DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY ROPAR

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IIT Ropar

FLUID MECHANICS (ME 303)

PROJECT REPORT

For

ASSYMMETRIC AIRFOIL

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LIFT DEMOSTRATION OF NACA 4412 AIR FOIL

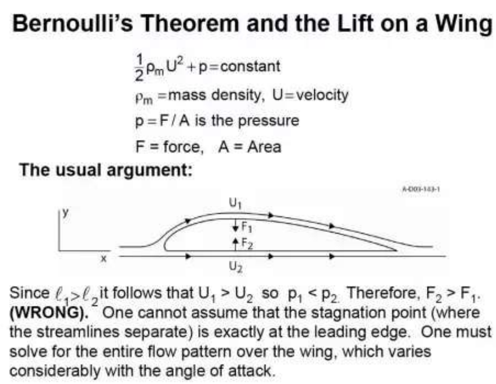
1 Aim of the experiment:

The aim of this experiment is to fabricate an aerofoil based on a selected profile (e.g., NACA 4412) and to demonstrate its lift characteristics by observing its behaviour at three different angles of attack. The lift generated by the aerofoil at various angles of attack will be recorded and analysed.

2 Theory related to the experiment :

The aerofoil's ability to generate lift depends on several factors, including its shape, the airflow speed, and the angle of attack.

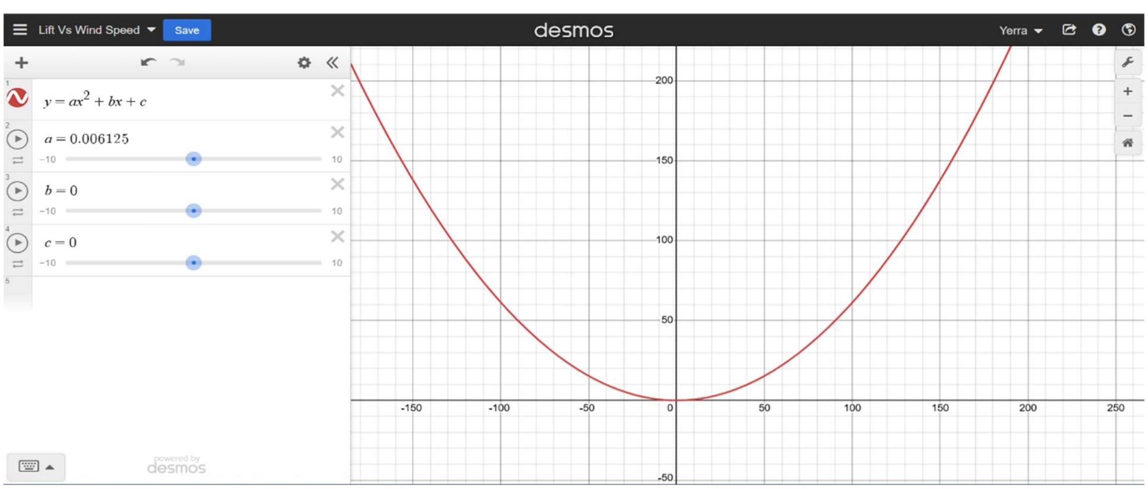
- Bernoulli's Principle: The velocity difference between the airflow above and below the aerofoil results in pressure differences that generate lift.



The selected NACA 4412 profile is characterized by:

- 4% camber located at 40% of the chord length.
- A 12% thickness relative to the chord length.

This profile provides a balance of lift and low drag, making it suitable for practical experiments at varying angles of attack.



Lift(N)

Vs

Wind Speed

(m/s)

[0 AOA]

 Aerofoil and Lift: An aerofoil is a streamlined shape designed to produce lift when air flows over its surface. The lift force on an aerofoil is generated due to the difference in air pressure across its upper and lower surfaces, governed by Bernoulli's principle and Newton's third law.

