Flow around an Airfoil

Fluid Mechanics I

Laboratory session 3 and 4

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1 Plots NACA2410, $\alpha = 6$.

1. **Contour plot of the static pressure.**

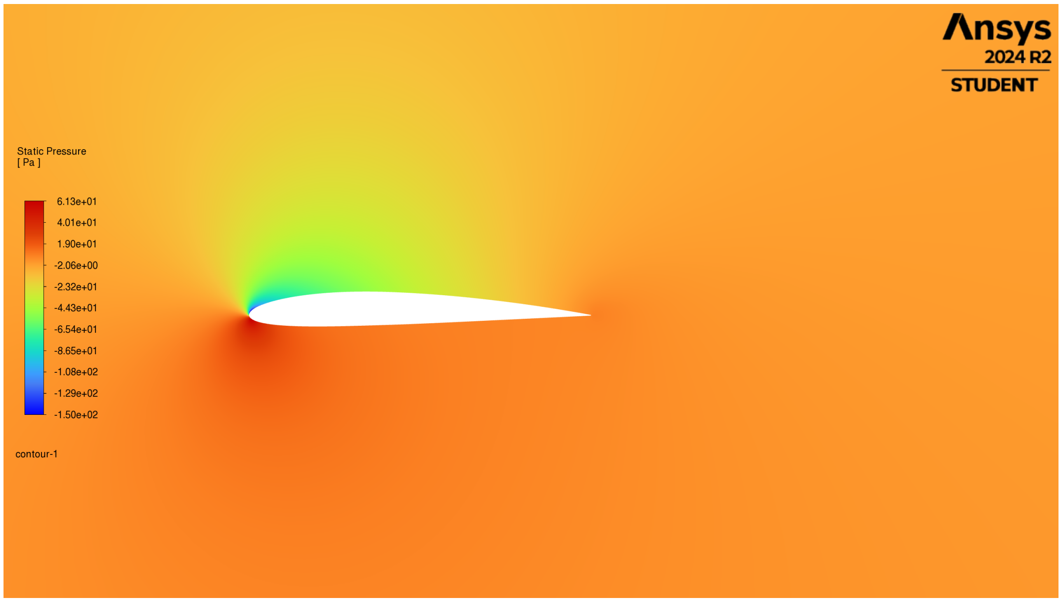

Figure 1: The plot of the static pressure distribution along the foil NACA2410.

