CFD Analysis of an Aerofoil NACA 4410 and Estimating its Coefficient of Lift and Drag

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Abstract - Aerofoil is a streamline body which plays an important role in any aircraft because it has to generate adequate amount of lift to hold the aircraft in the air with less amount of drag. In this work a detailed study of **NACA-4410** Aerofoil is done at Various **Angle of Attack (ie.0, 5, 16, 20, 25, 30)** and at the same **Mach No. 0.2915**. This report aims to describe the calculation of Coefficient of Lift and Drag force which is produced by Aerofoil using the software's like **Solidworks(Modelling), Salome (Pre-processing), OpenFoam, ParaView(Post-processing)**. This study includes all the data and comparison regarding Aerofoil pressure and velocity which can be used to derive the C_d and C_l when it is subjected to different Angle of Attack(**AOA**).

Key Words*:* **NACA, AOA, Salome, Coefficient of Lift, Coefficient of Drag.**

1. INTRODUCTION

The Aerofoil section is the incarnation of a wing or a lifting surface which is very important in an airplane wing design. While the shape of the aerofoil changes, their aerodynamic characteristics also change. This report deals with a study of **NACA 4410** with different ***Angle of Attack(AOA) i.e.*** **0, 5, 16, 20, 25, 30** at the Mach No. 0.2915. The pressure data from the analysis was used to generate the ***coefficient of lift*** and ***coefficient of drag.***

A wing is a **three-dimensional** shape that, when immersed in an appropriate flow, will produce usable force from a pressure imbalance. An aerofoil is the shape of a wing or blade or sail as seen in cross-section. An aerofoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called **lift**. The component parallel to the direction of motion is called **drag**.

1.1 AERO FOIL NOMENCLATURE

The various terms associated with an aerofoil are as follows:

1.**Leading edge**: It is the forward end of the aerofoil that faces the free stream during flight.

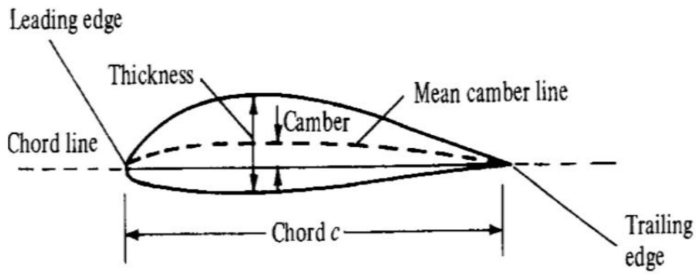
2.**Trailing edge**: It is the rearward end of the aerofoil.

3.**Mean camber line**: It is the locus of the points midway between the upper and the lower surfaces measured perpendicular to the mean camber line itself.

4.**Chord line**: It is a straight line connecting the leading and the trailing edges. The precise distance between the leading and the trailing edges is termed as "chord".

5.**Camber**: It is the maximum distance between the chord line and the mean camber line measured perpendicular to the chord line. A symmetric aerofoil is one with zero camber.

6.**Thickness**: It is the distance between the upper and the lower surfaces measured perpendicular to the chord line



The **NACA** aerofoils are classified into various series based on the number of digits that define the aerofoil configuration. The 4-digit series which is used in this project is explained below:

NACA Four Digit Series: In this series four digits are used to define the geometry of the aerofoil. The significance of the four digits are as follows:

First figure-The maximum camber as a percentage of chord.

Second figure-The position of maximum camber in tenths of chord.

Third and fourth figure-The maximum thickness as a percentage of chord

2. GEOMETRY

The standard coordinates of **NACA 4410** airfoil from aerofoil tool was used to create the geometry. The modeling was done using Solidworks.

The details of **NACA 4410** are:

Chord length: 1000mm

Thickness (%):100

Angle of Attack: **0, 5, 16, 20, 25, 30.**

Extruded:1000mm

Fig1.Angle of Attack-0 Degree.

Fig2.Angle of Attack-5 Degree.

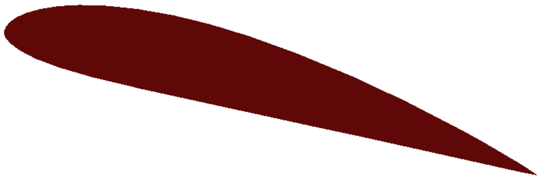


Fig3.Angle of Attack-16 Degree.