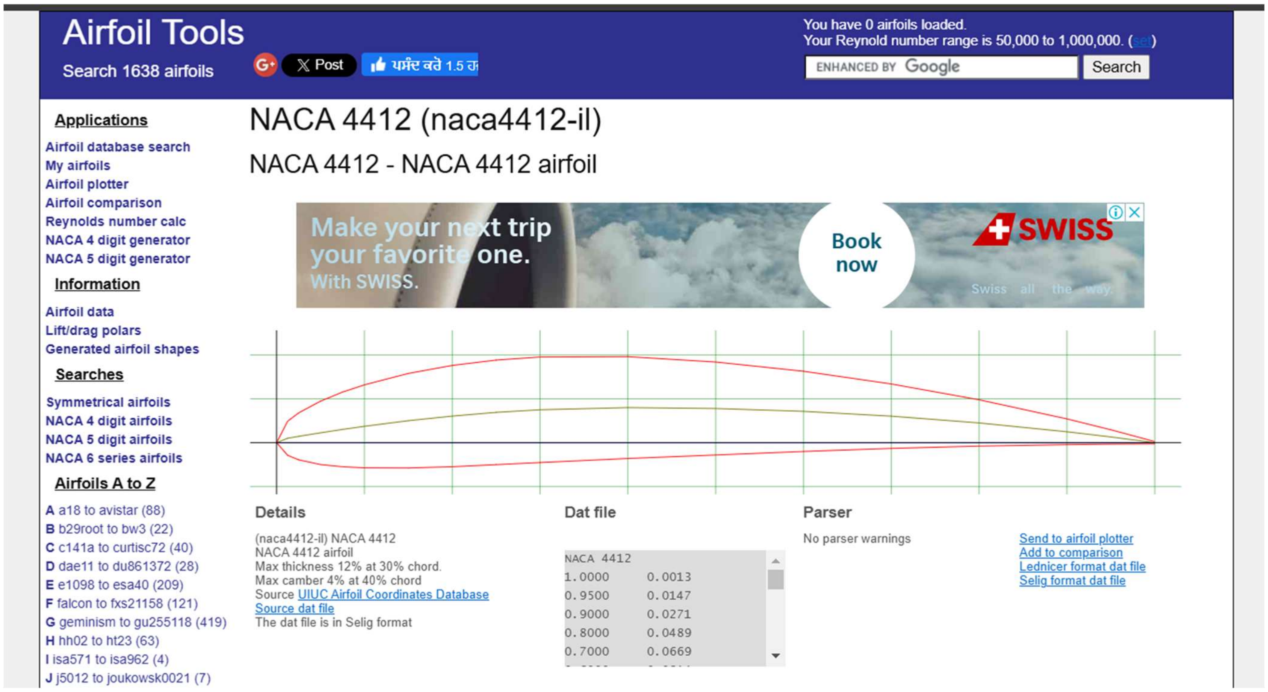
 NACA Profiles: NACA 4412 is a commonly used aerofoil profile where the numbering "4412" denotes its shape characteristics (maximum camber, location of maximum camber, and maximum thickness as a percentage of the chord length). The NACA 4412 profile is often used in aircraft wings and provides a good balance between lift and drag.

 Angle of Attack (AoA): The angle of attack is the angle between the chord line of the aerofoil and the direction of the airflow. As AoA increases, the lift initially increases until reaching a maximum point (stall point), beyond which lift rapidly decreases due to airflow separation.

