Vortex Panel Mini - Project

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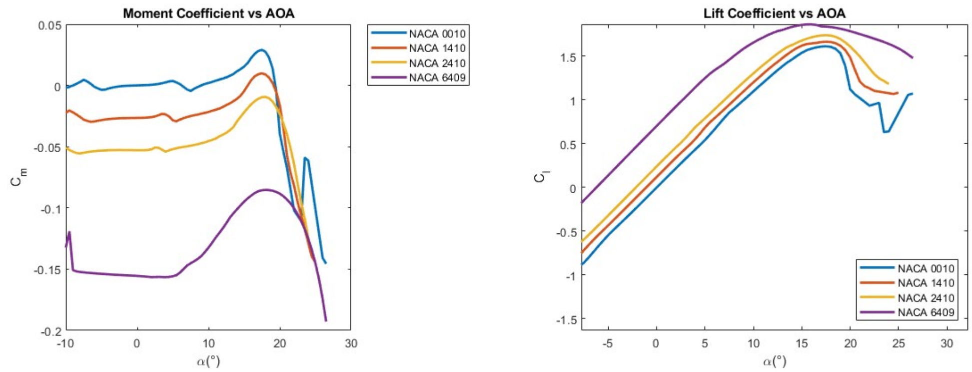
Nomenclature

C_D	Drag coefficient
C_L	Lift coefficient
C_M	Moment coefficient
C_P	Pressure coefficient
α	Angle of attack
$\frac{x}{c}$	x - location normalized to chord

I. Results and Discussion

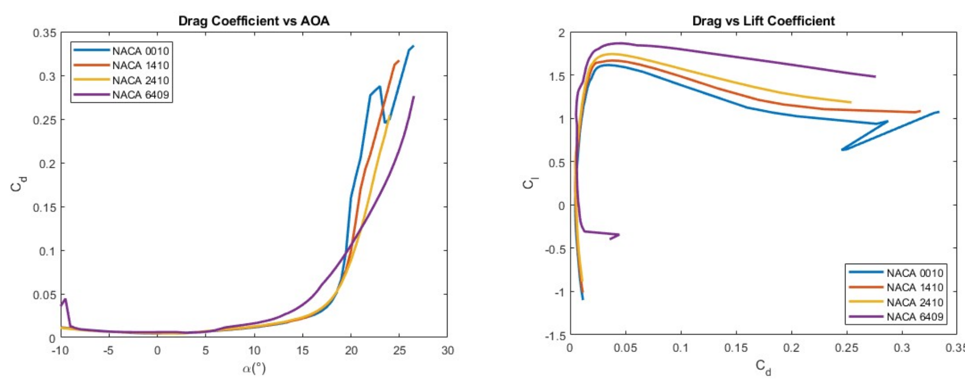
In the Vortex Panel Mini-Project, I gathered the aerodynamic characteristics of four airfoils NACA 0010, NACA 1410, NACA 2410, and NACA 6409. I set the Reynolds number (Re) to 3000000 and the Mach number (Ma) to 0.1 as instructed. I generate eight graphs describing the lift coefficient, drag coefficient, moment coefficient, and pressure coefficient for each airfoil at angles of attack $\alpha = 0$, 5, 10 degrees. Now after looking over the data for each airfoil we can see clear differences between them and their characteristics. The NACA 0010 is a symmetric airfoil with lower camber and sensitivity to changes in angle of attack. In the (fig:2-b) it shows a good amount of lift and low drag, making it proficient for high speed and efficiency designs. The NACA 1410 is also a symmetric airfoil with a larger lift coefficient than previous airfoil, similar to the NACA 0010 but now with a slightly higher drag. It has a more flatter camber and a longer trailing edge, this will result in a decrease in the drag force and a increase in the lift coefficient as we can see. The C_m versus α plot (fig:1-a) for the NACA 0010 is relatively flat and the takes a steep decline. This can indicate a higher sensitivity to angle of attack changes. The NACA 1410 has a very similar steeper slope which is demonstrated, making it more sensitive to changes in angle of attack. The Cl versus alpha curves show that the NACA 1410 has a slightly higher maximum lift coefficient of around 1.5 but reaches stall at a lower angle of attack compared to the NACA 0010. The

(C_D) versus α plot (fig:2-a) for the NACA 0010 shows a sudden increase in drag coefficient at 5 degrees, this also is indicating a stall. It has a high drag coefficient, making it more suitable for low-speed applications requiring high lift.