2. **Plot of the streamlines surrounding the airfoil.**

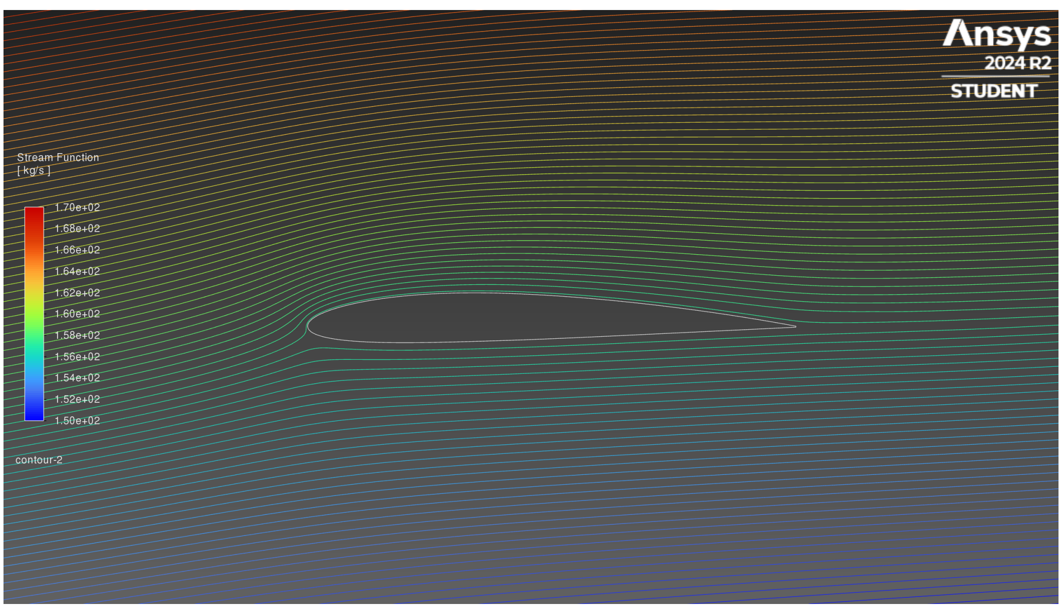

Figure 2: Streamlines

3. **Quiver plot of the velocity profiles (velocity vector field $\mathbf{v}(x, y)$) at the wake at Line/Rake positions $x = 1.0, 1.025, 1.05, 1.075, 1.1$, and 1.2.**

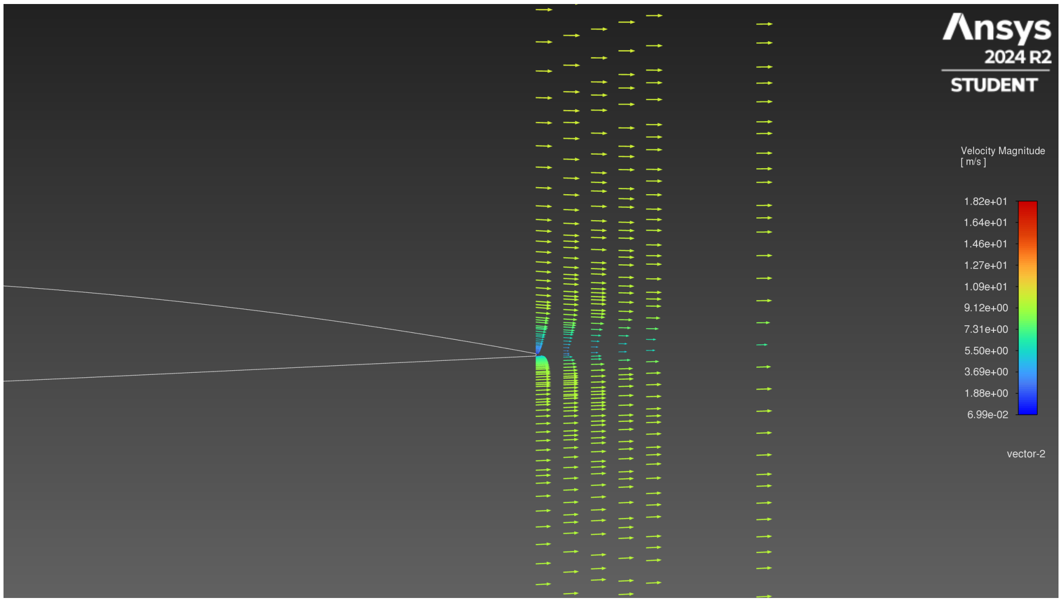

Figure 3: $\vec{v}(x, y)$ at the wake

4. **Quiver plot of the velocity profiles at the leading edge of the airfoil at $x = -0.05, 0.0, 0.025, 0.05, 0.1, 0.15$, and 0.2.**

