

DESIGN AND ANALYSIS OF I-SHAPED TAIL FOR SUBSONIC AIRPLANES

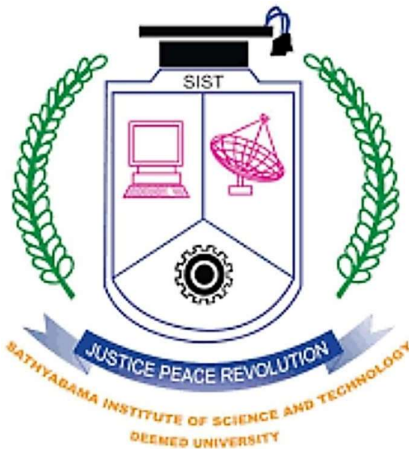
Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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DEPARTMENT OF AERONAUTICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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MAY 2022



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of NIKHIL ARISELLA (Reg. No. 38260030) and MANGINA LEELA KRISHNA (Reg. No. 38260023) who carried out the project entitled “<**DESIGN AND ANALYSIS OF I-SHAPED TAIL FOR SUBSONIC AIRPLANES**>” under our supervision from September 2021 to April 2022.

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DECLARATION

We NIKHIL ARISELLA (Reg.No.38260030) and MANGINA LEELA KRISHNA (Reg.No. 38260023) hereby declare that the Project Report entitled “**DESIGN AND ANALYSIS OF I-SHAPED TAIL FOR SUBSONIC AIRPLANES**” done by us under the guidance of **Dr. A. ANDERSON** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Aeronautical Engineering.

DATE: 05-05-2022

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ABSTRACT

The empennage which is termed as tail part or the tail assembly, is a shape on the rear end of the aircraft which gives balance at some point of the flight. It functions similar to the feathers attached to an arrow. It acts as a house for the main control surfaces of the flight. A traditional plane tail consists of lifting surfaces organized at right proper angles to every difference known as horizontal lifting floor and vertical lifting floor. Collectively those surfaces are known as empennage. The number one obligation of a plane tail is to offer balance in the longitudinal and vertical axis which in flip offers pitching and yawing movement. For protection and performance motives the elevator/ rudder is ready with a movable floor known as trim tab like elevator trim and rudder trim. This lets the pilot manipulate the location of the number one ground in order that the aircraft will stay in a hard and fast aerodynamic configuration.

In our project we are excited to design and analyse a different shape of empennage in order to improve the horizontal stability of the airplane. The designed shape resembles that of a twin tail (h-tail) aircraft placed in horizontal axis. It consists of two elevators mounted with a vertical fin named rudder in between. One of our primary goal of this expert postulation work is to learn about the behavior of the aircraft in cruising state in order to regain its stability in case of any deviation. We are advised to use the software's like CATIA V5 to create the design and solid works to stimulate the model.

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LIST OF SYMBOLS AND ABBREVIATIONS

Cl	Coefficient of Lift
Cd	Coefficient of Drag
Cm	Coefficient of Moment
P	Density
A	Area
V	Velocity
L	Lift
AR	Aspect Ratio
E	Efficiency Factor
AOA	Angle of Attack
X	Side Force
RPM	Rotations Per Minute
Hf	Manometer Reading
Cp	Coefficient of Pressure
Ps	Static Pressure
Pt	Total Pressure
E	Eccentricity
Cd	Drag Polar
Xnp	Neutral Point

V_h	Tail Volume Ratio
$de/d\alpha$	Induced Velocity
X_{ac}	Aerodynamic Centre

Chapter 1

INTRODUCTION

Every airplane's part is going via many modifications in layout before it is finally constructed in a manufacturing facility. These steps among the first ideas for a plane and the time whilst it's far absolutely flown make up the design process. This paper works with the design and analysis of I shaped tail for subsonic aircraft. The idea of this design is from twin tail aircraft which have two vertical fins known as rudders. Air passengers demand extra consolation and a more environmentally friendly plane. For the sake of this many technical challenges want to be balanced for a plane to be economically safe. The layout of an airplane is a complex and laborious job with more than a few factors and information which might be required to be checked to obtain the product ideally. The design begins with the scratch and ends up with a satisfying product involving many calculations, logics, and planning. The topics we went through to make the design as real model are as follows

Aerodynamics: it means taking a look at the way air flows around an airplane body. For an airplane to sustain in the air, the air has to waft over and under the wings. The greater the aerodynamics of the wing the less it opposes the air. If the air flows without any difficulty the work of the airplane engines becomes easier. The same way followed in our work by making the tail surface softer. one way of making the aircraft use less fuel is to make the body parts aerodynamically more efficient.

Propulsion: it is the action of making an object move forward. In our case we are considering this because of the interaction of the exhaust air with the flow of air around the tail. We just need the basics of propulsion.

Structures and Materials: it is the study of how good the airplane can withstand the pressure exerted on the surface. It also deals with the intensity of the work of engines.

History of Tail

A tailplane, also referred to as a horizontal stabiliser, is a small lifting floor placed at the tail (empennage) behind the number one lifting surfaces of a hard and fast-wing plane in addition to different non-constant-wing aircraft at

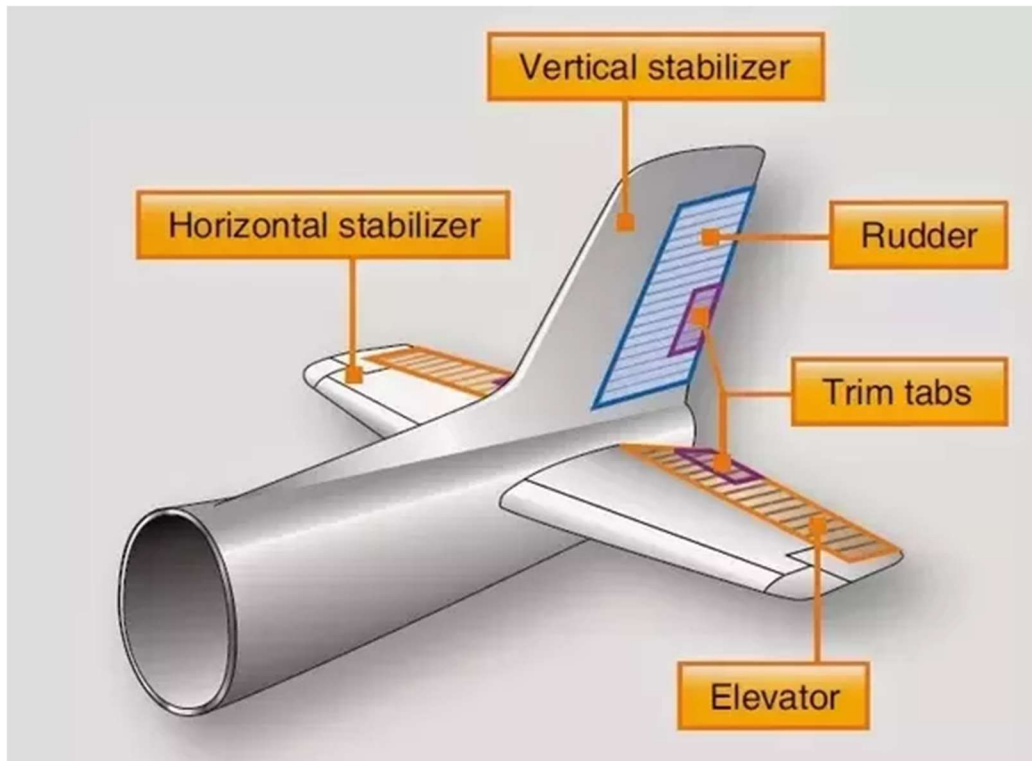


Figure 1.1 Tail and Parts

the side of helicopters and gyroplanes. no longer all constant-wing plane have tailplanes. Canards, tailless and flying wing aircraft haven't any separate tailplane, even as in V-tail aircraft the vertical stabiliser, rudder, and the tail-plane and elevator are blended to shape diagonal surfaces in a V layout.

The characteristic of the tailplane is to offer balance and manipulate. specifically, the tailplane allows modify for modifications in position of the centre of stress or centre of gravity because of adjustments in velocity and mind-set, gasoline consumption, or losing cargo or payload. The empennage, moreover called the tail or tail assembly, is a form at the rear of an aircraft that gives stability all through flight, in a way similar to the feathers on an arrow. The time period derives from the French language verb *empennier* which means that "to feather an arrow". most aircraft feature an empennage incorporating

vertical and horizontal stabilising surfaces which stabilise the flight dynamics of yaw and pitch, further to housing control surfaces. regardless of powerful manipulate surfaces, many early planes that lacked a stabilising empennage have been really unflyable. although-known as "tailless aircraft" commonly have a tail fin. Heavier-than-air plane with none form of empennage are rare, and typically use mainly formed airfoils whose trailing vicinity provide pitch balance, and rearwards swept wings, frequently with dihedral to offer the essential yaw balance. In some plane with swept wings, the airfoil segment or attitude of occurrence may exchange noticeably towards the tip.

Stability

A wing with a conventional aerofoil profile makes a horrible contribution to longitudinal stability. which means any disturbance which increases the nose produces a nostril-up pitching second which has a tendency to raise the nostril in addition. With the equal disturbance, the presence of a tailplane produces a restoring nostril-down pitching second, which might also moreover counteract

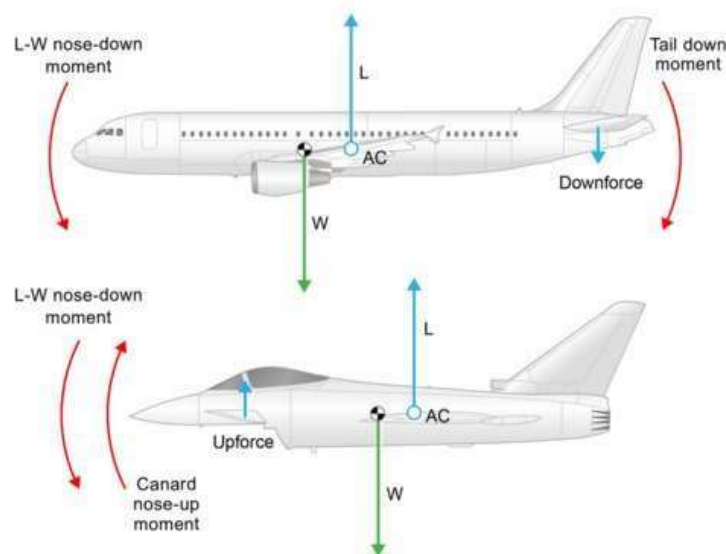


Figure 1.2 Stability

the natural instability of the wing and make the aircraft longitudinally strong. The longitudinal stability of a plane can also exchange whilst it is flown "palms-off"; i.e. even as the flight controls are task to aerodynamic forces but not pilot input forces.

1.1 Background

The airplane's main control surface to provide pitching moment and stability is the horizontal stabilizer and elevator. It is situated at the rear of the airplane's fuselage. The stabilizer is a set of wing segments whose activity is to provide balance for the plane. The elevator is a small transferring section at the rear end of the stabilizer which is joined with the help of hinges. Because of the elevator actions it varies the quantity of the pressure created by the surface and is used to control the pitching action of the plane. The elevators on each side work together like if one of the elevators goes up the other does the same. The elevator controls the movement of the airplane nose and the perspective of assault of the wing. When we change the slope of the wing the amount of lift generated differs which causes it to climb and

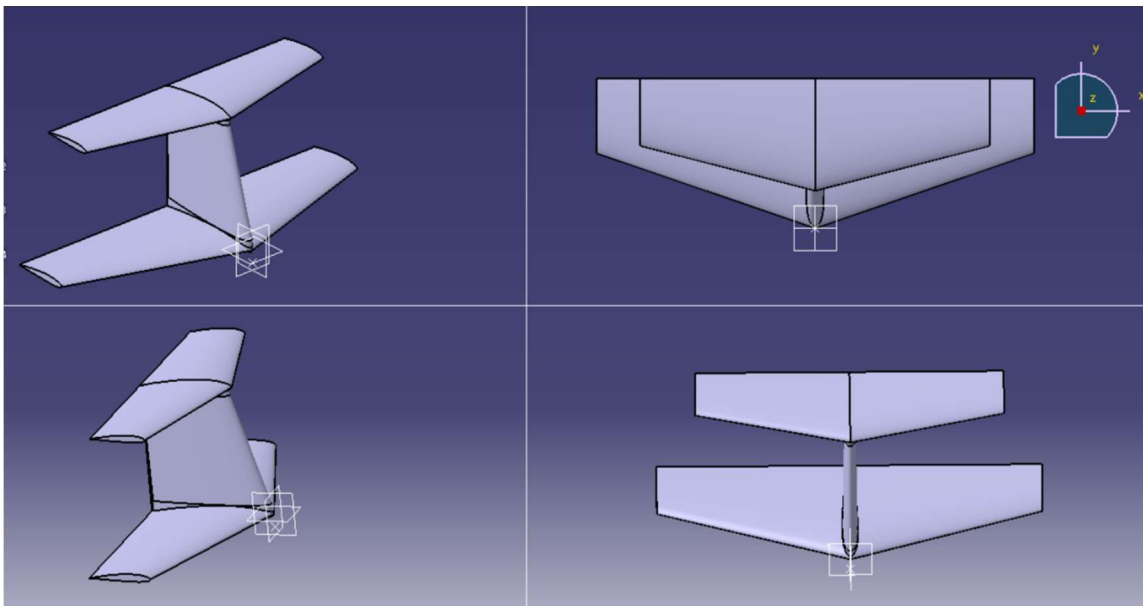


Figure 1.3 Design Structure

descend. For the duration of takeoff, the elevators are used to convey the nose of the plane up to initiate the climb. At some point of the banked flip elevator changes can boom

the lift and purpose a steeper turn. For this reason, the elevators are very essential for the plane's performance.