(a) **(b)**

Fig. 1: The (a) graph will be moment coefficient versus alpha, which will show the pitching moment of each airfoil at different angles of attack. The (b) graph will be lift coefficient versus alpha, which will show the lift coefficient of each airfoil at different angles of attack.

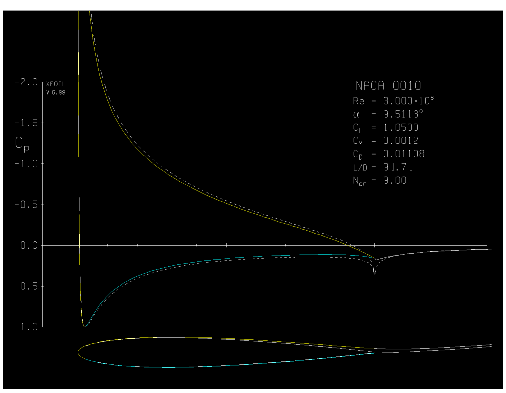


(a) **(b)**

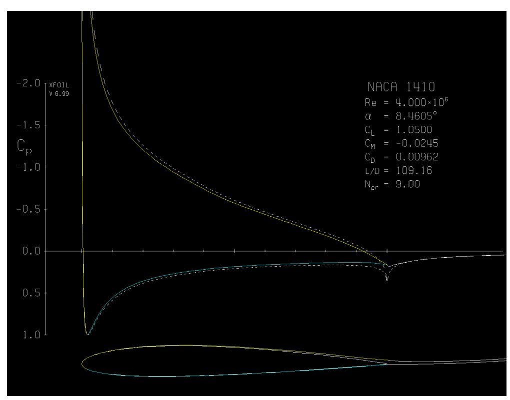
Fig. 2: The (a) graph will be drag coefficient versus alpha, which will show the drag coefficient of each airfoil at different angles of attack. The (b) plot is lift coefficient versus drag coefficient, which will allow us to determine the lift-to-drag ratio of each airfoil.

Now the third airfoil I chose to include is the NACA 2410. It has a lower camber and a thin body, so as you can imagine this would reduces the drag force and allow it to go faster. The fourth airfoil, NACA 6409 airfoil has a thick and cambered. It generates more lift but also more drag than the NACA 0010 airfoil (fig:2-b). In contrast, the NACA 2410 airfoil generates more lift than symmetric airfoils but has higher drag because of the camber. The NACA 6409 airfoil has a relatively flat curve with a slight positive slope, useful for providing lift at high angles of attack (fig:1-b). The NACA 0010 airfoil has a high drag coefficient, a lower C_D at low angles of attack and a more gradual increase in C_D with increasing α (fig:2-a).