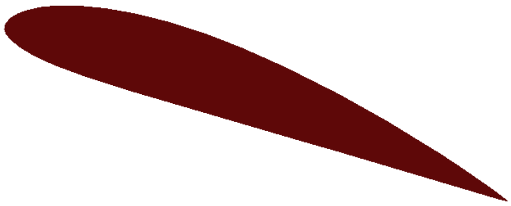


Fig4.Angle of Attack-20 Degree.

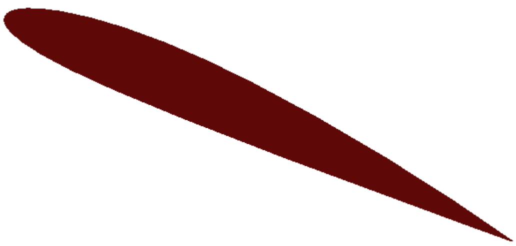


Fig5.Angle of Attack-25 Degree.

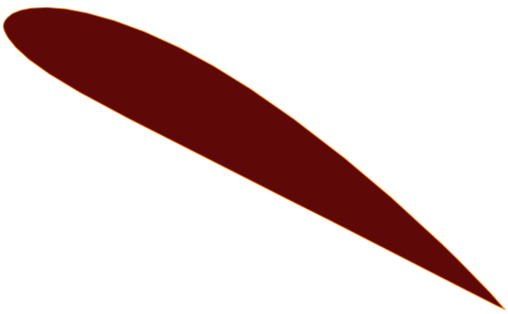


Fig6.Angle of Attack-30 Degree.

3. PRE PROCESSING

The preprocessing was done using **Salome** with the fine quality of mesh. The domain size was taken as 50X50m.Automatic Tetrahedralization was used for automatic meshing. Each STEP file was imported in **Salome** and domain of 50x50 was created then through boolean cut feature was used to cut the wing from domain,

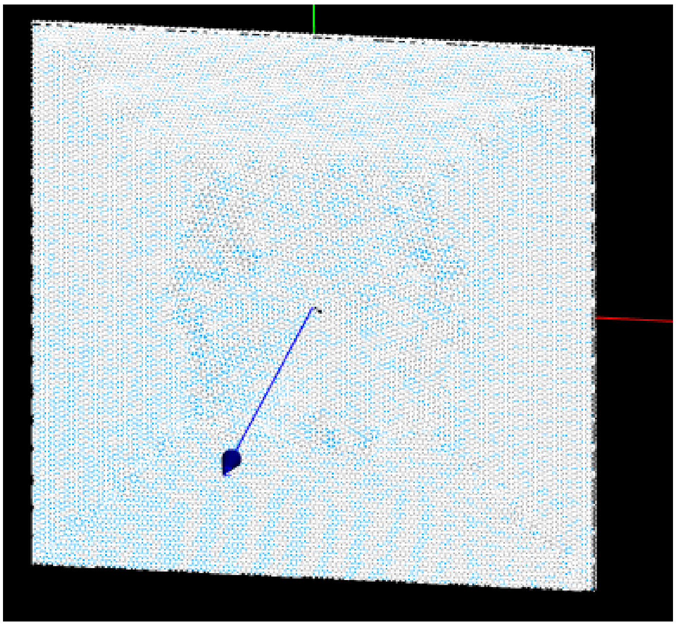


Fig7. Mesh (Angle of Attack-25 Degree).

4. SOLVER

The following solver was used to solve the case study
RAS-Model: Spalart Allmaras
Solver Type: Simple Foam
Inlet Velocity: 100m/s or 360km/hr.
Mach Number:0.2915
Density of Air: 1.6kg/m^3

Each model case study was made run for 2000 sec then pressure data was used to generate other data.

5. POST-PROCESSING

Post processing was done using ParaView. The normal pressure in Y axis was used to calculate the lift. The pressure in X axis was used to calculate the Drag.

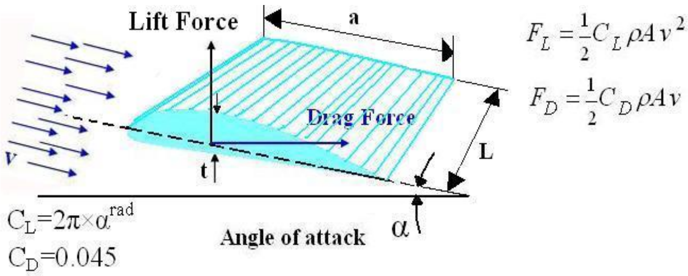


Fig8.Coefficient of Lift and Drag.

