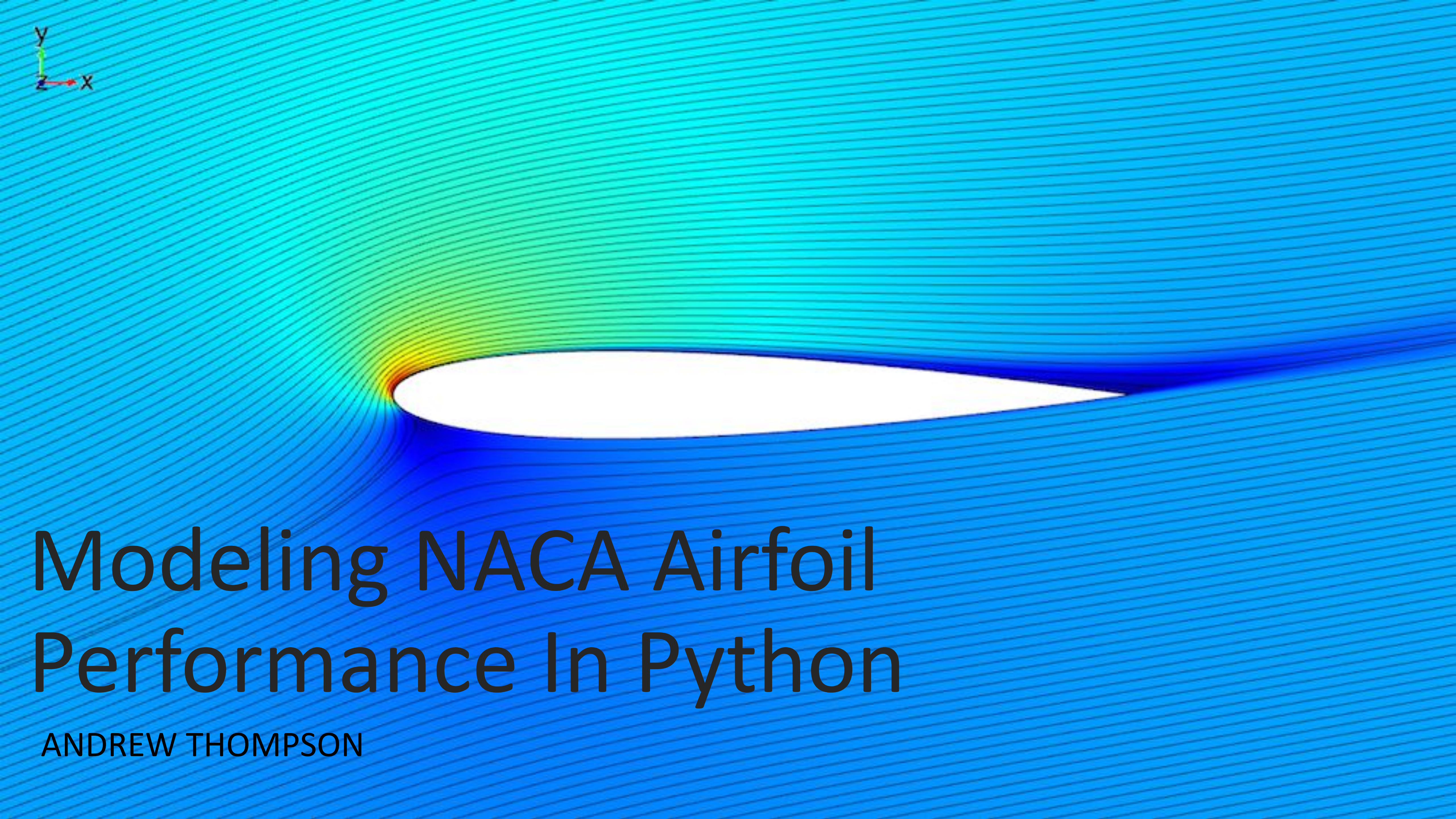


Modeling NACA Airfoil Performance In Python

ANDREW THOMPSON

Introduction

Aerodynamics is field which notoriously requires computational aid to solve problems. (e.g. the Navier Stokes Equations)

Many of the aerodynamic parameters which define an aircraft's performance are dimensionless, and must be determined through experimentation OR simulation.