3 Procedure of the experiment:

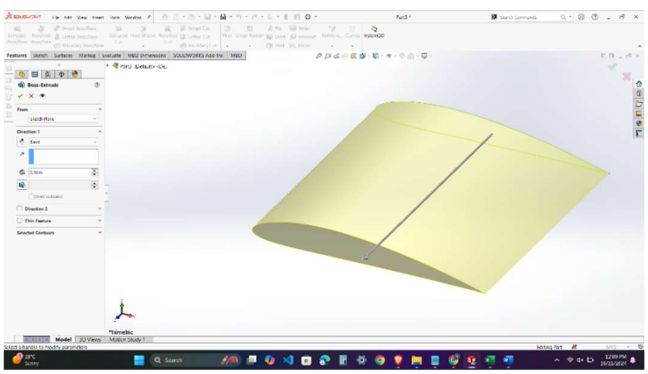
➢ Step 1: Fabricate the Aerofoil

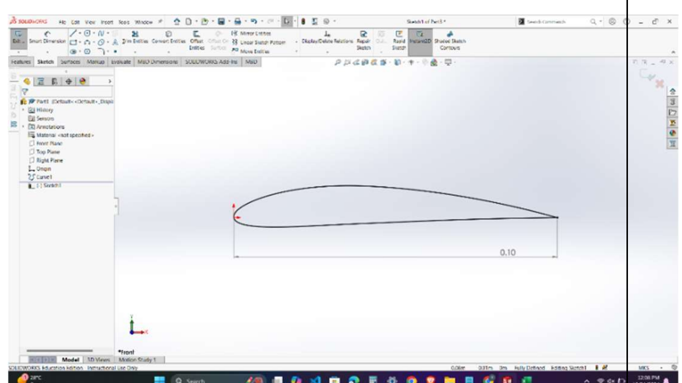
- Create a CAD model of the NACA 4412 aero foil, ensuring dimensions align with experimental requirements.
- Use appropriate fabrication methods (e.g., 3D printing, CNC machining) to manufacture the aero foil.
- **Design :**
- The aerofoil will be designed with a chord length of 10 cm and a wing span of 10 cm, will be used to generate a 3D model based on NACA 4412 coordinates. This design will serve as the basis for the physical fabrication.
- Design Process:
- 1. Obtain NACA 4412 Coordinates: The coordinates will be sourced from a NACA database or generated using tools like XFOIL or Airfoil Tools.



2. CAD Model with desirable dimensions

A CAD model of the NACA 4412 aerofoil has been created, based on the specified chord length of 10 cm and wing span of 10 cm. The model accurately