Aerofoil at AOA-0 Degree

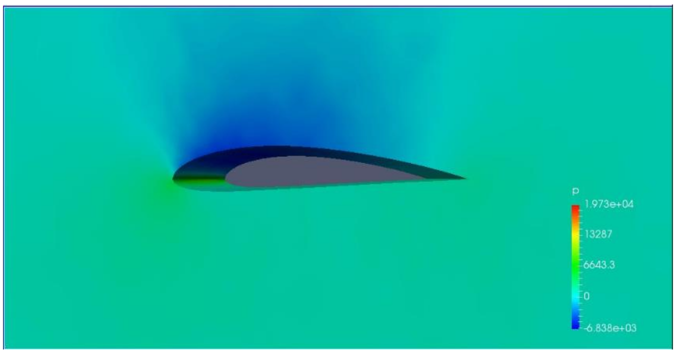


Fig9.0: Pressure data.

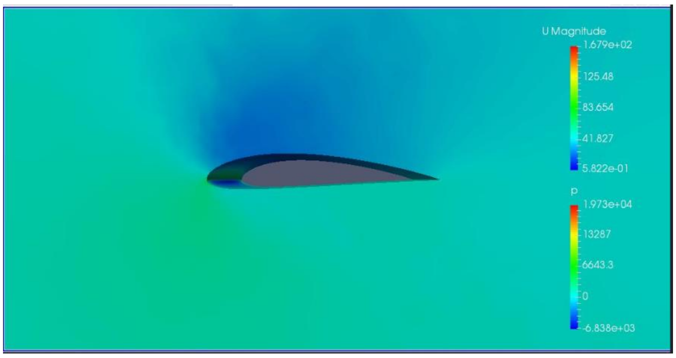


Fig9.1: Pressure & Velocity data.

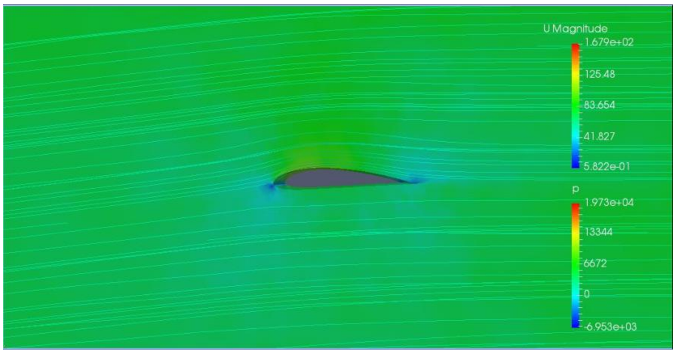


Fig9.2: Pressure & Velocity Stream line data.

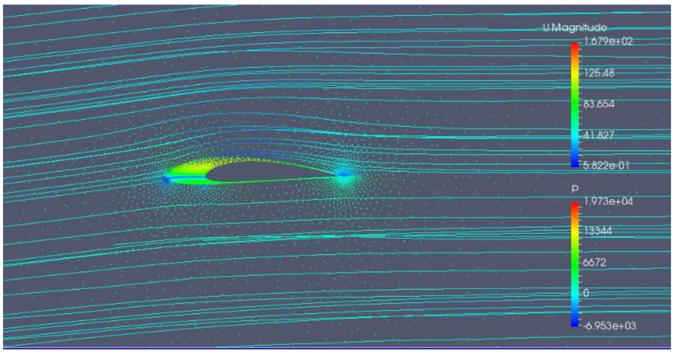


Fig9.3: Pressure & Velocity point line data.

Lift Force	4216.53**N**
Drag Force	-96.1584**N**

Aerofoil at AOA-5 Degree

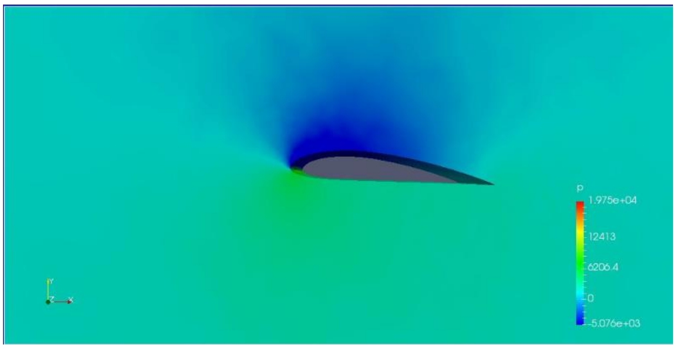


Fig10.0: Pressure data.

