source-doublet surface distribution, can use an iterative procedure to capture wake geometry, and sensitivities are calculated using an adjoint method. Flow is assumed to be inviscid, thus viscous and friction drag is neglected, however the wake model allows the user to calculate induced drag. A typical optimization problem is to minimize induced drag subject to lift and geometry constraints.



(a) (b)

Figure 1. (a) Shows a low fidelity model with planar trailing vortex lines. This method is cost efficient but can lead to inaccuracies for complex geometries. (b) Shows an iterative procedure for capturing the wake geometry. This method is more robust for complex geometries but substantially increases computational expense.