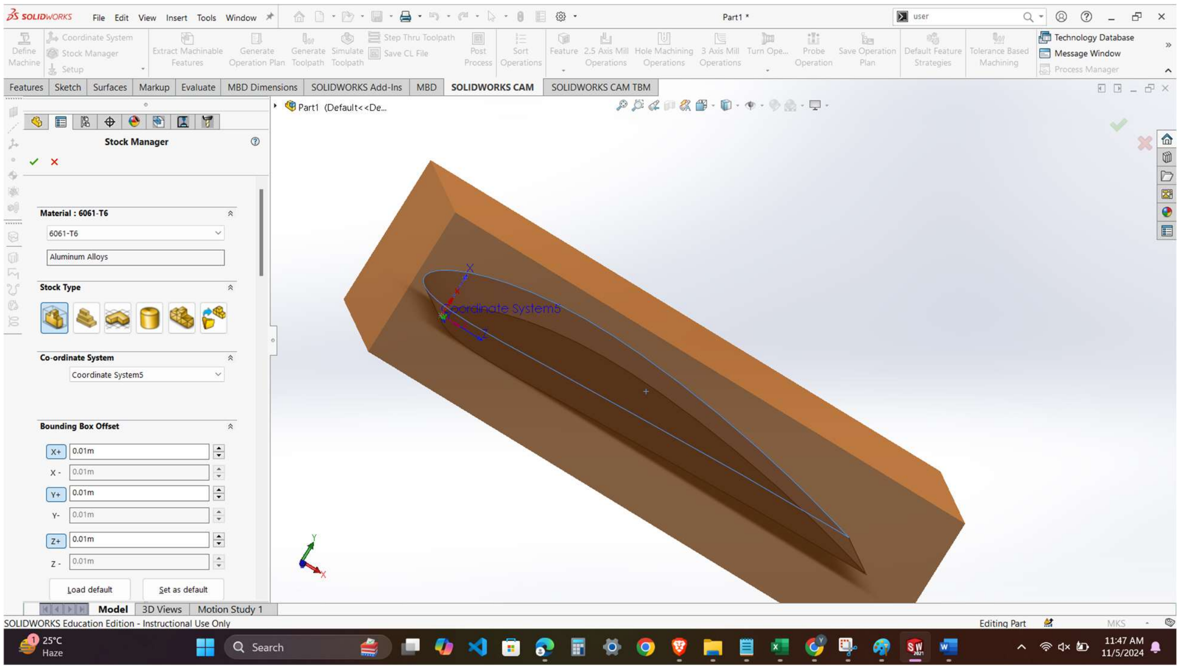


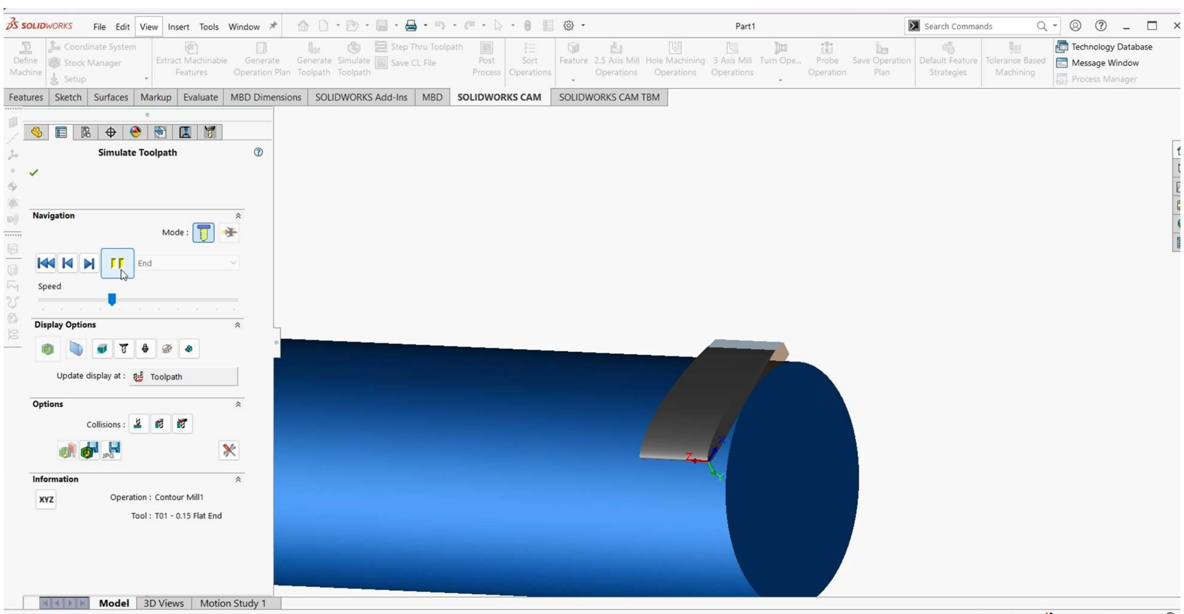
represents the NACA 4412 profile, ensuring correct camber and thickness distribution.

This model will be used for 3D printing or CNC machining.

- **Leading Edge**: Smooth and rounded to promote laminar flow, We 3d printed the cad model as it gives the best dimensional accuracy as we are limited by the tool size of 5cms with CNC milling machine.

We made the g code required for CNC milling of this air foil from wood but we are hurdled by the limited tool size





- Trailing Edge: Sharpened to reduce drag and improve lift performance.

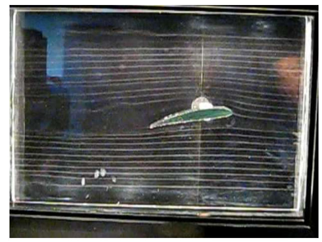
The wing span of 10 CMS is chosen because, greater the wing span, more the lift, but we are constrained by the dimension of the wind tunnel. So er fixed at the maximum limit of 10cms.