- Coefficient of Pressure C_p
- Coefficient of Lift C_L
- Etc.

Introduction

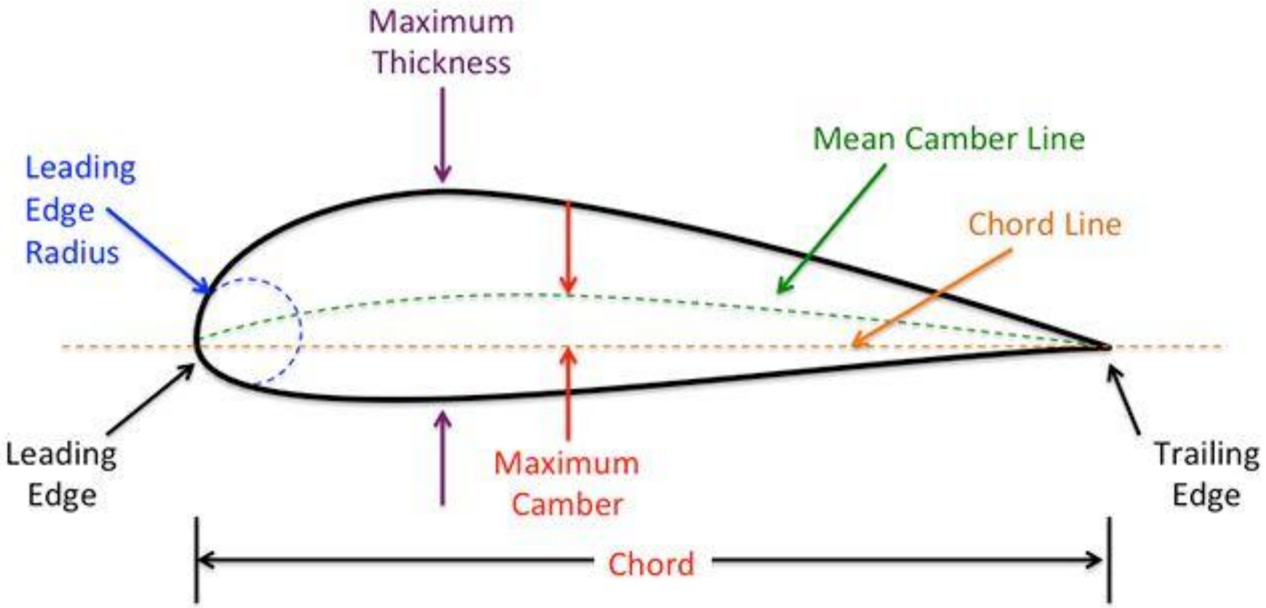
NACA 4 Digit Airfoil:

NACA XXXX

1st Digit: Maximum Camber

2cnd Digit: Maximum Camber Location

3rd & 4th Digit: Thickness



Objective: analyze the effect camber has on NACA 4 digit airfoil performance

Methodology

Generating NACA airfoil shapes

Camber (To be added to thickness)

$$y_c = \frac{m}{p^2}\left(2px - x^2\right) \qquad \text{from } x = 0 \text{ to } x = p$$

$$y_c = \frac{m}{(1-p)^2}\left[(1-2p) + 2px - x^2\right] \qquad \text{from } x = p \text{ to } x = c$$

Thickness

$$\pm y_t = \frac{t}{0.2}\left(0.2969\sqrt{x} - 0.1260x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4\right)$$