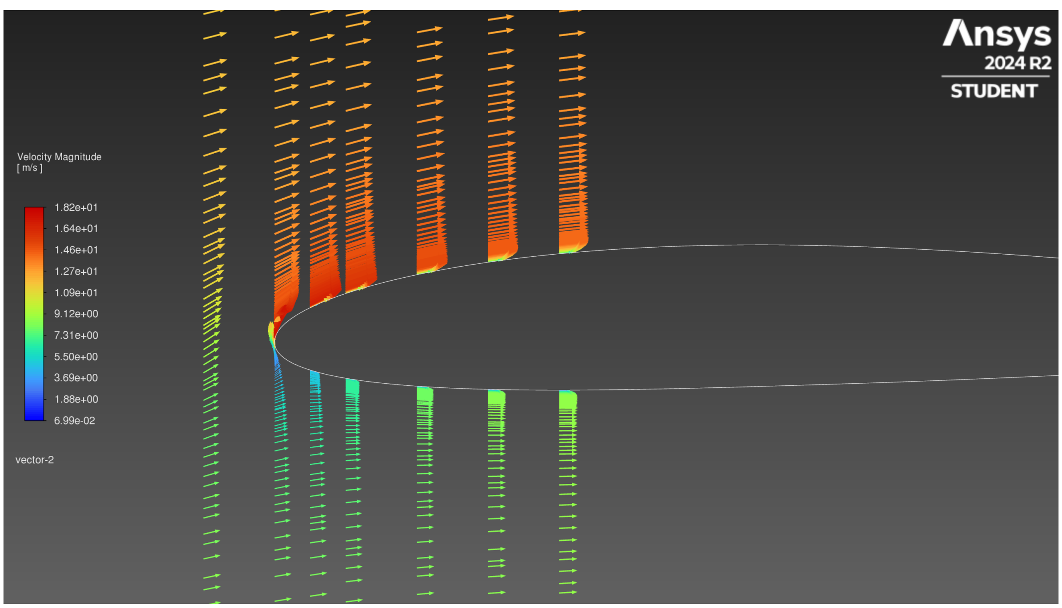

Figure 4: $\vec{v}(x, y)$ at the leading edge

5. **Plot, in the same graph, the Pressure Coefficient when the angle of attack is $3°, 6°$, and $9°$.**

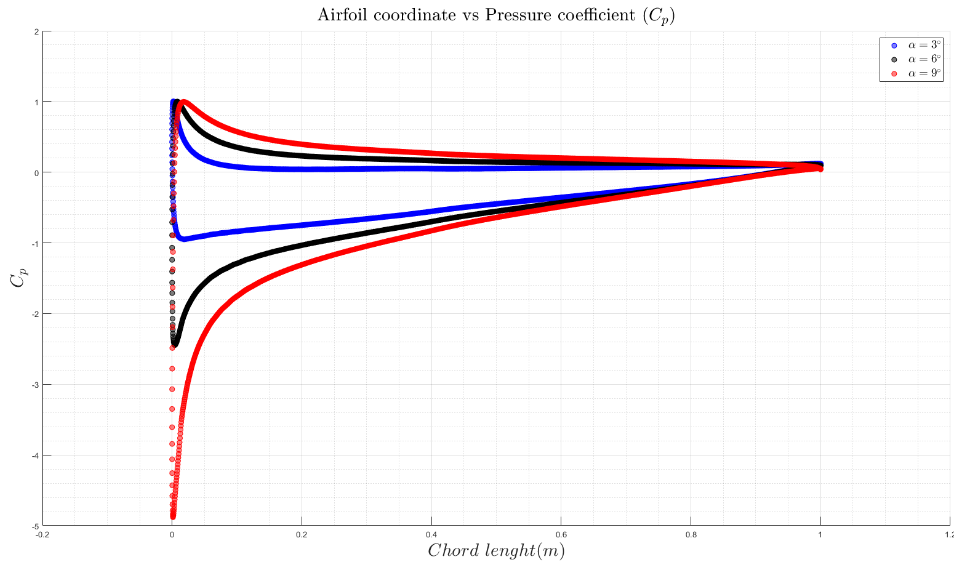

Figure 5: C_p for the 1 meter foil.

The units for the x-axis we supose to be in meters due to the design modeler geometry.

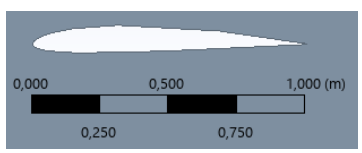

Figure 6: Scale for the foil.

We run the Ansys simulation again for an angle of attack of 10 and 12 degrees to record the different lift coefficientsand add all to the table bellow. (We also add 16 degrees).