Aircraft design layout is a compromising fact in between competing elements and the constraints. It is far important to understand these and to apprehend the effect of each on the aircraft configuration. This lesson describes the process by using the design which is conceived to satisfy many regulations. This type of manner entails the coordination of many specific specialist departments. Each of those work on the general design but have divided duty between the effectiveness of the airplane and expert objectives of their speciality.

1.2 Design

The design system of the project is the manner by which the factors competing and the constraints affecting the layout are more synthesized with professional venture design. This technique may be taken into consideration in three extraordinary parts

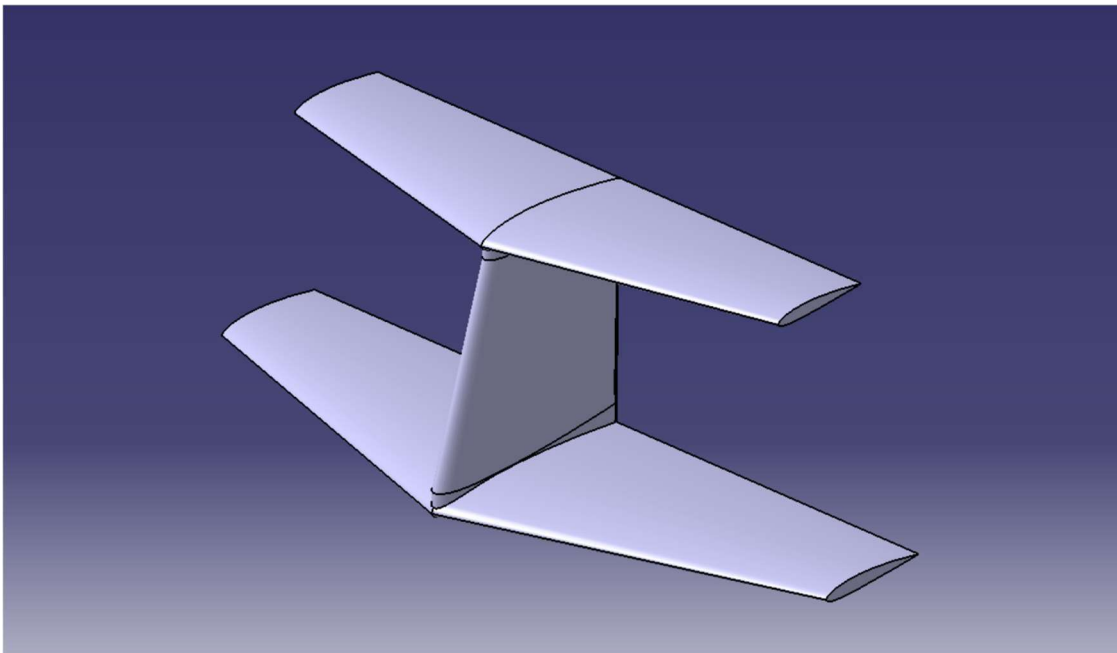


Figure 1.4 Design

- Conceptual design studies
- Initial design research
- Element design study

The difference between the second and 1/3 elements is incredibly blurred due to the separate definition of level of detail layout in the venture stage. The two parts are so often related and named as the initial design sector. The project layout hobby ends when the configuration is stuck and a decision is taken to proceed to the detail design phase. It is in this phase that the distinct issue is exact and the manufacturing approaches deliberate.

1.3 Empennage

The empennage which is termed as tail part or the tail assembly, is a shape on the rear end of the aircraft which gives balance at some point of the flight. It functions similar to the feathers attached to an arrow. It acts as a house for the main control surfaces of the flight. The tail assembly is of different types. A t-tail plane is a completely unique kind of configuration wherein the horizontal stabilizer together with the elevator is ready on the pinnacle of the vertical stabilizer. In the past and as a present it's getting used in lots of aircrafts. The aeroelastic evolution of the t-tail has a main characteristic in this research.

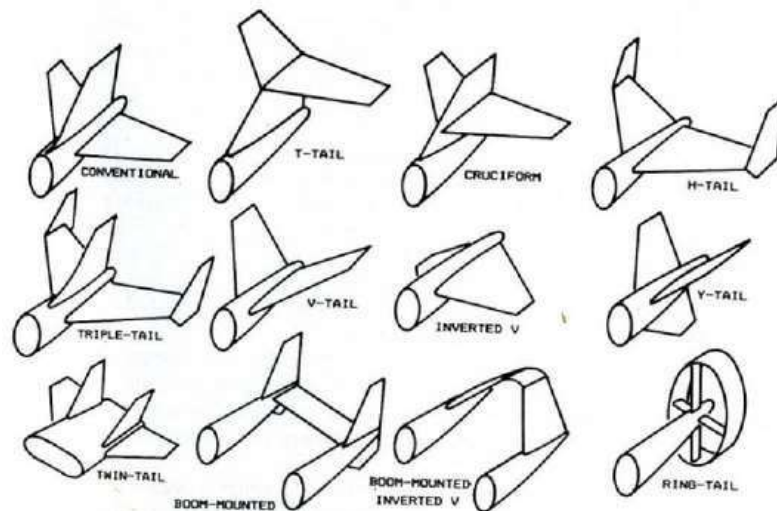


Figure 1.5 Types of tails

Because of the static upward push and the distortion of the elevator the vibration can carefully reason form failure and the vital flutter velocity is seriously reduced.

Contemporary immoderate pace planes have a tendency to be mild weight. This can cause flexible components including the tail to be afflicted by aeroelasticity problems. The ensuing issues are usually divided as static problems which include divergence and the capability of the rudder, balance of the flight and dynamics problems. A dual tail plane which is likewise termed as h-tail plane is a particular kind of vertically organized fins utilized by a few aircrafts. When we divide the controlling surfaces it offers greater vicinity to its characteristic with no need for an unmarried massive floor. This kind of association can lessen the requirement of the hanger; it additionally offers a redundancy possibility of appearing as an unmarried tail if one is inoperative. A v-tail layout is the only one which includes slanted tail elements that replaces the horizontal and vertical stabilizers. Rudder elevator is a part of the plane which acts as a rudder and the elevator



Figure 1.6 Rudder

The rudder is a number one flight manage surface which controls rotation approximately the vertical axis of an aircraft. Is called "yaw". The rudder is a movable surface that is established on the trailing fringe of the vertical stabilizer or fin. in contrast to a ship, the rudder isn't used to persuade the aircraft; alternatively, it's far used to conquer unfavorable yaw induced by using turning or, in the case of a multi-engine

plane, by way of engine failure and also allows the aircraft to be deliberately slipped while required

1.4 Split Rudder

Break up rudder gives an excessive pace manipulated in that the most effective decreases one motion at immoderate speeds reducing the exposed ground location and thereafter enhancing the manipulate effectiveness. There may be a structural benefit at the same time as the use of the rudder makes a manner for twisting load to behave at the fin that is to be considered. With the useful resource of certainly the use of the decrease rudder whilst the aircraft is at supersonic speeds, we're diverting the twisting load to different elements of the airframe. This works identical as we decrease the ailerons at excessive speeds A traditional plane tail consists of lifting surfaces organized at right proper angles to every difference known as horizontal lifting floor and vertical lifting floor. Collectively those surfaces are known as as empennage the number one obligation of a plane tail is to offer balance in the longitudinal and vertical axis which in flip offers pitching and yawing movement. For protection and performance motives the elevator/ rudder is ready with a movable floor known as trim tab like elevator trim and rudder trim. This lets the pilot manipulate the location of the number one ground in order that the aircraft will stay in a hard and fast aerodynamic configuration.



Figure 1.7 Spilt Rudder

Redundancy is one of the maximum essential strategies to reap the favored degree of protection in structures including aircraft, nuclear plants, chemical plants, and different protection vital applications. Its primary premise is to encompass redundant capability into a device that may be activated while screw ups of the regular working components arise and to validate and pick regular behavior. Safety important structures inclusive of planes require purposeful and hardware redundancy to reap prescribed protection levels. Discrete occasion management is carried out to make sure that a safe device configuration is to be had in any respect at times. Since, at present, formal verification techniques are confined to fashions with few non-stop states, on this paper, simulation is used to verify that the general device operates in step with the necessities while an actuator failure occurs.

1.5 Catia

Catia is a computer aided multi platformed software program which is an evolved program outcome from dassault systems in france. Because of its support for more than one range of designs, its miles are taken into consideration as a cax program sometimes named as 3-dimensional product life cycle management software. It issues collaborative engineering designs through an integrated cloud carrier and feature assistance is to be used for multiple disciplines. It offers the special capability other than versioning any product but to achieve something in real life operations within the age of experience.

1.6 Solidworks

SOLIDWORKS Simulation is a smooth-to-use portfolio of structural evaluation equipment that use Finite detail evaluation (FEA) to expect a product's real-world bodily behavior via really checking out CAD models. The portfolio presents linear, non-linear static and dynamic evaluation capabilities. SolidWorks is a stable modeler, and utilizes a parametric characteristic-based totally method which turned into to begin with evolved by using percent to create fashions and assemblies. The software program is written on Parasolid-kernel. Parameters may be both numeric parameters, inclusive of line lengths or circle diameters, or geometric parameters, including tangent, parallel, concentric.

Chapter 2

LITERATURE SURVEY

The need for stability of an aircraft comes with the presence of a tail section. For traditional planes the tail part is made up of horizontally stabilized surface and the vertically stabilized surface. In real life many new model planes doesn't really need the presence of empennage. Many aircrafts keep away from the use of horizontally stabilized surfaces and the vertically stabilized surface all together. For example, like B-2. The job of the horizontal surface is to help the plane in maneuvering safely, mostly the pitching moment is managed by this unit. Some aircraft which are used as fighters use the h surface in determining the roll moment too. That's in reality their handiest purpose. In the past day's technicians did not have as a whole lot expertise as we have in the present, so many past aircrafts used diverse empennage models so that it will supply their plane with best pitching authority.

2.1 Types of Tails We Offer Today Are

2.1.1 H-tail:



Figure 2.1 H-Tail

A dual tail plane which is likewise termed as h- tail plane is a particular kind of vertically organized fins utilized by a few aircrafts. When we divide the controlling surfaces it offers greater vicinity to its characteristic with no need for an unmarried massive floor.

This kind of association can lessen the requirement of the hanger; it additionally offers a redundancy possibility of appearing as an unmarried tail if one is inoperative.

2.1.2 V-tail:

A v-tail layout is the only one which includes slanted tail elements that replaces the horizontal and vertical stabilizers. Rudder elevator is a part of the plane which acts as a rudder and the elevator



Figure 2.2 V-Tail

2.1.3 T-tail:

A t-tail plane is a completely unique kind of configuration wherein the horizontal stabilizer together with the elevator is ready on the pinnacle of the vertical stabilizer. In the past and as a present it's getting used in lots of aircrafts. The aeroelastic evolution of the t-tail has a main characteristic in this research. Because of the static upward push and the distortion of the elevator the vibration can carefully reason form failure and the vital flutter velocity is seriously reduced.