◻ Step 2: Setup the Experiment

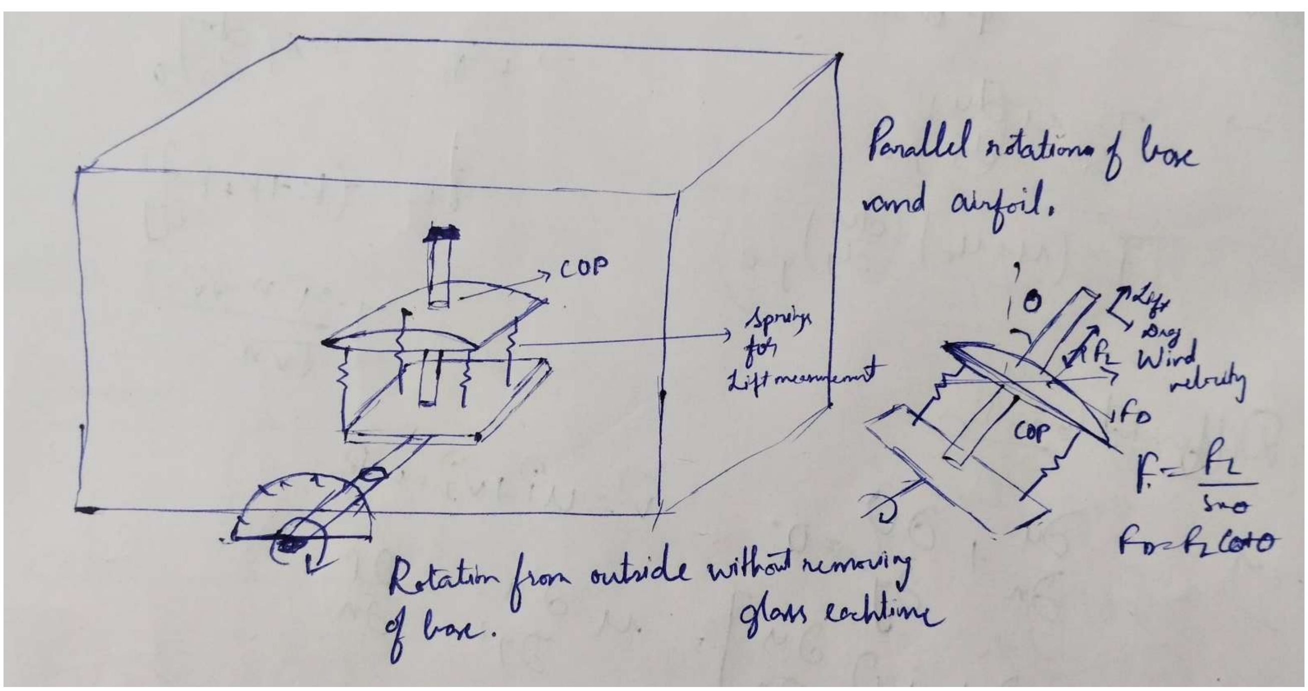
- Mount the fabricated aero foil onto a wind tunnel, we made holes and fastened them with nuts to fix that.

◻ Step 3: Angle of Attack Setup

- Start with the aero foil at a zero-degree angle of attack, recording the lift force.
- Increase the angle of attack incrementally (e.g., 5°, 10°, 15°) and record observations at each angle.
  - ➢ In The setup we use to change the angle of attack we have seen two possibilities:



1)By passing a smooth rod vertically through Center of Pressure and when the wind flows the lift is generated and the airfoil moves along the lubricated rod vertically ,and this vertical rod setup is attached to a base which is perpendicular and the angle of this can be changed using a spindle connected to this base and protrude outwards which can be rotated to rotate the entire setup , changing the angle of attack , and due to the lift generated due to this new angle of attack the airfoil moves along the vertical rod which is perpendicular to the base and along the direction of lift.