Upper/Lower Surface Points

$$x_U = x - y_t \sin\theta$$

$$y_U = y_c + y_t \cos\theta$$

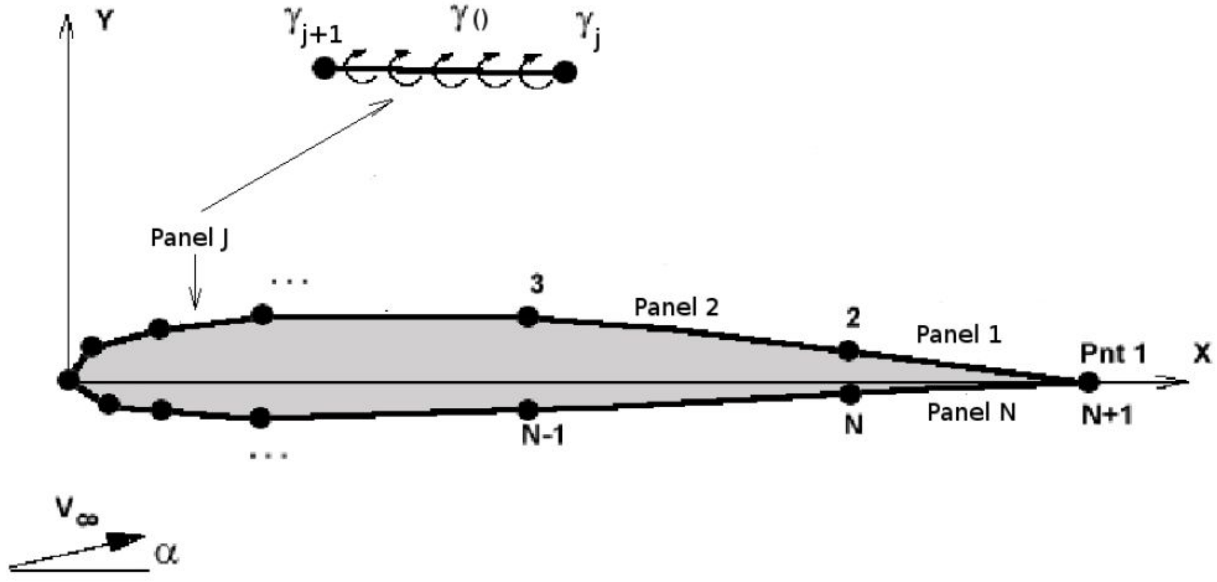
$$x_L = x + y_t \sin\theta$$

$$y_L = y_c - y_t \cos\theta$$

Methodology

Vortex Panel Method

- Separate Airfoil into discrete panels
- Place vortex at control point of each panel
- Superpose the 2D flow for each vortex, and the free stream
- Followed Keuthe and Chow's example in *Foundations of Aerodynamics*
- Can produce data such as coefficient of lift, pressure, circulation, etc.



Methodology

Graphical User Interface (PyQt5)