Figure 2.3 T-Tail

2.1.4 Conventional tail:

A conventional / traditional tail is the most commonly used tail model in civil aviation. The horizontal surface is split into two surfaces and are mounted to the sides of the rear fuselage. The rudder is elevated on the upper part and primed with presence of dorsal fin



Figure 2.4 Conventional tail

2.1.5 Triple tail:

The Lockheed Constellation is the name given to the propeller driven aircraft which uses three vertical tails for its operation. This constellation's design resembles that of the Lockheed P-38 aircraft differing in length. This triple tail configuration made the plane to match into current hangers. The wide tail fin integrated 3 vertical stabilizers, whilst its wide wing supported four huge prop engines. This accurate modeled airplane is created from flat and corrugated metal surface and given a vintage polished aluminium look. A handy stand is included, so that you can display off this handsome scale version on your table or bookshelf.



Figure 2.5 Triple Tail

2.1.6 Cruciform tail:

This configuration was introduced to enhance the rudder with undisturbed airflow over it. The cruciform tail is an aircraft empennage configuration which, whilst viewed from the plane's front or rear, seems much like a cross. The same old association is to have the horizontal stabilizer intersect the vertical tail somewhere near the center, and above the pinnacle of the fuselage. The design is frequently used to find the horizontal

stabilizer far from jet exhaust, propeller and wing wake, as well as to offer undisturbed airflow to the rudder.



Figure -2.6 Cruciform tail

2.1.7 Boom-Tail Design:

The dual boom allowed easy get admission to to the rear of the fuselage for loading and casting off cargo. The dual boom tail plane has also been used for an airplane with engines installed inside the fuselage, with one engine, known as the tractor, within the nose of the plane and one engine, referred to as the pusher, inside the rear of the aircraft. due to the fact the thrust of both engines is alongside the centerline of the airplane



Figure 2.7 Boom-Tail Design

2.1.8 Engine Mounted on Tail

Tail-installed engines work as efficaciously as we as compared to engine below the wing. however, there may be a trouble within the go with the flow of gas from gas tank to the engine established on the tail. Mounted on tail in this situation we cannot use the gravity to waft the gasoline to the tail part.



Figure 2.8 Engine mounted tail

2.2 Drag

In aerodynamics, drag refers to forces that oppose the relative movement of an object through the air. Drag usually opposes the motion of the item and in a plane, is overcome through thrust.

- Drag
- Induced Drag
- Parasite Drag
- Interference Drag
- Form Drag
- Friction Drag
- Wave Drag

- Surface Coatings and Drag Reduction

In this project we are main concentrating on few areas which are essential elements in the aerodynamics. They are

- Reduce induced drag
- Reduce parasitic drag
- Increase lift co efficient
- Polar drag
- Flutter
- Aero elasticity

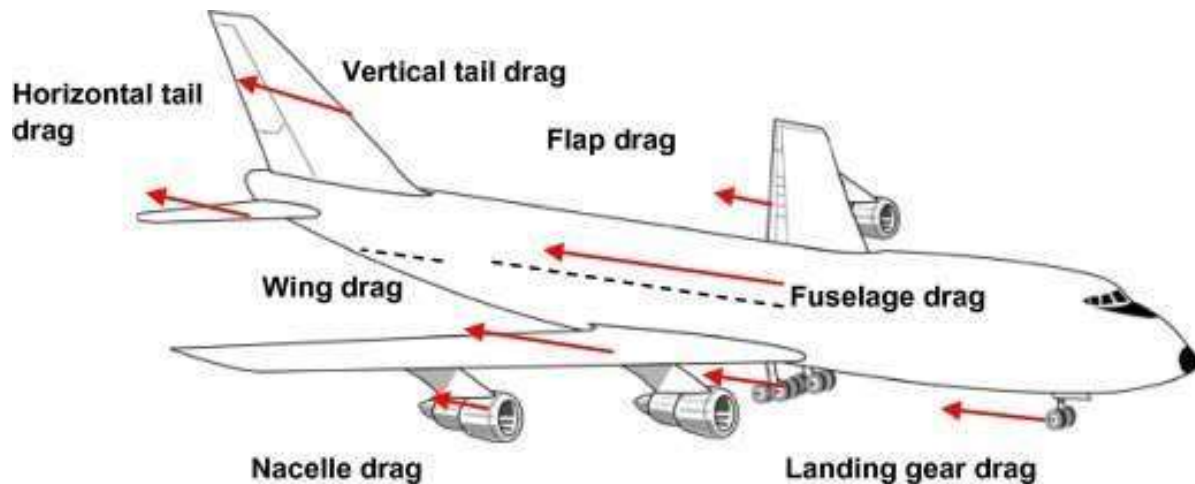


Figure 2.9 DRAG

2.2.1 Types of drag

Airfoil is nothing however go sectional form of a wing which create more carry than drag to create aerodynamic elevate. As, it is flying in the atmosphere or in fluid flow produces aerodynamic force. The shape of an airfoil designed specifically technique with invariant geometry. The aerodynamic forces are drag, thrust, raise, weight.

- The drag pressure acts parallel to the thrust that's produced at the same time as the aerofoil passing thru the fluid glide
- Thrust will act parallel to the drag. it's far created opposite to the movement of plane which act at the surface of the aircraft.

How wing slots reduce drag

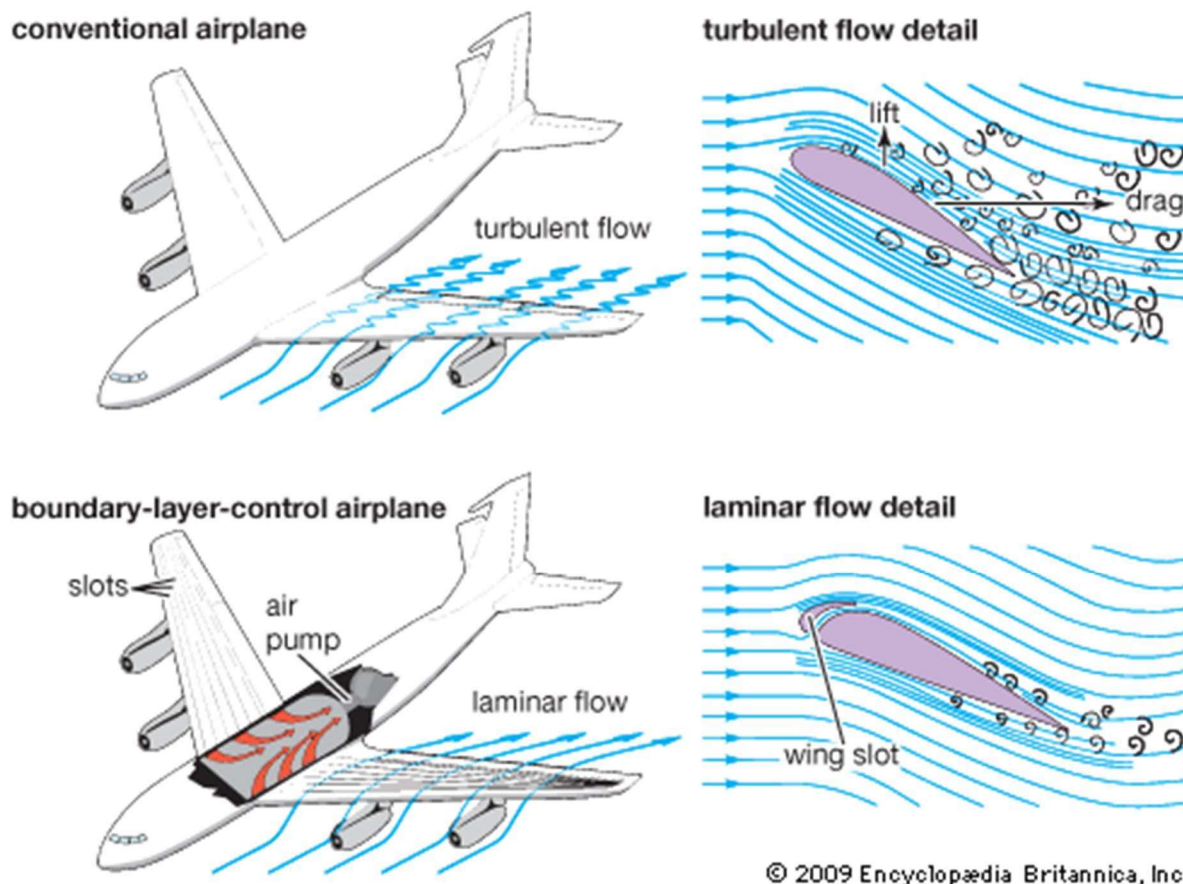


Figure 2.10 Types of drag

- elevate acts perpendicular to the plane in an unfastened flow speed. while the carry is acting on an aerofoil then concurrently it results in attitude of attack.
- Weight is a force with the intention to act opposite to lift for you to withstand the pressure.

In airfoil there are specific series like NACA four series, five collection, 6 collection, and many others.

2.3 Yaw stability

The vertical tail performs a determining function in yaw stability, presenting most of the required restoring second about the center of gravity when the aircraft slips. Yaw balance is usually quantified using the spinoff of moment coefficient with respect to yaw angle. The airflow over the vertical tail is frequently encouraged with the aid of the fuselage, wings and engines of the plane, both in importance and path. the principle wing and the horizontal stabilizer, if they are notably swept, can make a contribution significantly to the yaw stability; wings swept backwards tend to boom yaw stability. Sweep inside the wing and horizontal tail of a conventional aircraft, however, does not affect airplane trim in yaw. Dihedral inside the essential wing and horizontal tail also can have a small effect on the static yaw balance. This impact is complicated and paired with the effect of wing sweep and flow about the fuselage.

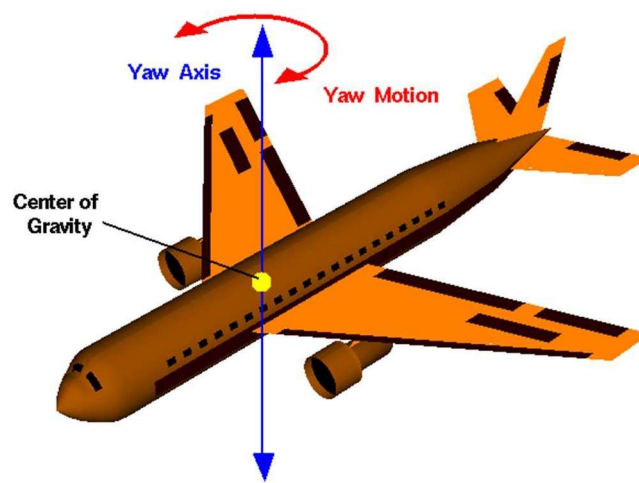


Figure 2.11 Yaw axis

Propellers, specially while they're advancing so that their axis makes a perspective to the freestream velocity, can have an effect on the static balance of an airplane in yaw

Chapter 3

AIM AND SCOPE

Planes must have a positive amount of inherent balance and controllability to be flyable. It is consequently essential to remember those traits while designing a new plane. Correct evaluation of the steadiness characteristics of any given plane is a reasonably complex technique, and isn't properly acceptable for preliminary or intermediate layout. The tail of a plane serves numerous purposes; however, the main motive is to provide stability for the plane, meaning that if the plane is tilted off course by way of a gust of wind, it could return to its unique position. The tail includes manipulate surfaces to manipulate the aircraft. there may be the vertical stabilizer, that is the "tail fin" of the plane. This keeps the plane consistent with the path of movement. In other phrases, it controls yaw. To alternate yaw, a pilot moves the rudder, additionally found on the tail. moreover, at the tail is the horizontal stabilizer, or "rear wing", which controls pitch. To exchange pitch, a pilot actions the elevator. So, the basic purpose of the project is to increase the stability for the plane which can upstand high velocity. The principle goal of this undertaking is to observe variation of raise, drag and pitching second coefficient feature (C_l , C_d and C_m) of attitude of assault and elevator deflection in longitudinal course. To make certain a plane flies easily it wishes to be stable. An unstable plane no longer provides an uncomfortable ride to its passengers but additionally will increase the workload of the pilot/s, increase aerodynamic strain on its components and if no longer corrected in time can result in aircraft attitudes outside of controllable limits. About the Boundary layer ingestion engines are a way of extensively decreasing this drag. this is completed with the aid of making the air waft in an extra ideal fashion on the tail of the plane, through the engines.

The primary problem with such engines is that the boundary layer presupposes a discontinuity inside the flow subject. This discontinuity translates into periodic excitations of the engine's fan/ compressor or, in different words, vibrations. Vibratory phenomena cause the collapse of the element thru fatigue, so are to be averted.