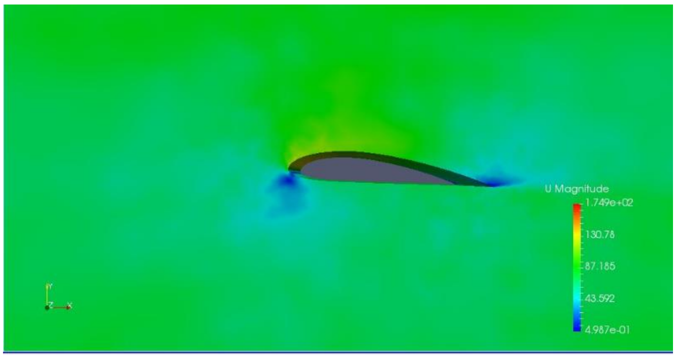


Fig10.1: Velocity data.

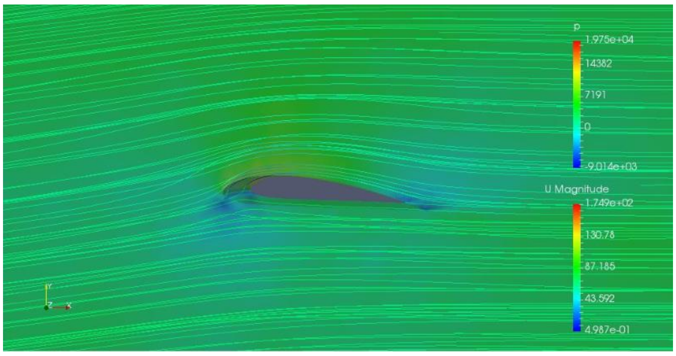


Fig10.2: Pressure & Velocity Stream line data.

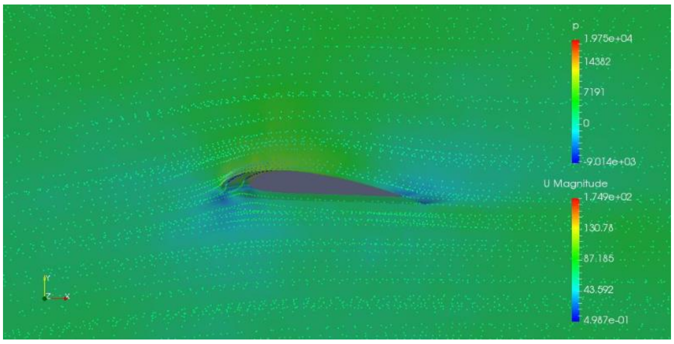


Fig10.3: Pressure & Velocity point line data.

Lift Force	6741.07**N**
Drag Force	-44.4061**N**

Aerofoil at AOA-16 Degree

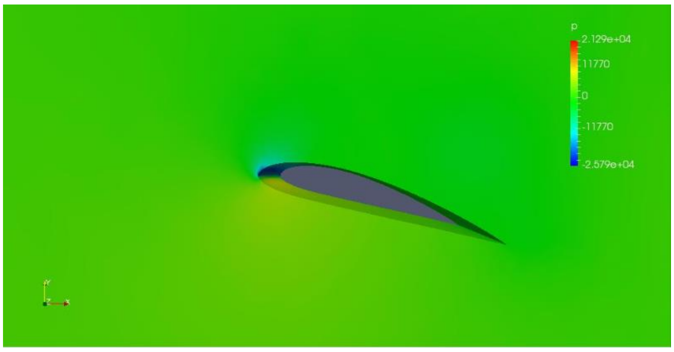


Fig11.0: Pressure data.

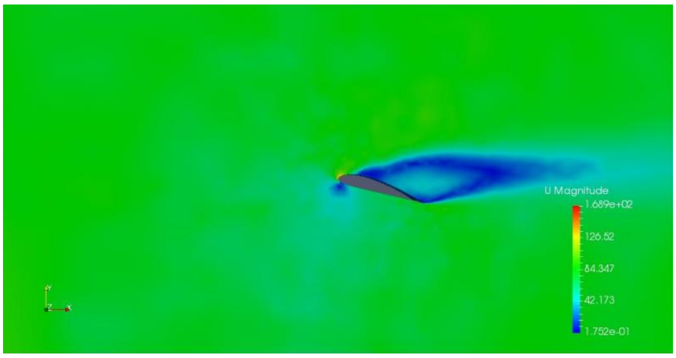


Fig11.1: Velocity data.