Angle of attack (α)	$3°$	$6°$	$9°$	$10°$	$12°$	$16°$
Lift coeficient (C_L)	0.53425753	0.8440304	1.1279936	1.2111097	1.3526398	1.3115294

6. **Plot a graph of the Lift Coefficient vs. angle of attack (for $3°, 6°, 9°, 10°$, and $12°$) and briefly compare your results with the literature. (We also add $16°$)**

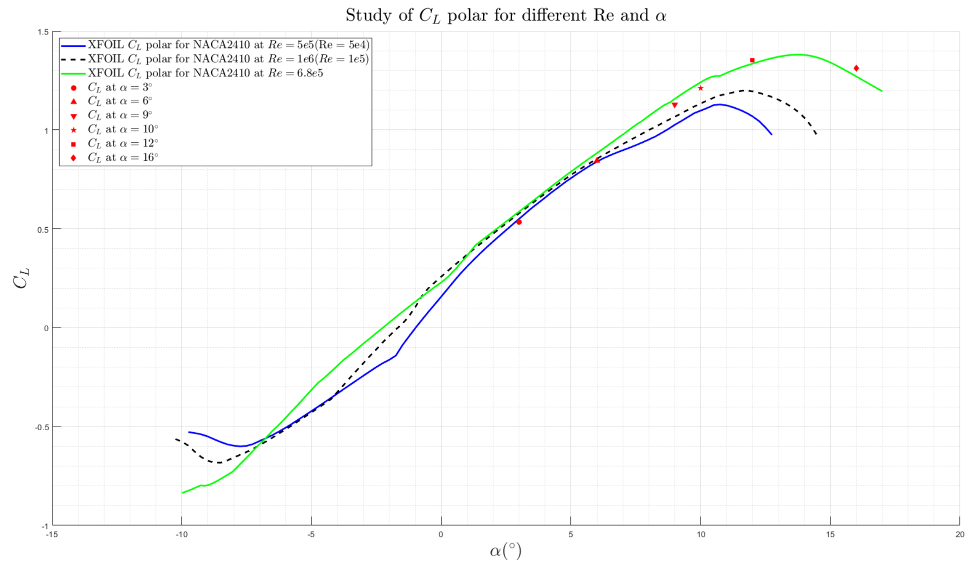

Figure 7: C_l vs α

The green line is explained in the second extra exercise.

As for the meaning, we can clearly tell that after around 13.750º, the lift coefficient begins to decrease, leading to our conclusion that a further increase in the angle of attack would result in less and less lift as the angle grows. Our values in red, while match up to both graphs in the first iterations, they quickly lose correlation as they approach higher degrees. We have plotted a new graph (in green) so as to visualize the proper results, which will be discussed in the sections that follow.

Through straight forward searches, we can compare our results with different sources, confirming that, indeed, the lift coefficient peaks at around 13.750º of angle of attack for a regular airfoil.

2 Extra Exercises

1. **Change the maximum number of iterations to 1000. What happens if you try to run the simulation for an angle of attack of 16º? Why is that?.**

An increase in the angle of attack results leads to growth in both lift and drag up to certain point. The maximum C_L is reached at 13.750 degrees aproximatelly, as we analyzed, in what is known as the stalling angle of attack. If the angle of attack keeps being increased, the plane will stall due to flow separation (as the attack increases, the flow becomes more and more disrupted, as seen in burbling occurring on top of the airfoil) and thus, lose lift until it reaches a critical point.

In the fluent simulation we conclude that for 16 degrees, our C_L is arround 1.3115294 wich is lower that the one for 12 degrees.

The change on the number of iterations is almos not noticeable.

Doing the simulation in xflr5, that is not as precise as fluent, but serve to give us an aproximation; we found that this critical point is at 18.143 degrees, when C_L drops from 1.0824 to 0.9170. The 0.9170 result is not reliable because is beyond the critical point.