So, Cp vs x/c for alpha = 0, 5, and 10 degrees, we can observe the pressure distribution along the four airfoils. Beginning with the NACA 0010 airfoil (fig:3-1), we can see that it exhibits a low maximum lift coefficient and high drag at high angles of attack, which implies a sudden decrease in the maximum lift coefficient. The Cp versus x/c curve for the NACA 0010 airfoil is symmetric, with both upper and lower surfaces having the same magnitude of pressure coefficient, and the point of maximum pressure occurring near the leading edge of the airfoil, with the value of Cp gradually decreasing towards the trailing edge. Comparing the airfoils, the NACA 0010 has the highest peak Cp values near the leading edge, indicating a higher level of pressure buildup in that region, with the maximum pressure point happening a little bit further back on the leading edge than on the NACA 1410. Moving on to the second airfoil, the NACA 1410 (fig:3-b) is similar to the NACA 0010 but shows a higher maximum lift coefficient and a more gradual decrease in lift as the angle of attack increases. In contrast, the Cp vs x/c curve for the NACA 1410 airfoil shows a lower degree of pressure buildup near the leading edge but a more gradual pressure gradient along the airfoil. This implies that the NACA 0010 airfoil has a higher level of pressure buildup near the leading edge. However, the NACA 1410 airfoil has a more gradual pressure gradient, indicating a more stable and predictable lift behavior at different angles of attack.



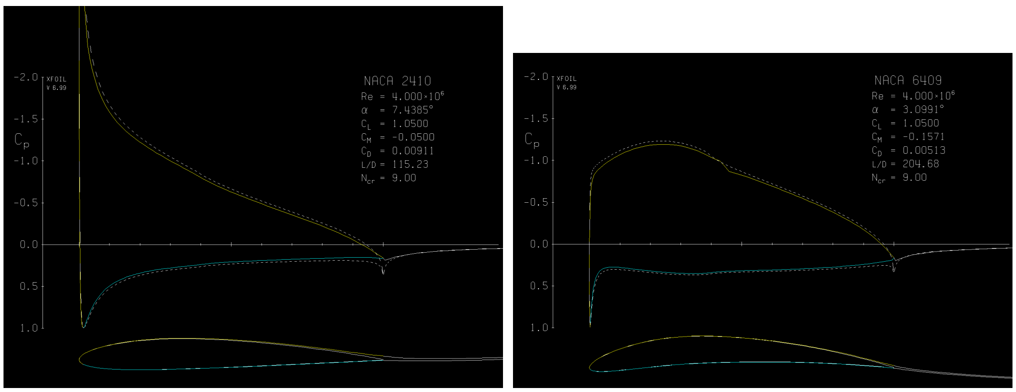
(a)



(b)

Fig. 3: The (a) graph it the pressure coefficient (C_P) verses the $\frac{x}{c}$ of the NACA 0010 airfoil. The (b) graph it the pressure coefficient (C_P) verses the $\frac{x}{c}$ of the NACA 1410 airfoil.

Now, the pressure distribution along the airfoil. For the NACA 2410 airfoil has a lift curve very similar to the NACA 1410. But with a slightly larger drag force at all of the angles of attack we plotted at. The Cp versus x/c curve for NACA 2410 (fig:4-a) has a slightly asymmetric shape, with the upper surface showing a more pointier peak in pressure coefficient than the lower surface. The maximum pressure point is located closer to the leading edge than for NACA 1410, but the overall magnitude of the pressure coefficient is similar. The Cp versus x/c curve has a steeper slope between the leading edge and the point of maximum pressure than for NACA 1410, indicating a more rapid pressure gradient along the upper surface of the airfoil.



(a) **(b)**

Fig. 4: The (a) graph it the pressure coefficient (C_P) verses the $\frac{x}{c}$ of the NACA 2410 airfoil. The (b) graph it the pressure coefficient (C_P) verses the $\frac{x}{c}$ of the NACA 6409 airfoil.

The NACA 6409 airfoil (fig:4-b) has a significantly higher maximum lift coefficient compared to the other three airfoils, but it also shows a higher drag force at all angles of attack we are observing. The Cp versus x/c curve for NACA 6409 has a highly odd shape. This is showing us that the upper surface has a large peak with the pressure coefficient that is close to the leading edge while the lower surface has a flatter slope with a smaller Cp value. The maximum pressure point is close to the leading edge, with a sudden drop in Cp occurring immediately.Now Comparing this to the other airfoils, NACA 6409 has a much higher degree of pressure buildup near the leading edge, but a more rapid decrease in pressure along the upper surface.