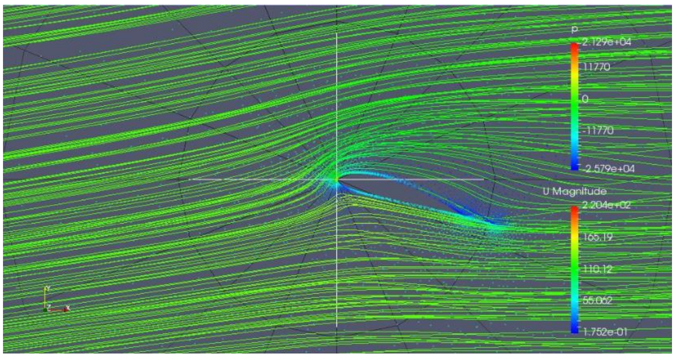


Fig11.2: Pressure & Velocity Stream line data.

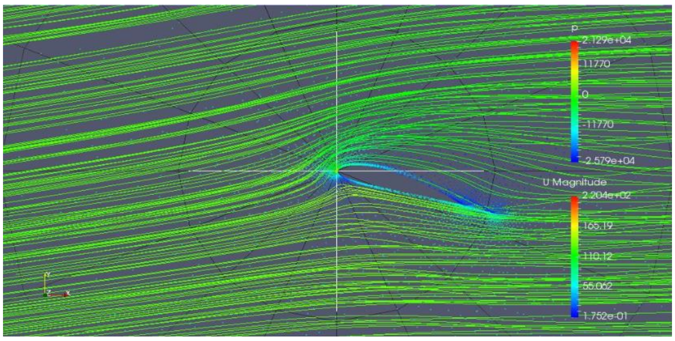


Fig11.3: Pressure & Velocity point line data.

Lift Force	8039.48**N**
Drag Force	793.932**N**

Aerofoil at AOA-20 Degree

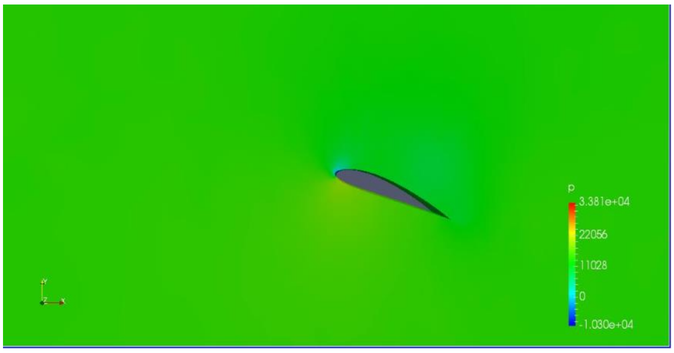


Fig12.0: Pressure data.

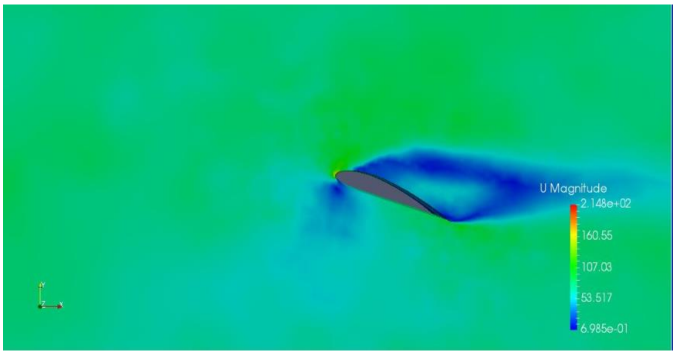


Fig12.1: Velocity data.

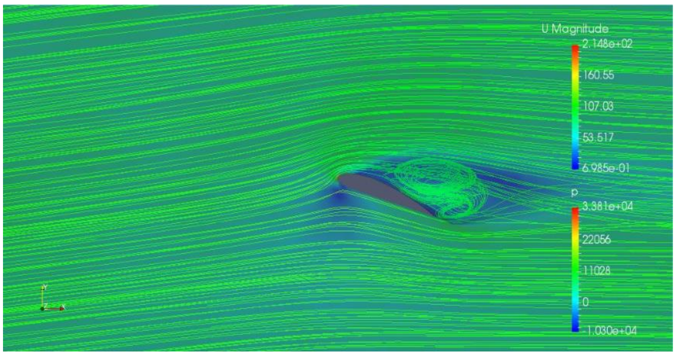


Fig12.2: Pressure & velocity stream line data.

