EAE 127 Applied Aircraft Aerodynamics

Project 3
Source Panel Method

Upload all files to the 'Assignments' section on Canvas in a single, compressed (zip) folder, which must contain a '.ipynb' Jupyter Notebook report (all Python code must run), a '.html' hard copy, and all data files necessary to run code. 'Run All' before uploading. (More details: 'EAE127_FAQ.pdf').
DUE: Monday 11/9/20 11:59pm

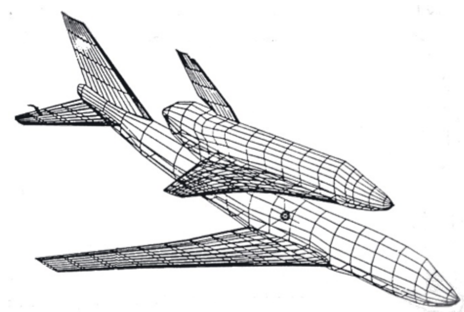

Fig. 1: 3D panel representation of the Shuttle Carrier Aircraft

1 Flow Over A Non-Rotating Cylinder

Create a source panel method solver to compute flow over a non-rotating cylinder. You may use AeroPython Lesson09 as a reference for constructing your code, but make sure you gain a fundamental understanding of the panel method process, as you will need to modify this code in the future without an example to go off of.

Discretize the cylinder into **8, 32, and 128 panels** for three independent solutions to observe the effect of panel size distribution. Use the panel centers as the control points.

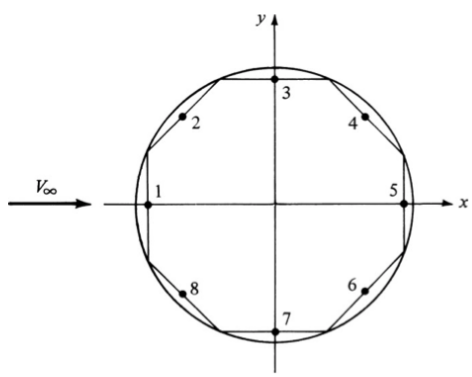

Fig. 2: Panel representation of cylinder

For each case, solve the cylinder panel system to determine the panel strength values that achieve the tangency condition and **check** that the resulting panel source distributions **create a closed body** according to Eqn 3.157 in Anderson. On a **single figure** for all of the following cases, **plot surface pressure distribution as a function of** θ (Anderson Fig 3.43) for:

- Cylinders discretized with 8, 32 and 128 panels (Hint: plot as points, not line)
- Non-rotating cylinder potential flow theory results (Anderson Eqn. 3.101)

Comment of the sensitivity of the solution to the number of panels used.

Plot the error in the cylinder surface pressure distribution compared to the analytic solution as a function of number of panels to quantify the effect of number of panels on accuracy (Use more data points than just the previous three cases extending to greater than 128 panels). **Calculate the error** as the difference of the integrated areas of the surface pressure curves of the analytical and panel method solutions (Eqn 1).

$$Error = \int_0^{2\pi} C_{P,Analytic} \cdot d\theta_{Analytic} - \int_0^{2\pi} C_{P,Panel} \cdot d\theta_{Panel} \tag{1}$$

For the case with 32 panels, **additionally plot**:

- **Pressure contours** surrounding cylinder (plot coefficient of pressure)
- **Streamlines** surrounding cylinder
- **Surface pressure gradient** $\frac{\partial C_P}{\partial \theta}\, vs\, \theta$ for $\theta = 0$ to π

2 Symmetric Airfoil

Use your source panel method solver to compute horizontal flow ($\alpha = 0^o$) over a NACA 0018 airfoil (See AeroPython Lesson10).

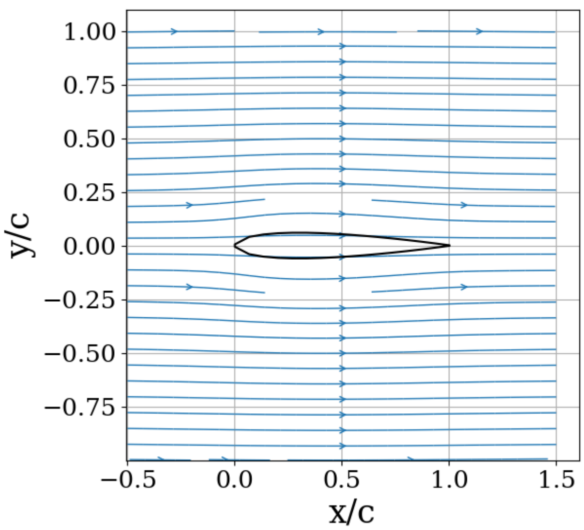

Fig. 3: A source panel solution for the horizontal flow over a symmetric airfoil

Use **101 panels**, **constantly spaced in the x-direction** (see panel discretization demo) with control points at the centers of the panels (Note: Do not use the circle-mapping panel spacing method in AeroPython).

Observe the performance of your panel code by plotting **(on the same plot) surface pressure distribution for**:

- Your panel method solution
- Inviscid XFOIL panel code results

With your panel code results, **additionally plot**:

- **Pressure contours** surrounding airfoil
- **Streamlines** surrounding airfoil

Discuss behavior of the potential flowfield surrounding the airfoil.

Using your panel code results, **integrate the surface pressure for solutions with increasing numbers of panels, (starting with 11)** to calculate the aerodynamic force coefficients C_l and C_d.

Plot the force coefficients against number of panels used to determine the number of panels where the solution converges and **report this number and justify your reasoning**. **What would you expect the values of the force coefficients to be for truly inviscid, symmetric flow**?

NOTE: For problems 1 and 2, use a freestream velocity $V_\infty = 1$.

3 Additional Problems

3.1 Irrotationality

In Lecture 8, we learned about a point-source potential flow. **Show that such a flow is indeed irrotational.**

3.2 Boundary Layers

Show (via equations) why no boundary layer is irrotational.

3.3 Potential Flow

For the potential uniform + source flow in Lecture 8, **derive the equation** for the distance from the location of the source at which the radial velocity is one-third the freestream velocity, if $\theta = 90^o$?

3.4 Circular Cylinder

For the 747 that carried the Space Shuttles, consider the cylindrical strut that supported the nose of the Shuttle (see photo). Assuming potential flow about a cylinder, **estimate the pressure on the strut at the leading edge, and at** 45^o **from the leading edge**. Assume 12 inch diameter, 20,000 ft altitude, standard atmosphere, and 185knots airspeed.

Fig. 4: Shuttle Carrier Aircraft with Space Shuttle Endeavor mounted above