Chapter 4

COMPUTATIONAL ANALYSIS

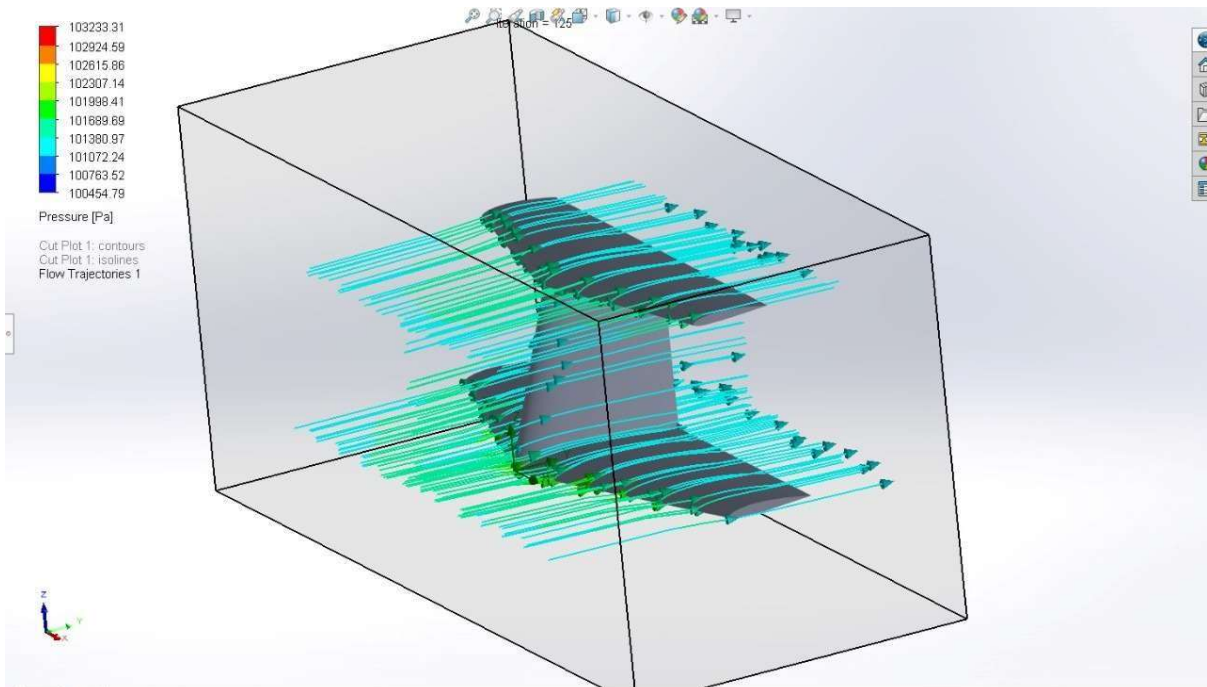
Before proceeding to the fabrication and experimental analysis we thought to examine the layout behaviour when it subjected to specific conditions with the aid of inserting in versatile softwares like strong works and ansysis to look the aero elasticity and aerodynamic's of the version. we have choosen fabrication cloth as aluminium alloy and we used mixed mess

We created an encloser across the design version as a test section, which allows to use the situations with inside the encloser limit. we've got delivered the design to extraordinary angle of assaults within the test section to calculate the elevate and drag.

The velocity choosen for analysis of the layout model is 30m/s. s the electric automobiles in no way exceeds Mach No 1.

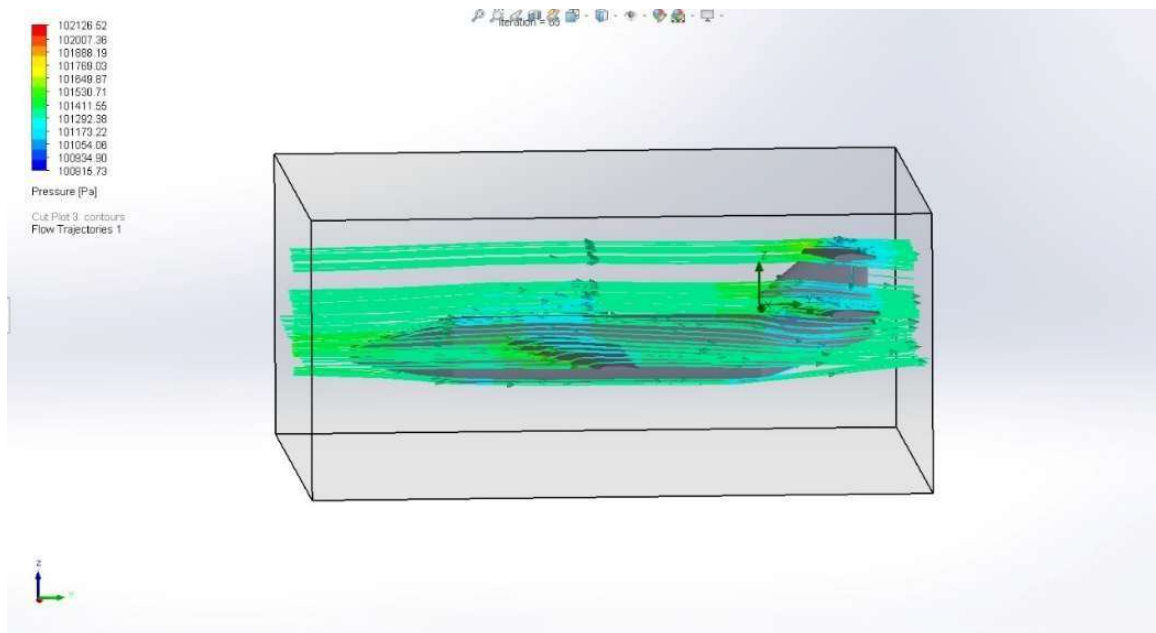
- Flow Trajectory
- Contours
- Stream lines
- Pressure distribution over the wing
- Lift
- Drag
- Side Force

4.1 Flow trajectory's



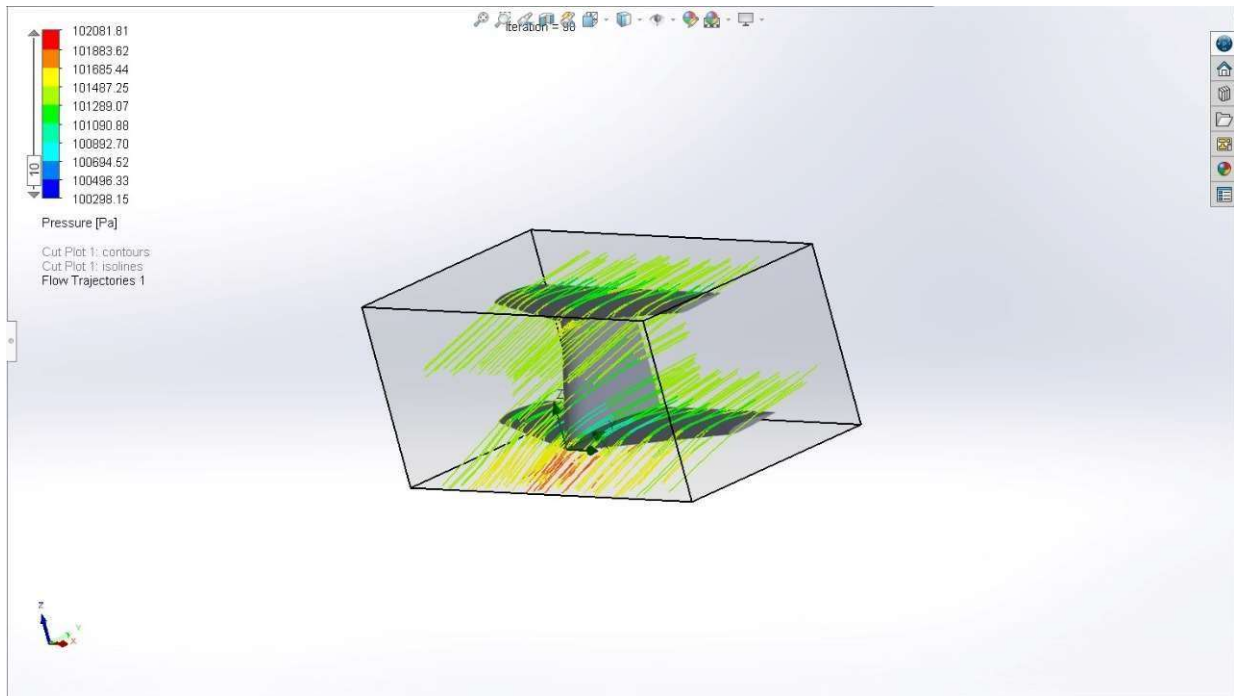
Here we can see the flow trajectory of I tail at AOA 0° with light deviation in the path

Figure 4.1 I tail flow trajectory at aoa 0°



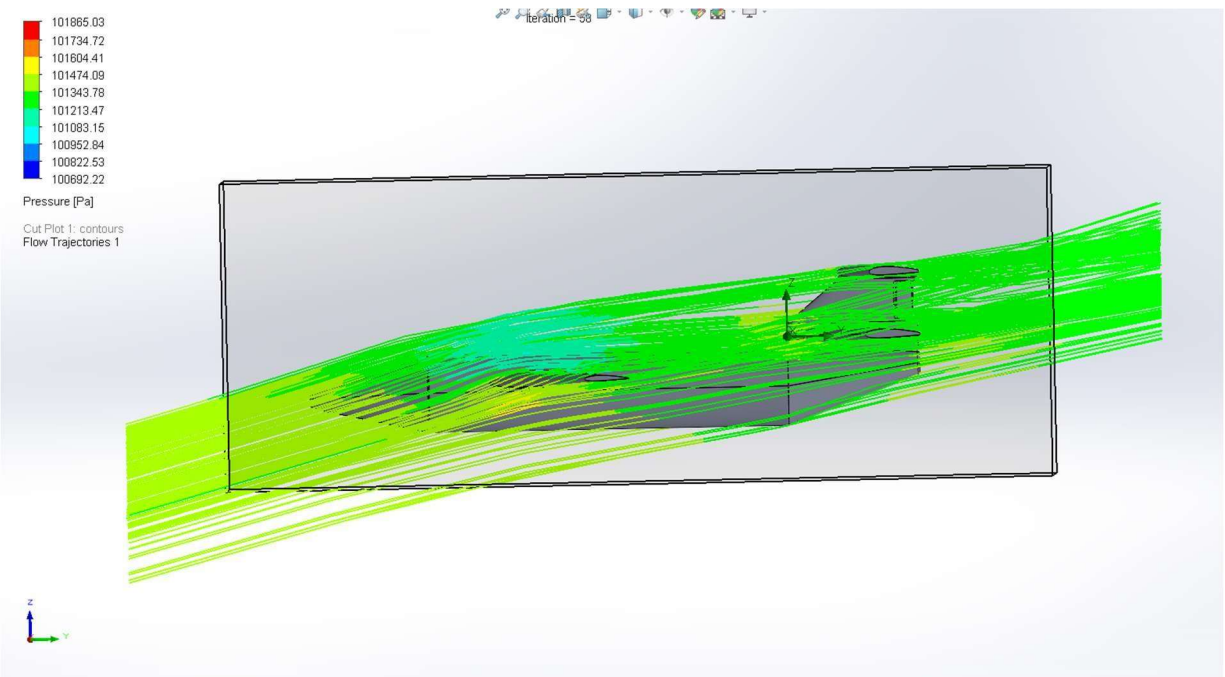
Here we can see the flow trajectory of airplane at AOA 0° with deviation in path