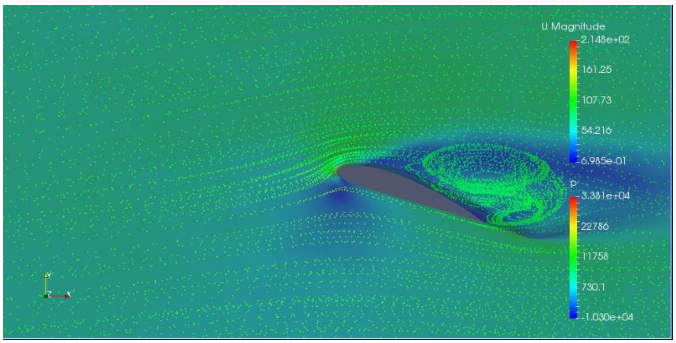


Fig12.3: Pressure & Velocity point line data.

Lift Force	7493.0**N**
Drag Force	1396.5**N**

Aerofoil at AOA-25 Degree

Fig13.0: Pressure data.

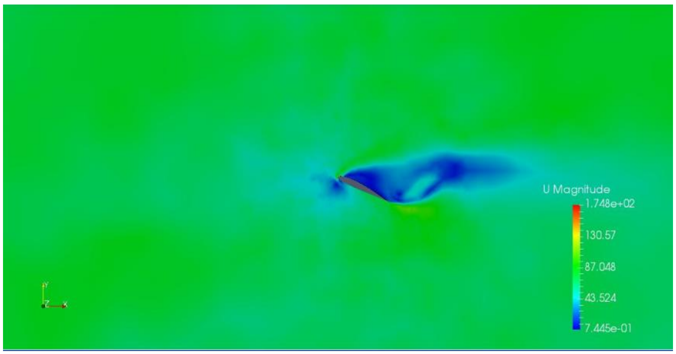


Fig13.1: Velocity data.

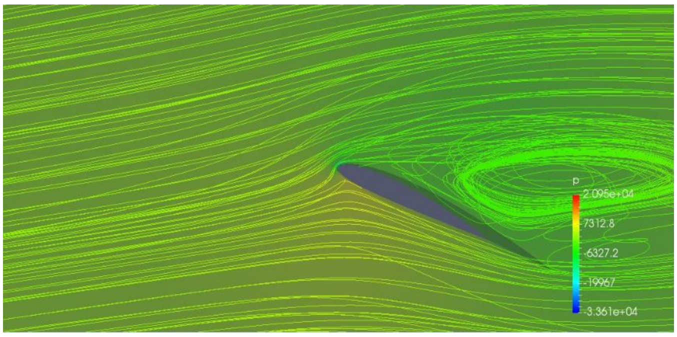


Fig13.2: Pressure Stream line data.

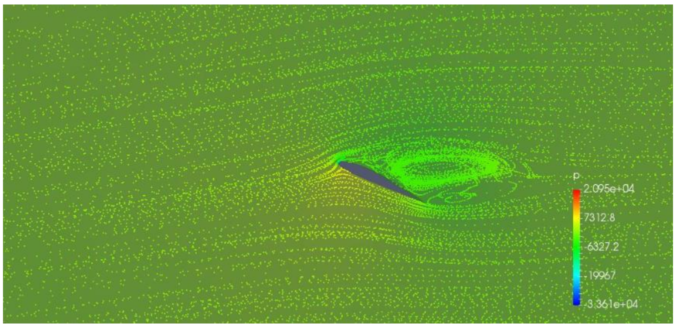


Fig13.3: Pressure point line data.

Lift Force	6173.05**N**
Drag Force	2126.55**N**

Aerofoil at AOA-30 Degree

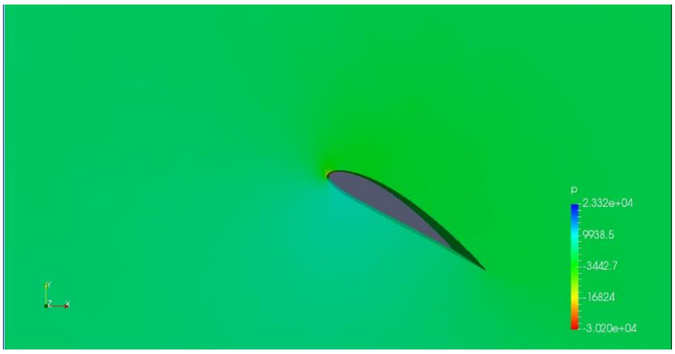


Fig14.0: Pressure data.