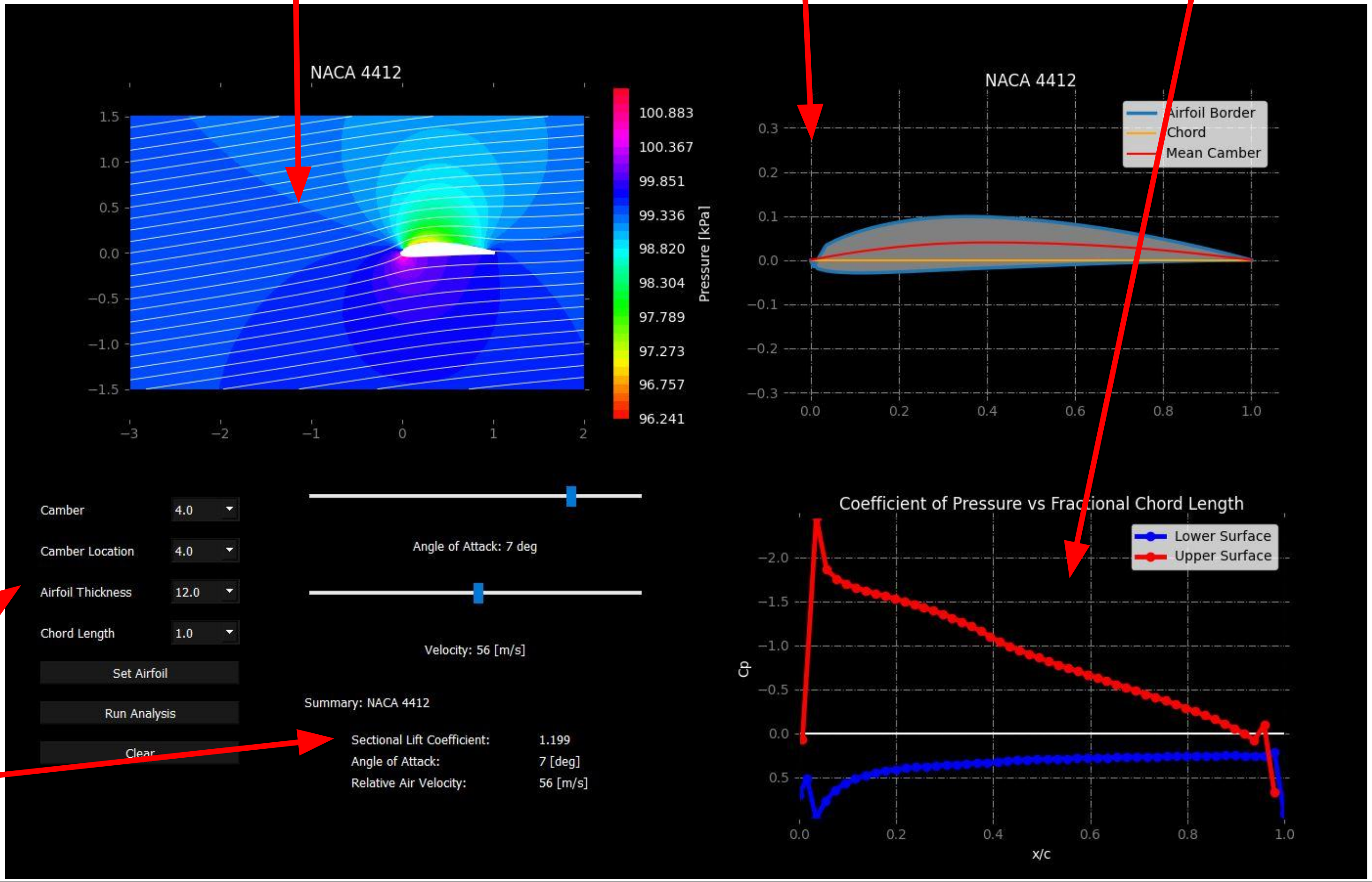
Why?

- To have a useful tool that can actually be used to analyze airfoils
- Resume project
- I am a computer nerd

Stream & Pressure Contours

Any 4 Digit Airfoil

Coefficient of Pressure



Airfoil Parameters

Lift Results

Methodology

class Naca4Digit

- Contains fields that describe the airfoil
- Contains fields that describe the airflow
- Vortex Panel method implementation
- Handles contour plotting

class CentralWidget

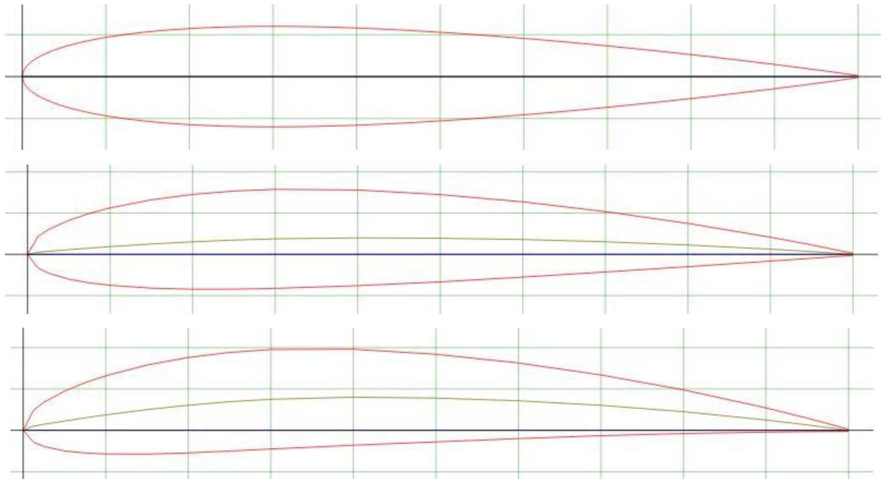
- Manages Naca4Digit instance
- Handles coefficient of pressure plotting
- User input & interface
- Post-processing

class MplCanvas

- Object to ‘wrap’ a matplotlib canvas
- Allows compatibility with PyQt5
- Used for all plots