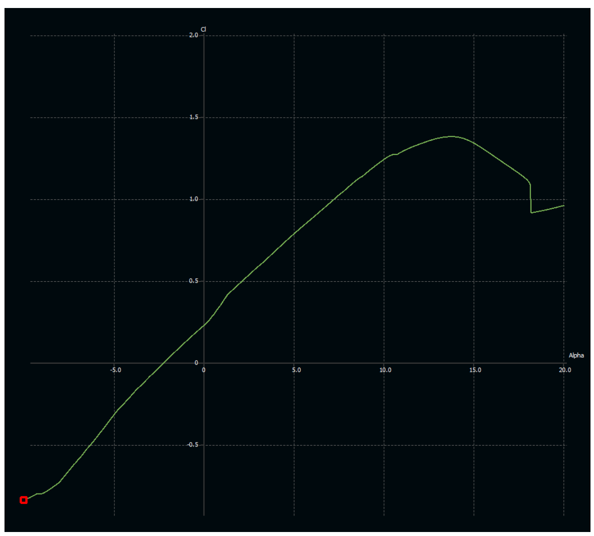

Figure 8: C_l vs $\alpha \in [-10, 20]$

According to our finding, from 16 degrees on, the function will decrease dramatically, and around 18.143 degrees, the C_L will abruptly cease to exist.

2. **In the provided MATLAB code, explain which of the lift curves provided is the best one for our approximation.**

   If we compare the points to the blue or black dashed lines, none of them seems to fit in our analysis. That is weird because the blue line is closed to our reynolds number. We have computed an analysis in xflr5 and come to the conclusion that the two lines were for a reynolds number of an order of 10 times less.

   We have configured the analysis as follows:

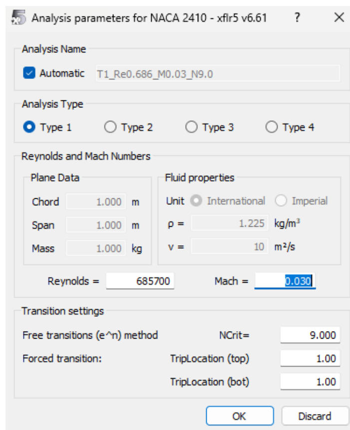

Figure 9: Analysis parameters for NACA2410 - xflr5 v6.61

   Then we have computed the analysis for $\alpha \in [-10, 16]$ with a $\Delta\alpha = 0.001$.

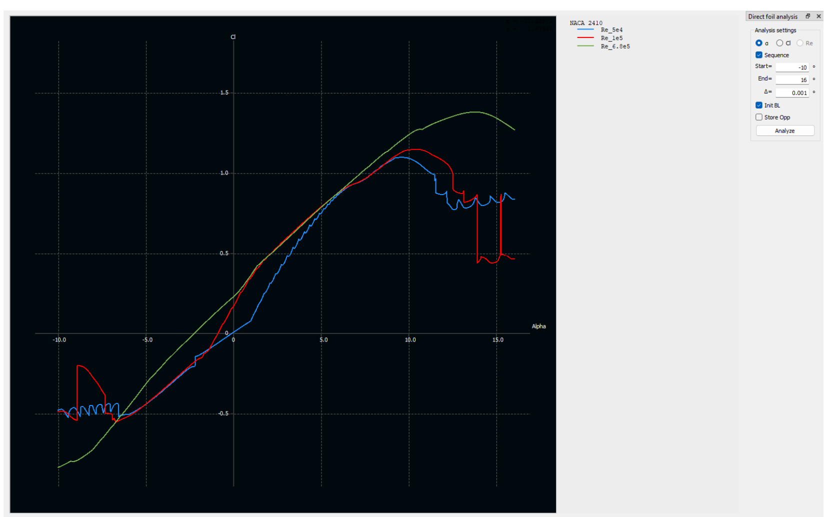

Figure 10: xflr5 simulation for reynolds number 6.8e5, 1e5, 5e4

   Red and blue lines seem to be pretty similar to the dashed and blue lines from Matlab, we can say that the one that approximate more to the result is the dashed one (red in xflr5). Also it is assumed that the intention of the laboratory was to make the blue line represent the lift coefficient for $R_e = 5e5$, that is not the case (it is actually for $R_e = 5e4$); so we plotted also the green line that shows the best approximation for our simulation for the actual reynolds number $R_e = 685748$.