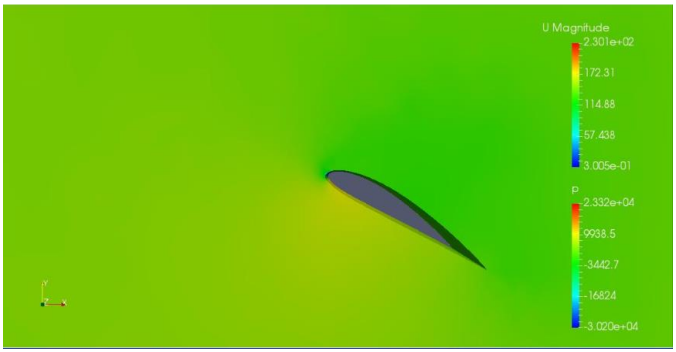


Fig14.1: Pressure & velocity data.

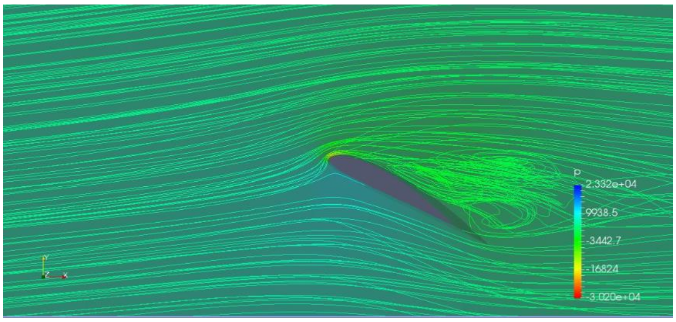


Fig14.2: Pressure Stream line data.

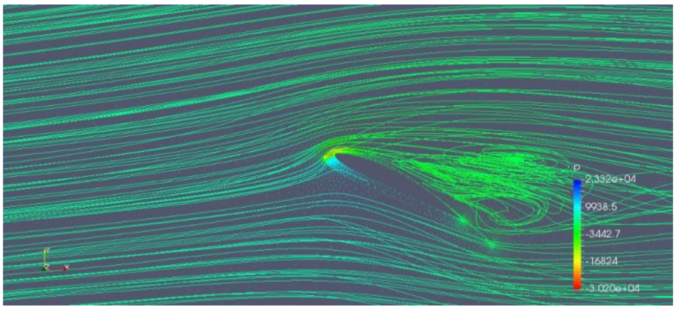


Fig14.3: Pressure Point line data.

Lift Force	7427.94**N**
Drag Force	2750.27**N**

CALCULATION

1. Aerofoil at AOA-0 Degree

Front area of Aerofoil is 155X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	4216.53**N**
Drag Force	-96.1584**N**

So ***Coefficient of Lift***: **3.4**

and ***Coefficient of Drag***: **-0.077547**

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2. Aerofoil at AOA-5 Degree

Front area of Aerofoil is 174X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	6741.07**N**
Drag Force	-44.4061**N**

So ***Coefficient of Lift***: **4.8427**

and ***Coefficient of Drag***: **-0.031901**

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3. Aerofoil at AOA-16 Degree

Front area of Aerofoil is 325X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	8039.48**N**
Drag Force	793.932**N**

So ***Coefficient of Lift***: **3.09216**

and ***Coefficient of Drag***: **0.30535**

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4. Aerofoil at AOA-20 Degree

Front area of Aerofoil is 382X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	7493.0**N**
Drag Force	1396.5**N**

So ***Coefficient of Lift***: **2.45189**

and ***Coefficient of Drag***: **0.4569**

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5. Aerofoil at AOA-25 Degree

Front area of Aerofoil is 441X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	6173.05**N**
Drag Force	2126.55**N**

So ***Coefficient of Lift***: **1.7497**

and ***Coefficient of Drag***: **0.602763**

5. Aerofoil at AOA-30 Degree

Front area of Aerofoil is 524X1000mm.

$$F_L = \frac{1}{2} C_L \rho A v^2$$

$$F_D = \frac{1}{2} C_D \rho A v$$

Density of Air: 1.6kg/m^3

Using the following data:

