Homework #: Aerodynamic Properties of an Airfoil

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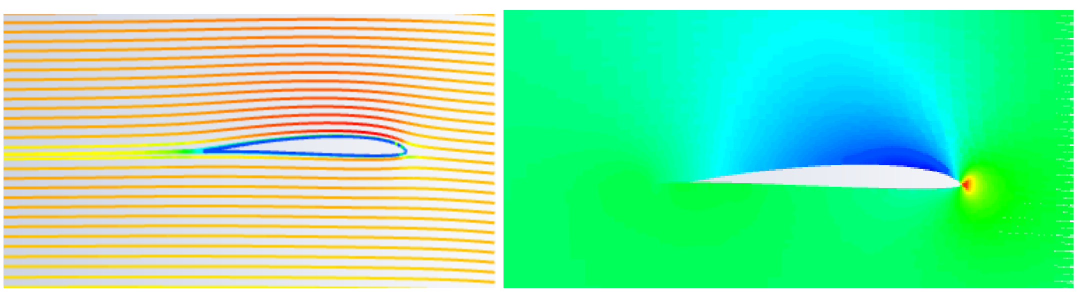
Intended learning outcomes

- Understand how airfoils can generate lift
- Use CFD to calculate the aerodynamic properties of a wing

Overview of Lift

Asymmetric Airfoils like the one shown below, are designed to generate lift and minimize drag. The curved top of the airfoil causes the air to move faster than the flow on the bottom of the wing. The reason this happens is quite complicated and often oversimplified leading to misconceptions, if you're interested in learning more see slides 14 and 15 in the CFD tutorial. Using Bernoulli's Equation you can show that the higher velocity flow means there is less pressure. Leading to low pressure on top and high pressure on the bottom pushing the wing up.

$$\text{Bernoulli's equation: } P_1 + \frac{\rho V_1^2}{2} = P_2 + \frac{\rho V_2^2}{2}$$



Figures 1,2: (Left) air flow lines over the airfoil colored with the velocity.
(Right) Pressure gradient around the wing showing the inverse correlation between velocity and pressure.

The pressure on the surface is ultimately what causes lift. There is pressure normal to the surface at every point on the wing. By integrating the pressure over the area you can find a force vector, the vertical component of which is the lift force and the horizontal component is the pressure drag (note that you can also have surface drag caused by shear force, and induced drag from air spiraling over a wing tip).

Lift and drag equations

Solving for force using pressure is complicated and time intensive, so it's typically much easier to use the Lift and drag equations that wrap the complex parts of geometry and surface interaction with the fluid into two coefficients (C_L & C_d) to find forces of lift and drag.

$$Force\ of\ Lift = \frac{C_L \cdot \rho \cdot V^2 \cdot A}{2} \qquad Force\ of\ Drag = \frac{C_d \cdot \rho \cdot V^2 \cdot A}{2}$$

Where

- F = Force [N]
- Rho = density of fluid [kg/m^3]
- V = Velocity of object [m/s]
- A = Reference area - for airfoils typically wing chord or cross section area [m^2]

The Coefficients C_L & C_d are normally looked up in tables for common geometries or found experimentally. But we will be finding them for an airfoil using ANSYS Fluent.

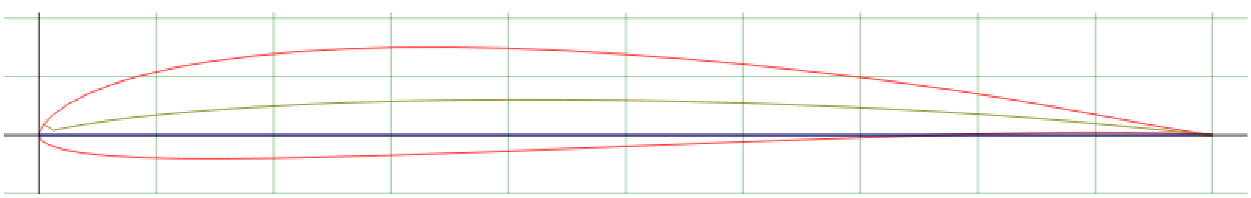
Note that while velocity shows up in the lift and drag equations, the lift and drag coefficients are dependent on Reynolds number. So remember to find the coefficients for Reynolds numbers close to your final application.

Finding properties of a 2D shape with ANSYS Fluent

Due to the computational intensity of running a 3d simulation and the limitations of the olin laptops, we will be analyzing a 2d airfoil. An in depth explanation of how to use ANSYS Fluent can be found here.

Challenge

Find the lift and drag coefficient of the SD7037 airfoil, assume velocity of 15 mph, airfoil shape is shown below.



Once you have a value, compare it with the value found here. How similar are they? If there are discrepancies what do you think is causing them?