Figure 4.2 Airplane flow trajectory at aoa 0°



we can see some deviation in flow trajectory at AOA 15° of I tail

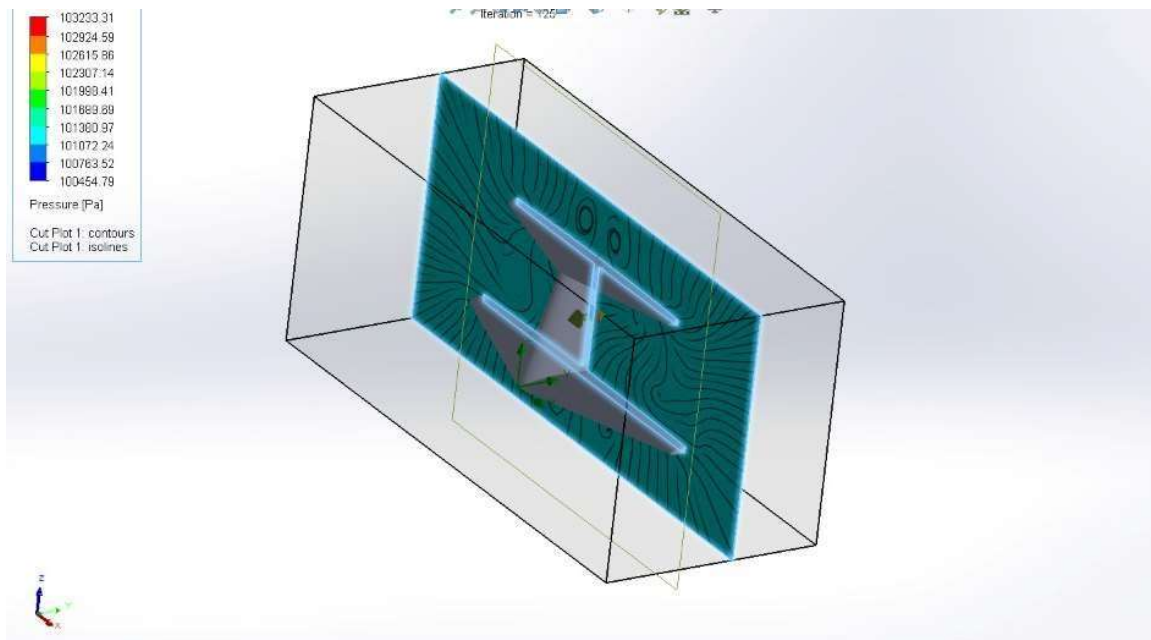
Figure 4.3 I tail flow trajectory at aoa15°



we can see some deviation in flow trajectory at AOA 15° of airplane

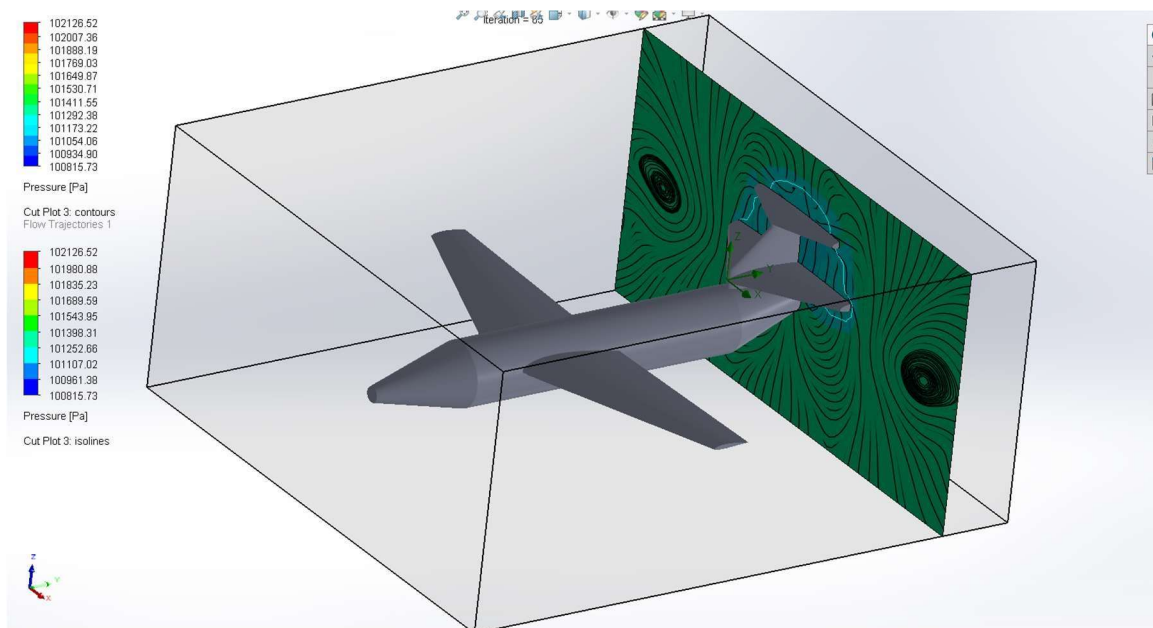
Figure 4.4 Airplane flow trajectory at aoa 15°

4.2 STREAM LINES AND COUNTOURS



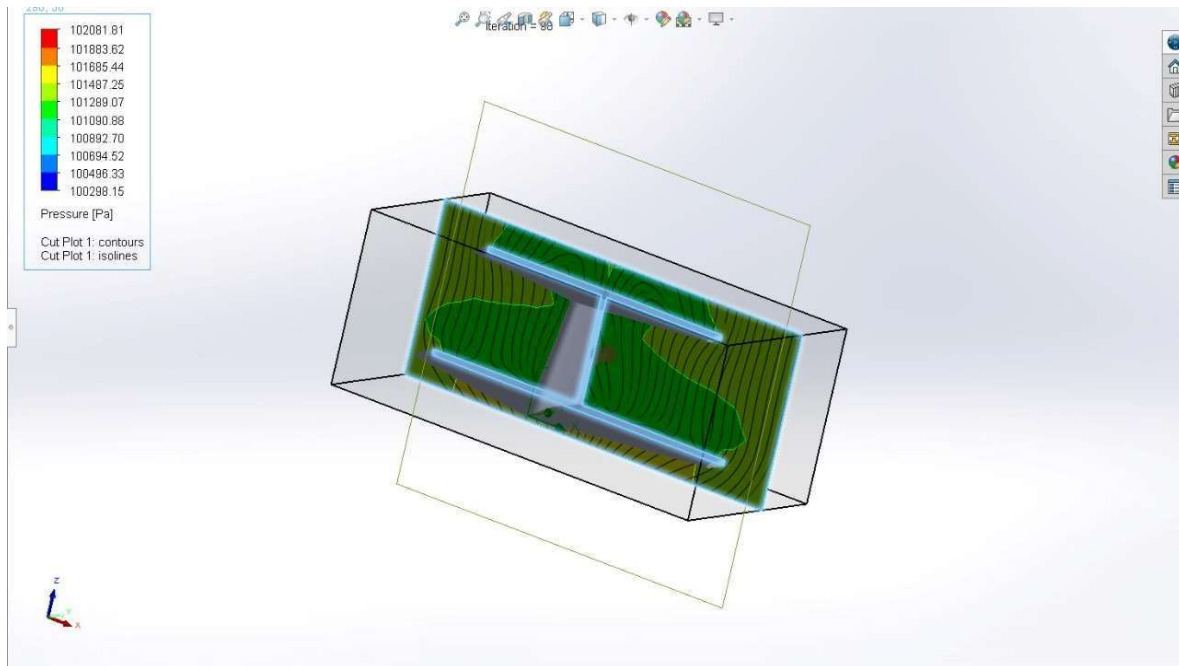
Here we can visualize the streamlines around the I tail at AOA 0°

Figure 4.5 I tail streamlines at aoa 0°



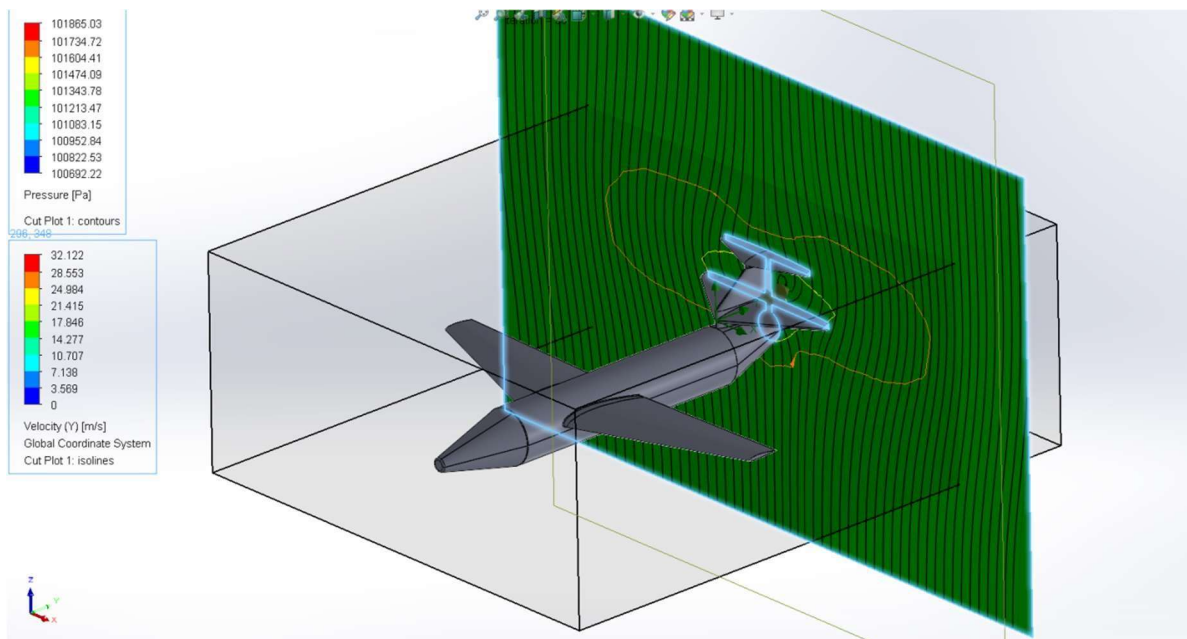
Here we can visualize the streamlines around the airplane at AOA 0°

Figure 4.6 Airplane streamlines at aoa 0°



Here we can visualize the countours around the I tail at AOA 15⁰

Figure 4.7 I tail countours at aoa 15⁰



Here we can visualize the streamlines around the airplane at AOA 15⁰

Figure 4.8 Airplane countours at aoa 15⁰

4.3 PRESSURE DISTRIBUTION OVER THE WING

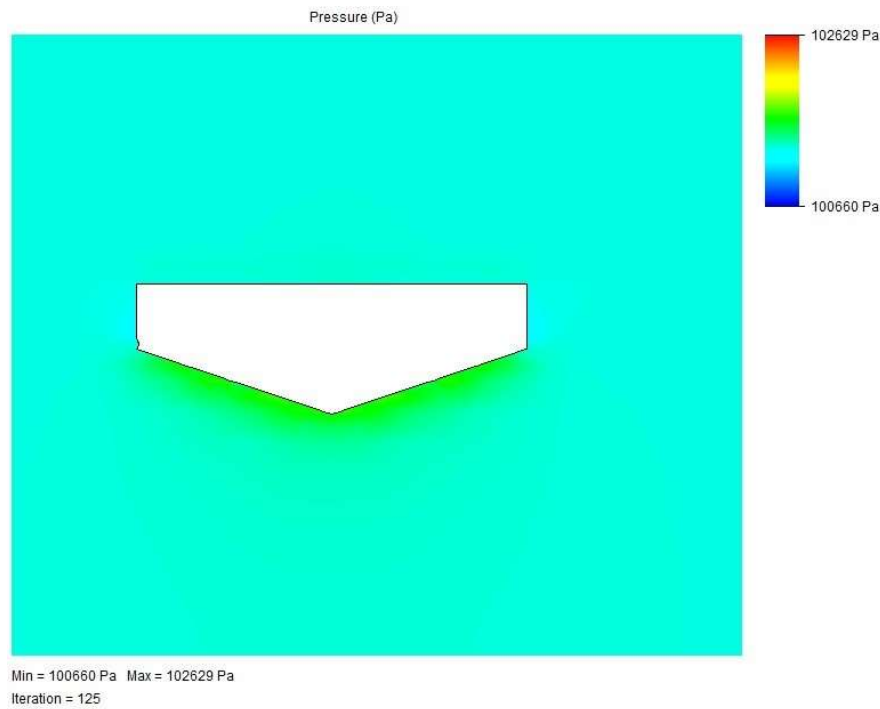


Figure 4.9 I tail pressure distribution

Pressure distribution of any part is the important factor to calculate the lift produced. Here the maximum pressure is 102629 pa and minimum pressure is 100660 Pa.