Lift Force	7427.94**N**
Drag Force	2750.27**N**

So ***Coefficient of Lift***: **1.77719**

and ***Coefficient of Drag***: **0.6560**

Graphs for Coefficient of Lift and Drag:

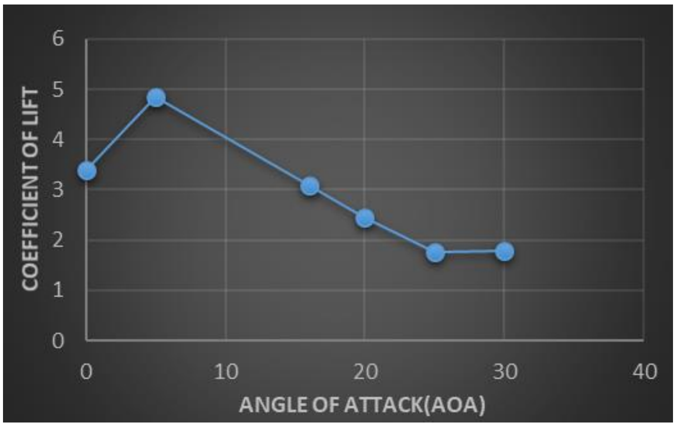

Fig15: Coefficient of Lift vs AOA

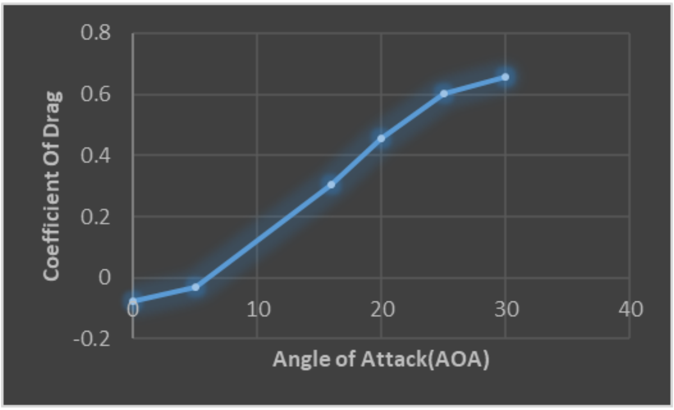

Fig16: Coefficient of Drag vs AOA

Graphs for Lift Force and Drag Force:

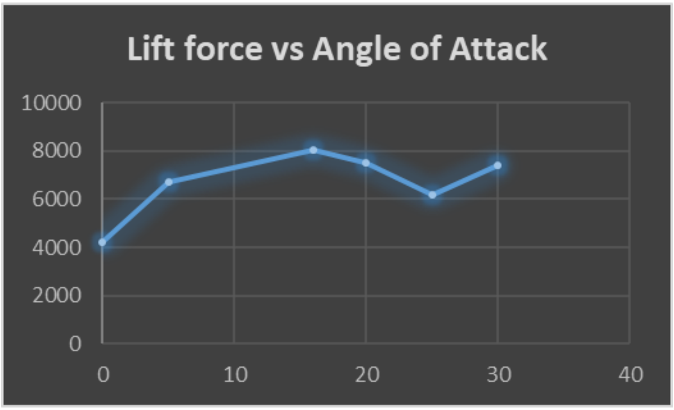

Fig17: Lift Force vs AOA

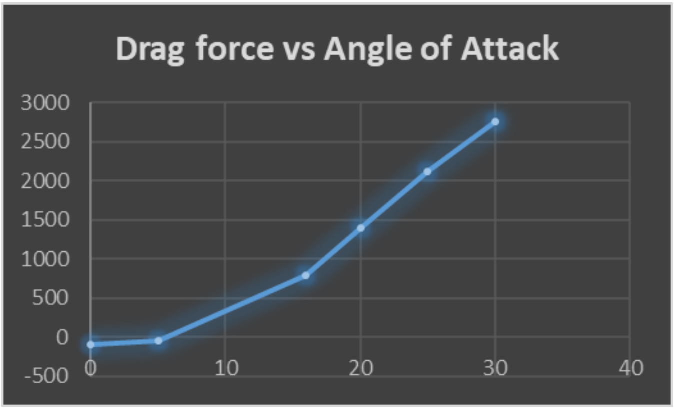

Fig18: Drag Force vs AOA

Conclusion

Lift coefficient was found to be higher for 5 degree and Drag coefficient was found to be higher for 30 degrees. Results obtained from the study Airfoil characteristics was satisfactorily matched with the standard data.

Reference

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