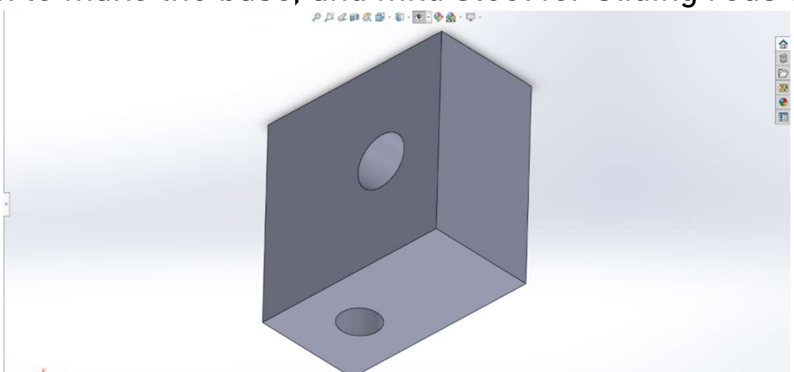


Drawback: As a vertical rod has to pass through the airfoil it will interfere with the airflow and create much more drag and COP changes with angle of attack , creating a moment turning the airfoil and hindering the displacement along the vertical direction, so we did not use this setup.

2) In this setup we use a spindle which passes perpendicular to the profile of the airfoil and through its COM the airfoil is fixed w.r.t spindle, this spindle can be rotated to change the angle of attack .

We used laser cutting and drilling to get the fiber glass in dimensions for the clamps.

We used sheet metal to make the base, and mild steel for sliding rods and spindle and mseal



Step 4: Data Recording

- Measure and record the lift generated at each angle. Take note of airflow characteristics and any visual indicators of airflow separation at higher angles.

4 Observation and Calculations :

$$V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{max}}}}$$

Angle of Attack	Lift Generated (L=0.5×CL×ρ×V^2×A)	CL
0	1.65	0.3
5	3.85	0.7
10	6.05	1.1
15	7.15	1.3
	5.5	1