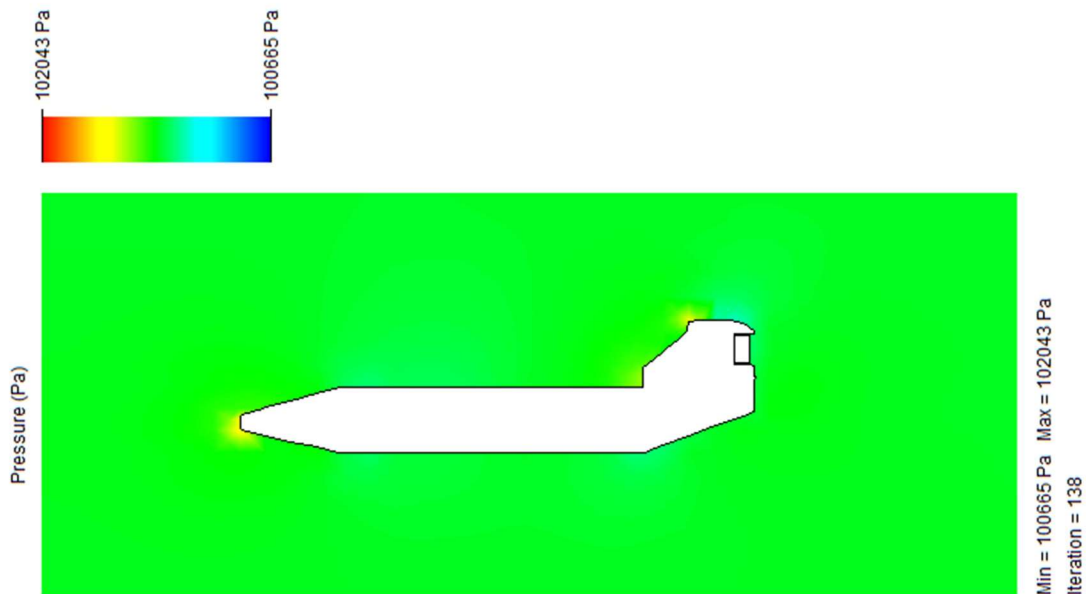


Figure 4.10 airplane pressure distribution

Here we can see that the maximum pressure is 102043 pa and minimum pressure is 100665 Pa.

4.4 Finding Cl

Cl (Coefficient of Lift)

$$Cl = \frac{L}{\rho V^2 A/2}$$

Where ρ is the density of the air

A is Surface Area

V is Velocity of Air

L is lift

Finding cd

Cd (COEFFICIENT OF DRAG)

$$AR = \frac{s^2}{A}$$

$$Cd_i = \frac{Cl^2}{\pi AR e}$$

Where s is Chord Length

A is Surface Area

AR Aspect Ratio

E is Efficiency Factor

4.5 Numerical Calculation

TABLE 4.1 I tail numerical calculations of Cl and Cd

drag (y)	lift(z)	x	Cl	Cd
3.06267	1.45082	0.0164738	0.02892	0.06105
0.709693	3.2077	-0.0442753	0.06394	0.014148
1.09988	3.61666	-0.115011	0.0721	0.021926
0.603141	2.92181	0.0490293	0.05825	0.012023
1.01782	4.30722	0.00434896	0.08586	0.02029
1.03755	3.59539	0.080969	0.07167	0.020683
1.50311	3.79548	-0.0262782	0.07566	0.029964
0.992465	5.27327	-0.0483675	0.10512	0.019785
1.37579	7.13434	-0.0248461	0.14222	0.027426
0.457741	8.34187	0.0459824	0.1663	0.009125
0.221874	8.45324	-0.0638077	0.1685	0.004423
1.16493	8.56883	0.027426	0.17082	0.023223
1.14805	10.7682	-0.0260978	0.21466	0.022886
1.48422	14.8838	0.000821542	0.2967	0.02959
0.337825	11.7335	0.0968826	0.2339	0.006734
0.168659	15.8797	0.00149839	0.31656	0.003362

These cl and cd values are obtained from solidworks

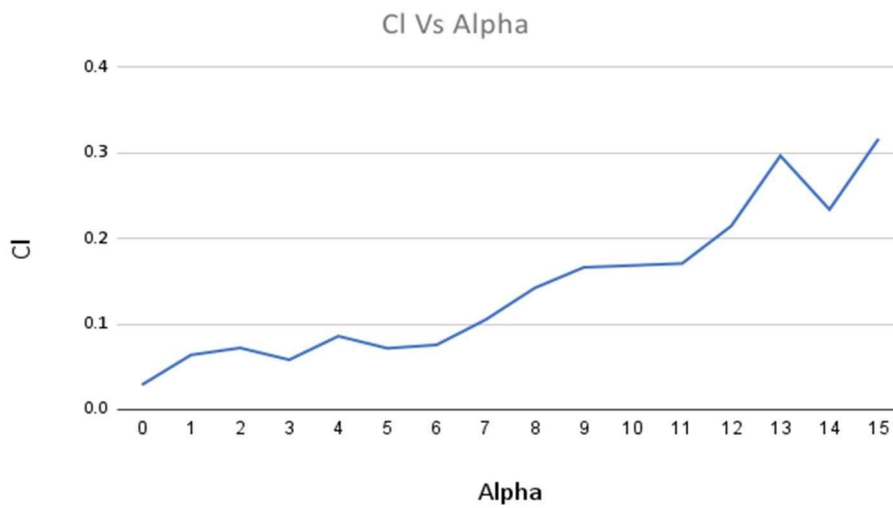


Figure 4.11 I tail Cl Vs alpha

Here the coefficient of lift is increasing from 0.02892 at 0° AOA to 0.31656 at 15° AOA

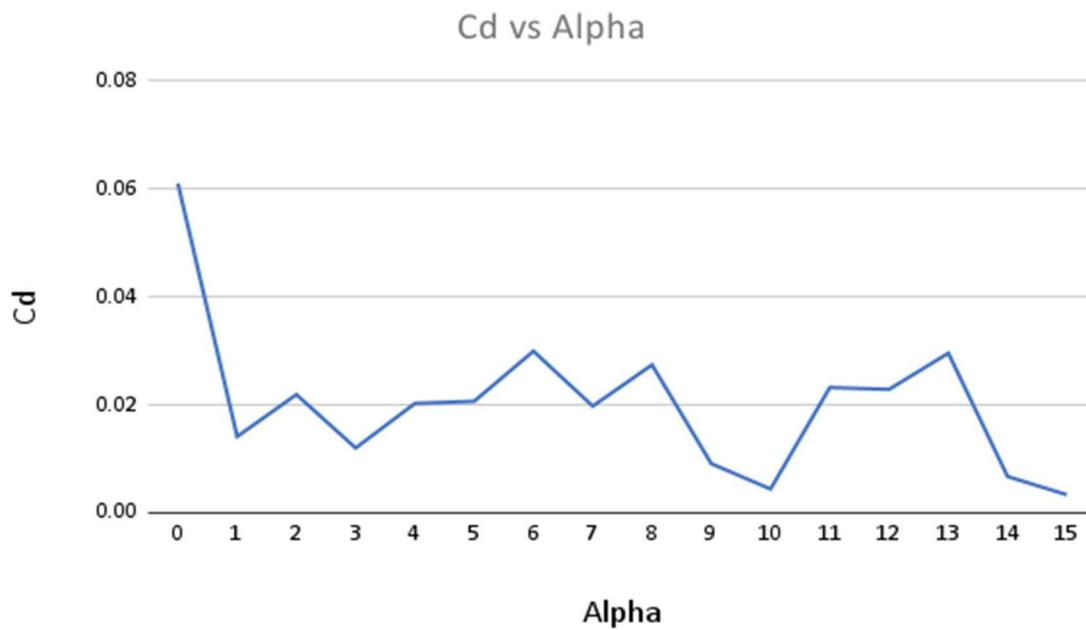


Figure 4.12 I tail Cd Vs Alpha

Here the coefficient of Drag is decreasing from 0.0613 at 0° AOA to 0.0012 at 15° AOA

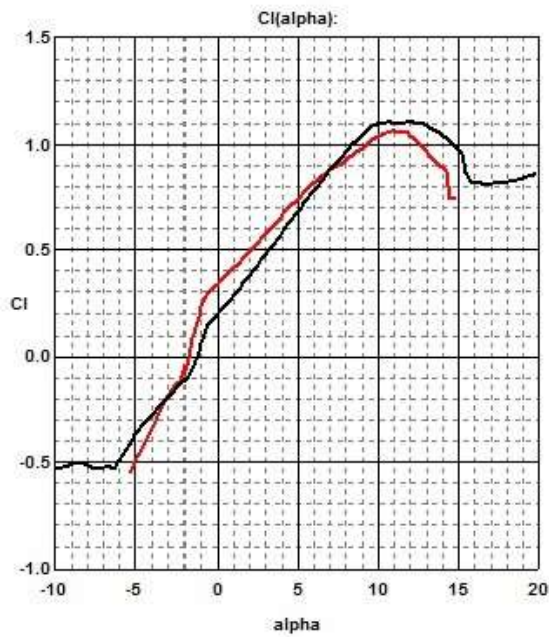


Figure 4.13 C_l Vs Alpha

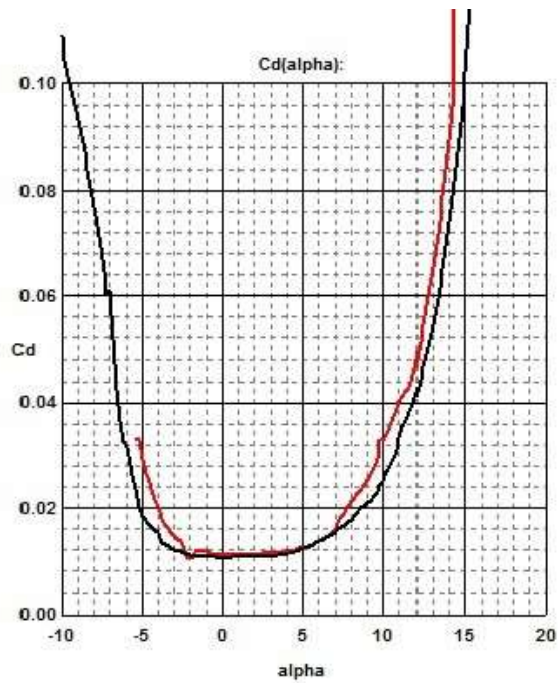


Figure 4.14 C_d Vs Alpha (Reference)

Cd vs. C_l

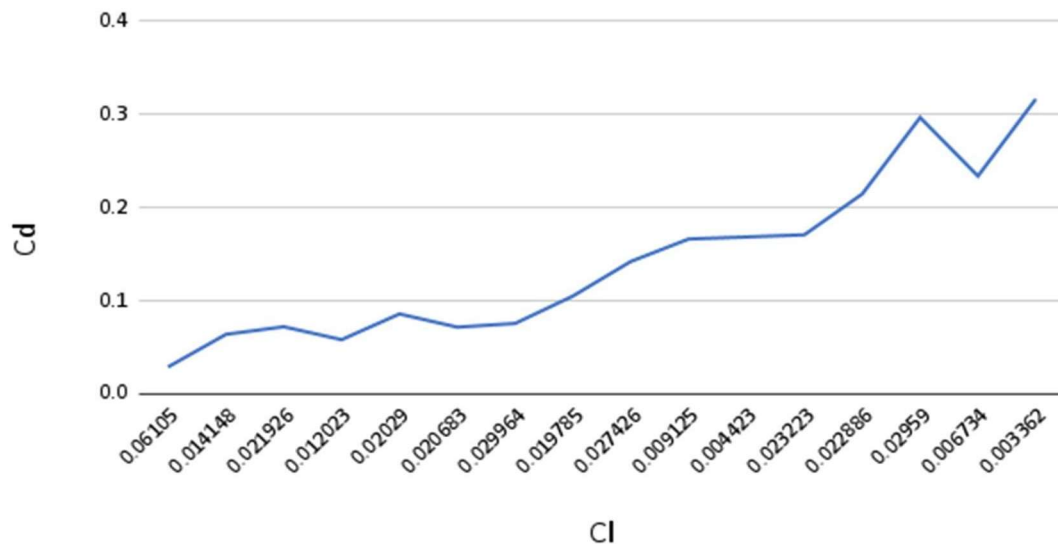


Figure 4.15 I tail Cd Vs C_l

Here the coefficient of Drag is increasing from 0.0453 at 0.06105 C_l to 0.31656 at 0.003362 C_l value

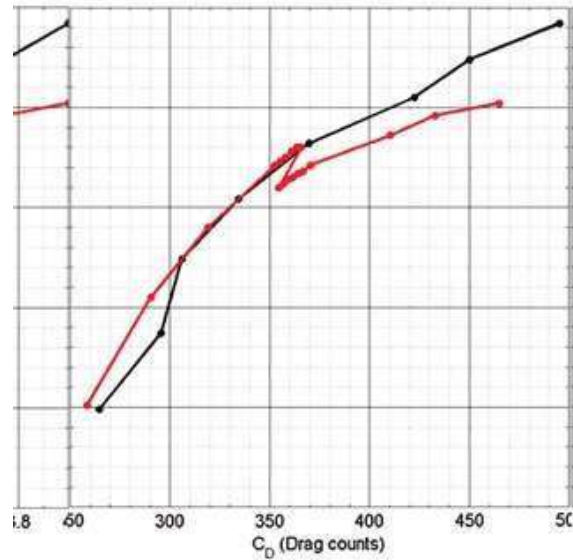


Figure 4.16 Cl vs Cd (Reference)