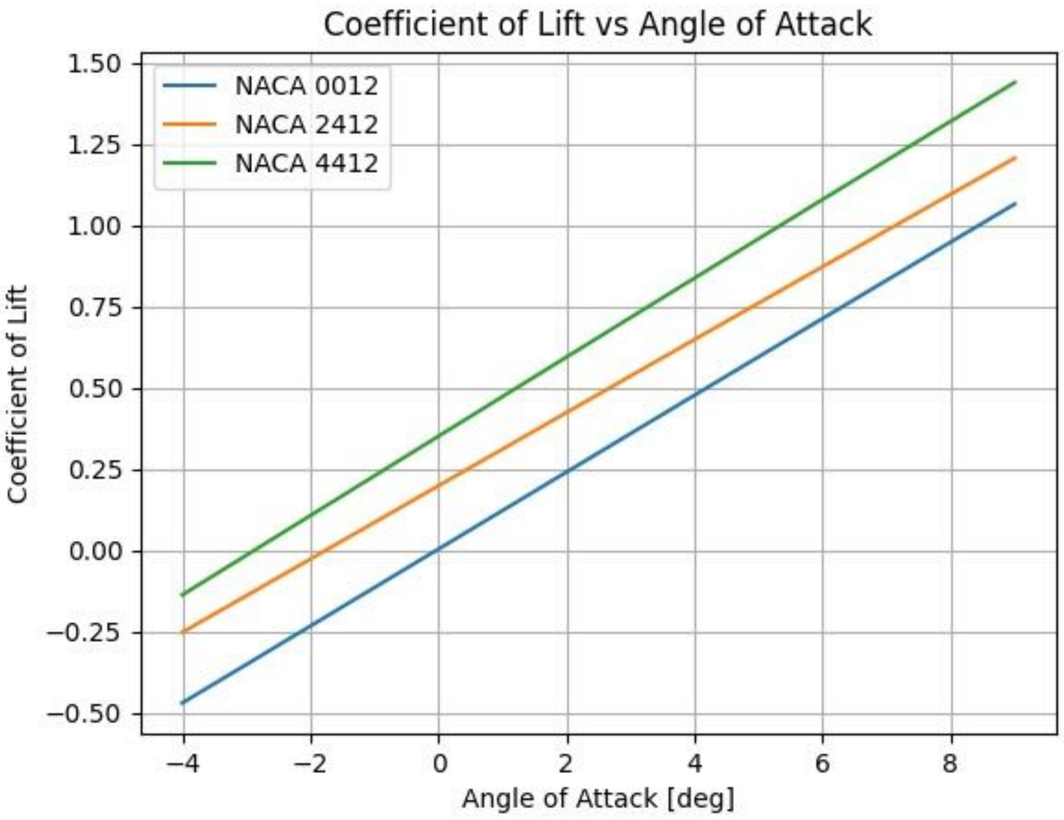
Results

NACA 4 Digit Airfoil	Camber Percentage	Coefficient of Lift at Zero Angle of Attack
NACA 0012	0% (Symmetric)	C_L = 0.005 (~0)
NACA 2412	2% Chord Length	C_L = 0.198
NACA 4412	4% Chord Length	C_L = 0.350



Results

The trend can be seen more clearly when comparing each airfoil at a variety of angles of attack.



Conclusion

Adding camber to an aerodynamic body such as a NACA 4 digit airfoil results in a higher sectional coefficient of lift.

References

[1] Anderson, John David. *Fundamentals of Aerodynamics*. McGraw-Hill Education, 2017.

[2] Erickson, Larry L. “Panel Methods--an Introduction - NASA.” *NASA Technical Paper 2995*, https://ntrs.nasa.gov/api/citations/19910009745/downloads/19910009745.pdf.

[3] Kuethe, Arnold M., and Chuen-Yen Chow. *Foundations of Aerodynamics: Bases of Aerodynamic Design*. J. Wiley, 2000.

[4] *MIT OpenCourseWare | Free Online Course Materials*. https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-100-aerodynamics-fall-2005/lecture-notes/16100lectre12_cg.pdf.

[5] “NACA 4 Digit Airfoil: Nomenclature and Equations.” *The Genius Blog*, 8 Dec. 2021, https://www.geniuserc.com/naca-4-digit-airfoil-nomenclature-and-equations/.