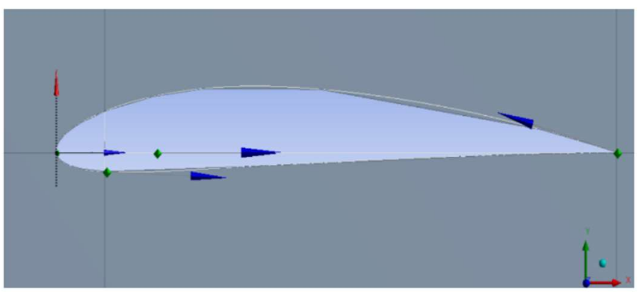


Fig.2 NACA 4412 airfoil created in Ansys Fluent Design Modeler

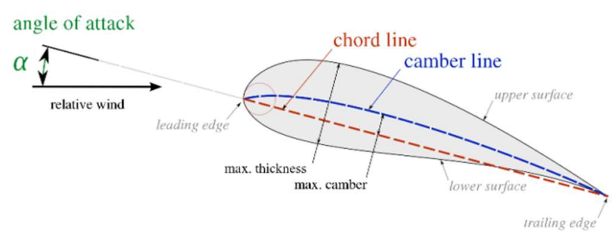


Fig.3 Airfoil nomenclature from Wikipedia

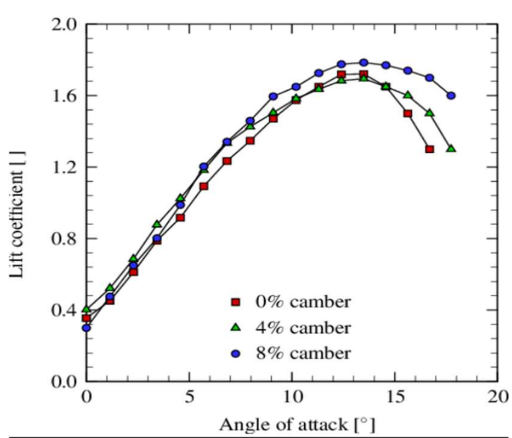
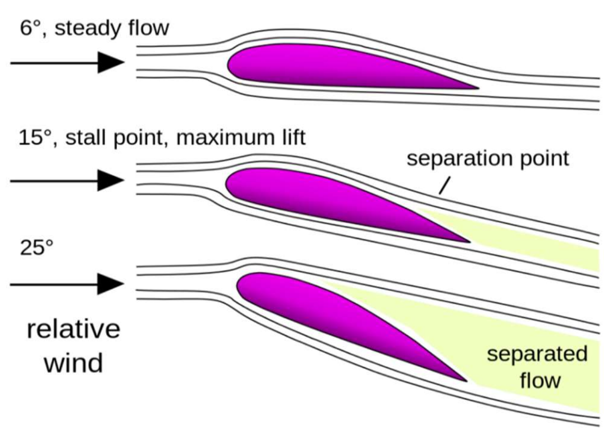


Fig.4 Cl vs angle of attack for different cambered airfoil



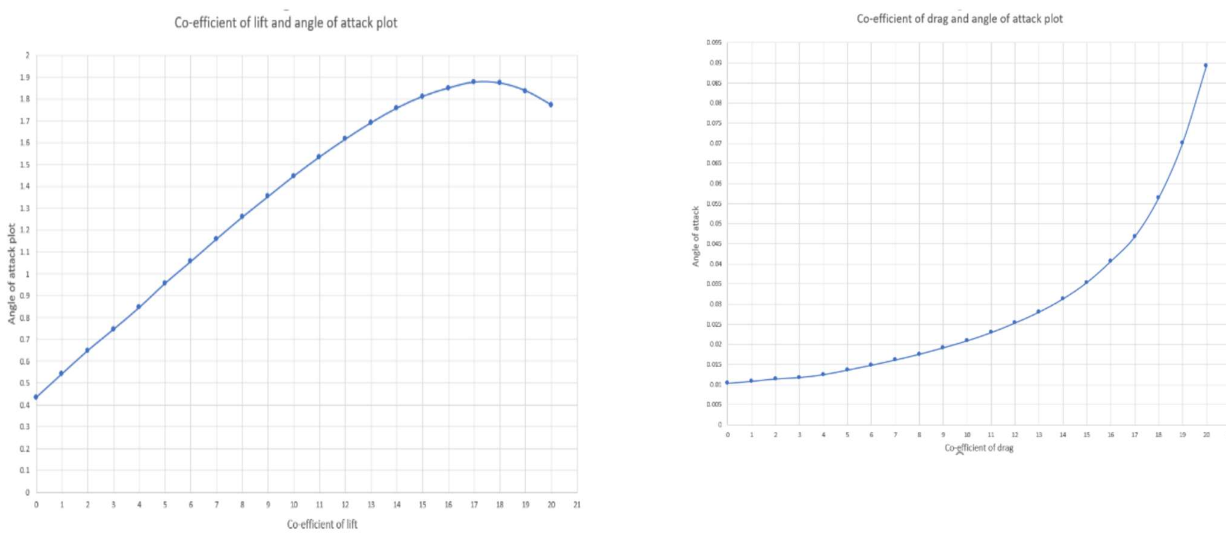


Fig.5 Variation of Coefficient of lift with angle of attack, Variation of coefficient of drag with angle of attack.

5 Conclusion and Discussion:

The experiment successfully demonstrates the generation of lift at varying angles of attack using the NACA 4412 airfoil. As the angle of attack increases, the lift force initially rises due to enhanced pressure differences between the upper and lower surfaces, a characteristic of the NACA 4412's cambered design optimized for high lift. Beyond a critical angle, however, lift decreases due to flow separation, showcasing the limits of aerodynamic efficiency. This highlights the relationship between air foil geometry, airflow behaviour, and the principles of Bernoulli's equation and pressure distribution.