Table 4.2 Airplane Numerical calculations of Cl and Cd

angle	Drag(Y)	lift(Z)	X	Cl	Cd
0	2.622	1.851	-0.04227	0.011865	0.016807
1	1.889	3.254	0.02109	0.02086	0.012109
2	1.070952	4.01	-0.025352	0.025705	0.010958
3	2.8623	3.4318	0.02577	0.022	0.018348
4	2.548	4.2258	-0.098	0.02709	0.01633
5	2.449	5.1164	0.11027	0.032797	0.015698
6	2.3915	6.1869	-0.01913	0.03966	0.01533
7	2.3002	6.7464	-0.00355	0.043245	0.014745
8	2.0954	7.4441	0.0267	0.04772	0.013432
9	2.2915	7.4822	0.14919	0.04796	0.01469
10	2.126	8.121	0.0031	0.05206	0.013628
11	1.9971	9.7588	0.02952	0.06255	0.012802
12	1.61814	10.1637	0.03078	0.06515	0.010372
13	1.9433	11.0086	0.14234	0.07057	0.012457
14	1.9593	11.5923	0.00549	0.07431	0.01256
15	1.87018	12.0906	0.00312	0.0775	0.011988

These cl and cd values are obtained from solidworks

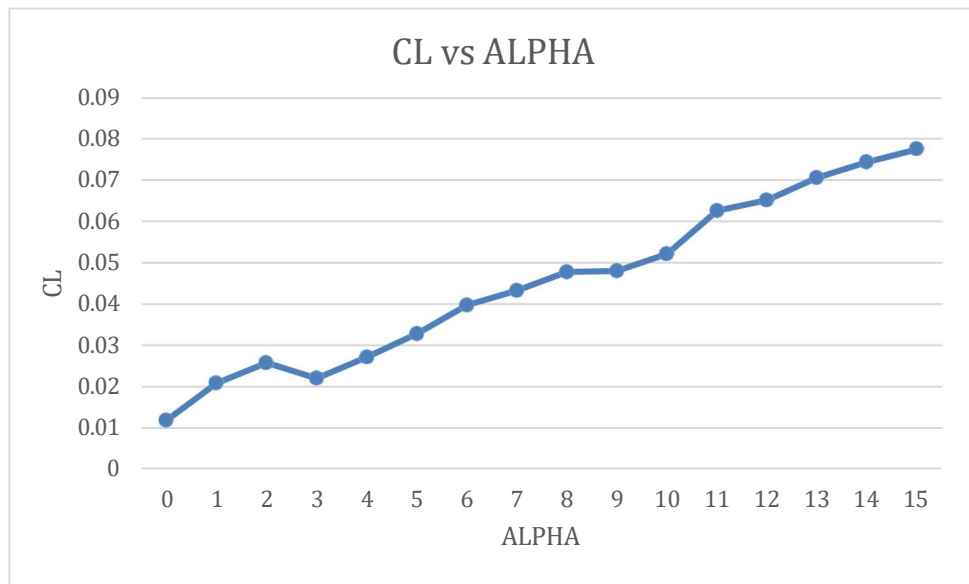


Figure 4.17 Airplane CL Vs Alpha

Here the coefficient of lift is increasing from 0.01221 at 0° AOA to 0.07564 at 15° AOA

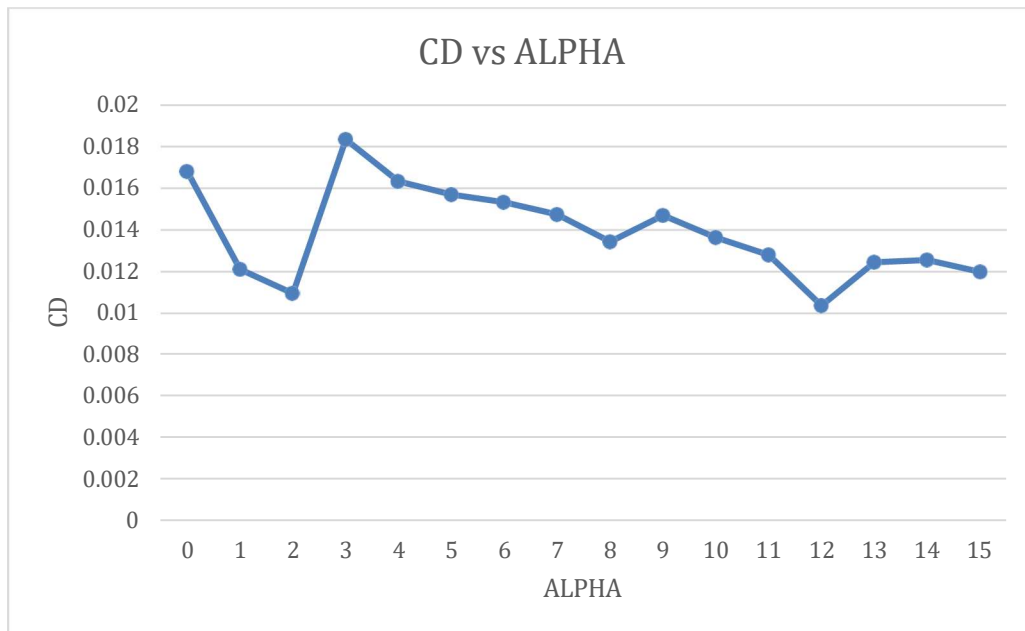


Figure 4.18 Airplane cd vs alpha

Here the coefficient of Drag is decreasing from 0.01643 at 0° AOA to 0.01198 at 15° AOA

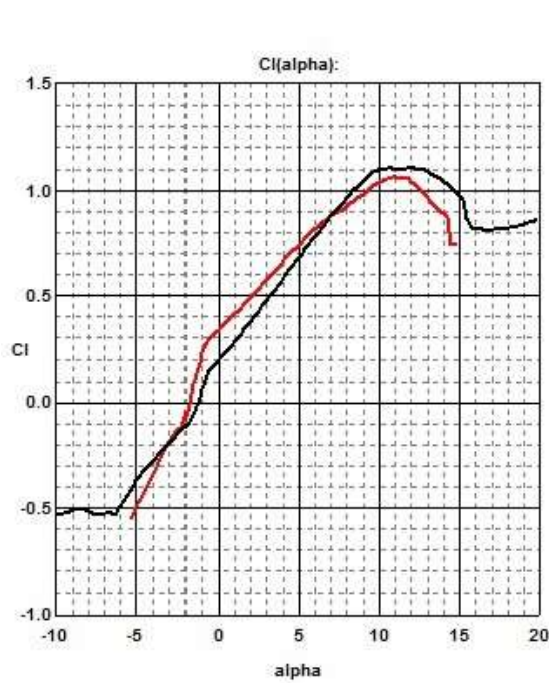


Figure 4.19 C_L Vs Alpha

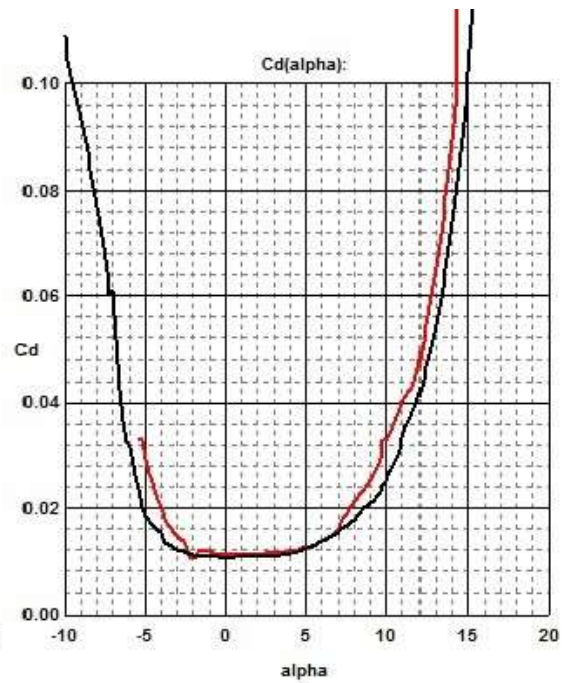


Figure 4.20 C_d Vs Alpha (Reference)

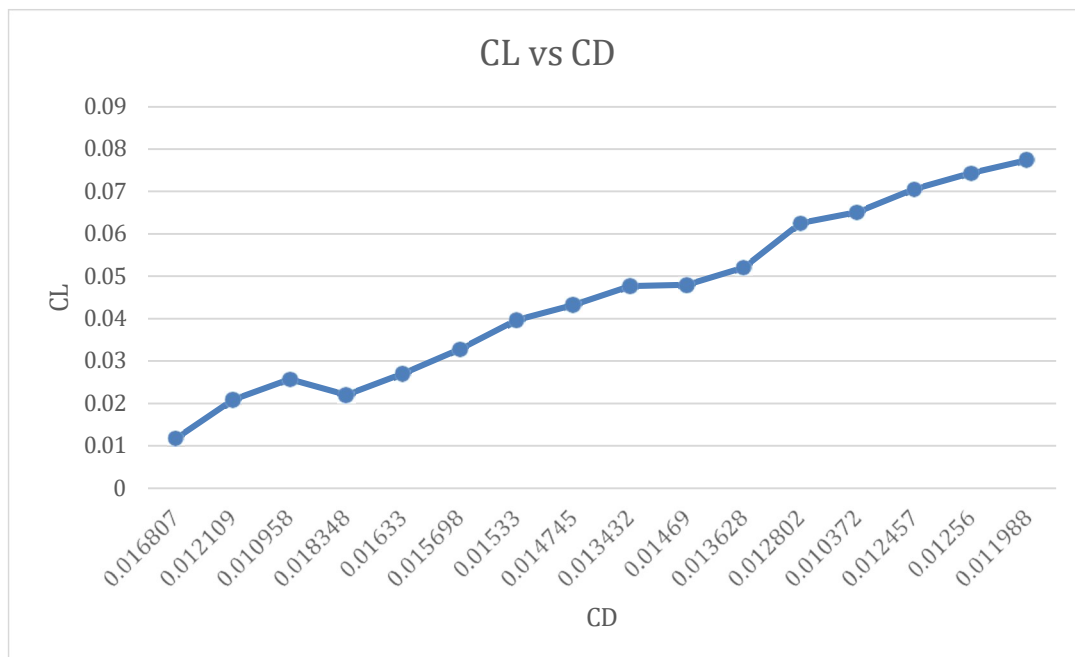


Figure 4.21 Airplane C_L vs c_d

Here the coefficient of Drag is increasing from 0.016807 at 0.01865 C_L to 0.0775 C_L value

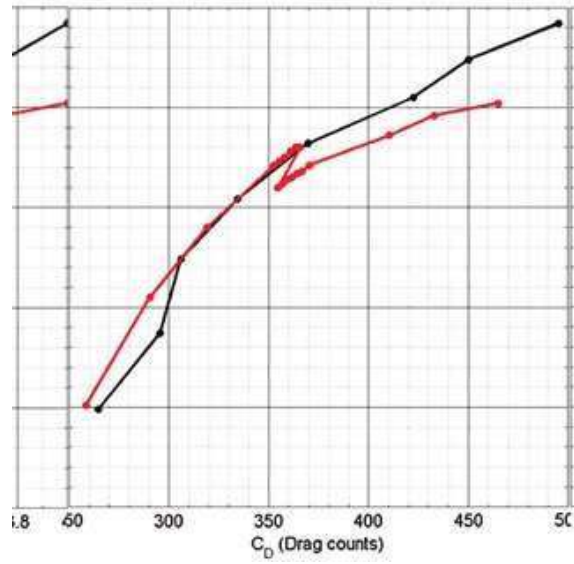


Figure 4.22 C_I vs C_d (Reference)

CHAPTER 5

EXPERIMENTAL ANALYSIS

After completing the computational analysis, we decided to perform the experimentation with model 1 which is I shaped tail plane. For the fabrication of the model we used 3D printer. The necessary calibrations are done before hand and we inserted 2mm hollow tubes into the 8 tappings which is made clock wise around the model. 4 on the upper surface and 4 on the bottom surface. The model with the tubes is fitted into the test section and experimentation is done.

Conditions of the wind tunnel –

- Speed - 700 RPM
- manometer liquid - ethanol
- ports connected – 8

Table 5.1 Calibration table

RPM (x axis)	hi = 0.2		
	manometer	h	V m/s
100	0.3	0.05×10^{-2}	2.51
200	0.65	0.225×10^{-2}	5.33
300	1.15	0.475×10^{-2}	7.74
400	1.9	0.85×10^{-2}	10.36
500	2.85	0.425×10^{-2}	7.32
600	4.1	1.95×10^{-2}	15.69
700	5.55	2.675×10^{-2}	18.38
800	7.25	3.525×10^{-2}	21.1
900	9.25	4.525×10^{-2}	23.91
1000	11.45	5.625×10^{-2}	26.66

1100	13.85	$\frac{6.825 \times 10^{-2}}{2}$	29.36
1200	16.4	8.1×10^{-2}	31.99

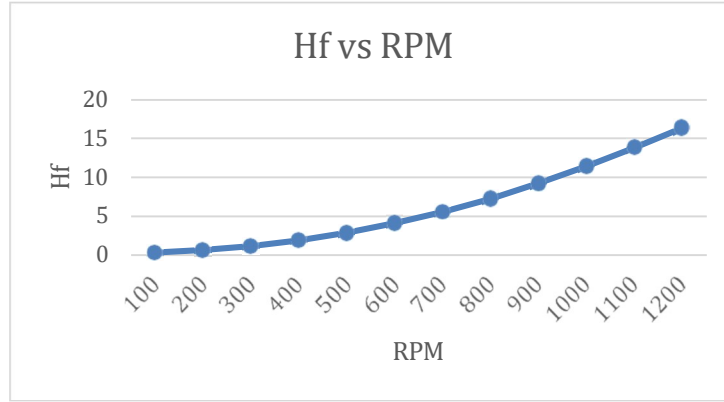


Figure 5.1 Hf vs RPM graph

5.1 Calibration formula's

$$H_a = \frac{(h_1 - h_2)}{2} \quad V = \frac{\sqrt{2\rho w g}}{\rho a}$$

Table 5.2- The experimental results are as follows

AOA	0	2	4	6	8	10	12	14	15
PORTS									
1	4.8	4.9	5	5.1	5.2	5.2	5.4	5.4	5.6
2	3.3	3.3	3.4	3.4	3.3	3.2	3	3.1	2.9
3	4.4	4.4	4.5	4.4	4.3	4.4	4.1	4.1	4
4	3.6	3.7	3.7	3.8	3.8	3.9	4.3	4.4	4.5
5	4.3	4.4	4.5	5.5	5	4.5	4.6	4.3	4.3
6	3.2	3.1	3.2	3.1	3.2	3.2	3	2.9	3
7	4.2	4.1	4.1	4	4	4.1	4.1	3.9	4
8	3.1	3.2	3.3	3.3	3.2	3.2	3.4	3.5	3.5

Calculation of coefficient of pressure-

It is found using the below formula

$$C_P = (P_s - P_s) / (P_t - P_s)$$

Table 5.3 Cp values

PORTS AOA	0	2	4	6	8	10	12	14	15
1	- 0.27272 7273	- 0.31818 1818	- 0.3636 364	- 0.4090 9091	- 0.4545 4545	- 0.45454 5455	- 0.54545 455	- 0.54545 4545	- 0.63636 3636
2	0.40909 0909	0.40909 0909	0.3636 3636	0.3636 3636	0.4090 9091	0.45454 5455	0.54545 4545	0.5 4545	0.59090 9091
3	- 0.09090 9091	- 0.09090 9091	- 0.1363 636	- 0.0909 0909	- 0.0454 5455	- 0.09090 9091	0.04545 4545	0.04545 4545	0.09090 9091
4	0.27272 7273	0.22727 2727	0.2272 7273	0.1818 1818	0.1818 1818	0.13636 3636	- 0.04545 455	- 0.09090 9091	- 0.13636 3636
5	- 0.04545 4545	- 0.09090 9091	- 0.1363 636	- 0.5909 0909	- 0.3636 3636	- 0.13636 3636	- 0.18181 818	- 0.04545 4545	- 0.04545 4545
6	0.45454 5455	0.5	0.4545 4545	0.5	0.4545 4545	0.45454 5455	0.54545 4545	0.59090 9091	0.54545 4545
7	0	0.04545 4545	0.0454 5455	0.0909 0909	0.0909 0909	0.04545 4545	0.04545 4545	0.13636 3636	0.09090 9091
8	0.5	0.45454 5455	0.4090 9091	0.4090 9091	0.4545 4545	0.45454 5455	0.36363 6364	0.31818 1818	0.31818 1818

These coefficient of pressure values are calculated using $C_P = (P_s - P_t)/(P_t - P_s)$

5.2 Calculate x/c and y/c for each port location

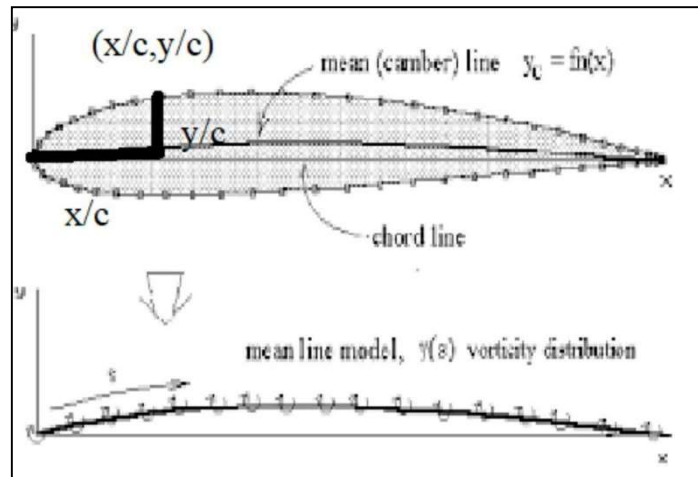


Figure 5.2- x/c and y/c

Further the x/c which is distance from one tapping to the other in horizontal direction is measured from the fabricated model and y/c is the distance from each tapping to the chord line in vertical direction.

C_l , C_d and C_m will be calculated using the x/c and y/c values by choosing only the max negative value and min negative value at every angle of attack.

Table 5.4- x/c and y/c values

x/c	y/c
0.7155	0.3024
2.9779	0.2527
2.9661	0.1073
0.6821	0.1848
0.9583	0.3578
3.3102	0.2807
3.2963	0.1192
0.925	0.2103

5.3 Formula's for C_l , C_d , C_m and eccentricity

$$C_l = (\text{max value upper camber} - \text{min value lower camber}) * (x/c_{\text{max}} - x/c_{\text{min}})$$

$$C_d = (\text{max value upper camber} - \text{min value lower camber}) * (y/c_{\text{max}} - y/c_{\text{min}})$$

$$C_m = (ac - x/c_{\text{max}}) * (C_l * \cos(\text{AOA}) + C_d * \sin(\text{AOA}))$$

For the complete airplane, the drag coefficient is written as

$$C_D = C_{D0} + K C_L^2$$

This equation is the drag polar for an airplane

$$K = \frac{1}{\pi e A R}$$

Table 5.5- cl, cd, cm, eccentricity

Cl	1.307 1	1.544 75454 6	1.544 75454 5	1.544 75454 5	1.307 1	1.425 92727 3	1.544 75454 5	1.782 40909 1	1.901 23636 4
Cd	0.125 25	0.148 02272 7	0.148 02272 7	0.148 02272 7	0.125 25	0.136 63636 4	0.148 02272 7	0.170 79545 5	0.182 18181 8
Cm	- 3.999 6814	- 4.725 7774	- 4.725 7774	- 4.725 7774	- 4.342 35618	- 4.369 93772 2	- 4.696 70494 8	- 5.394 33649 7	- 5.738 02722 1
Cdo	0.024 06	0.024 06	0.024 06	0.024 06	0.024 06	0.024 06	0.024 06	0.024 06	0.024 06
k	0.059 22703 2	0.051 94839 8	0.051 94839 8	0.051 94839 8	0.059 22703 2	0.055 36718 8	0.051 94839 8	0.046 18705 6	0.043 74410 9
AR	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
pi	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4	3.141 59265 4
E(Eccentricity)	11.94 31159	13.61 64988 8	13.61 64988 8	13.61 64988 8	11.94 31159	12.77 57130 4	13.61 64988 8	15.31 50115 6	16.17 02985 5
FOR WING									
Cl	1.112 85	1.128 52	1.043 3	1.005 4	0.993 5	0.885 4	0.824 7	0.666 7	0.594 5
Cd	1.335 5	1.354 8	1.225 7	1.200 9	1.133 52	1.022 576	1.008 3	0.954 8	0.747 8

cl, cd, cm, for tail E, cl and cd for wing is shown here

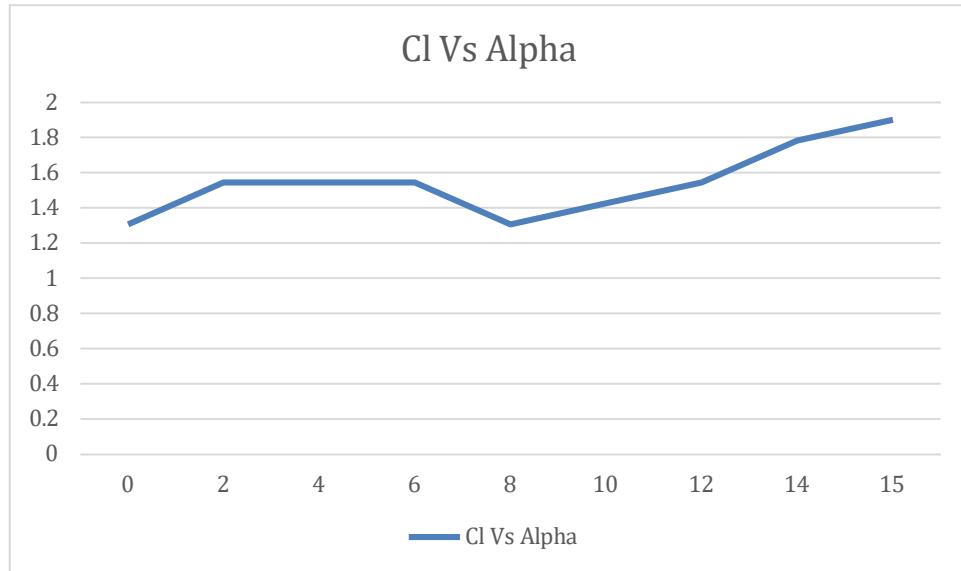


Figure 5.3- Cl vs AOA experimental

Here the coefficient of lift is increasing from 1.23 at 0° AOA to 1.92 at 15° AOA

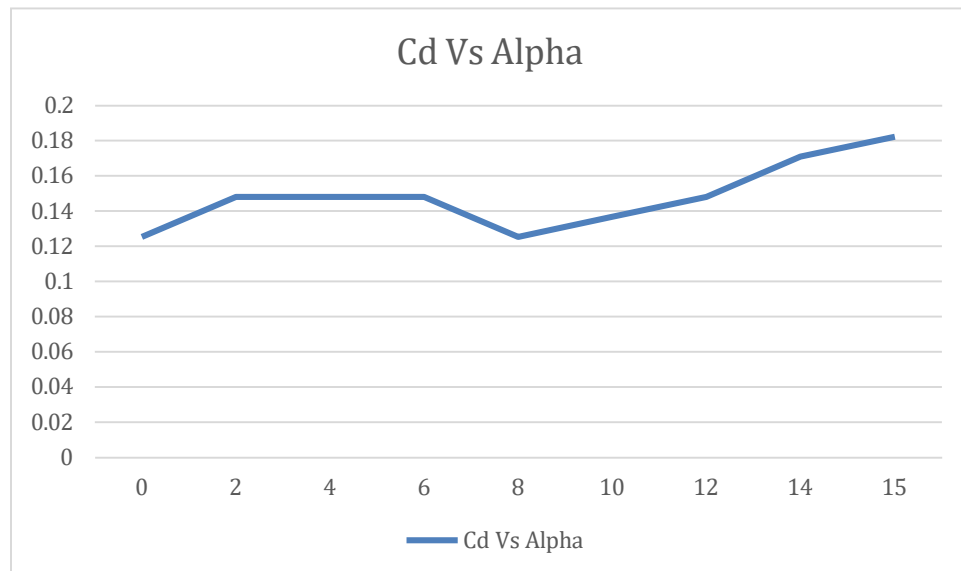


Figure 5.4- Cd vs AOA experimental

Here the coefficient of lift is increasing from 0.127 at 0° AOA to 0.182 at 15° AOA

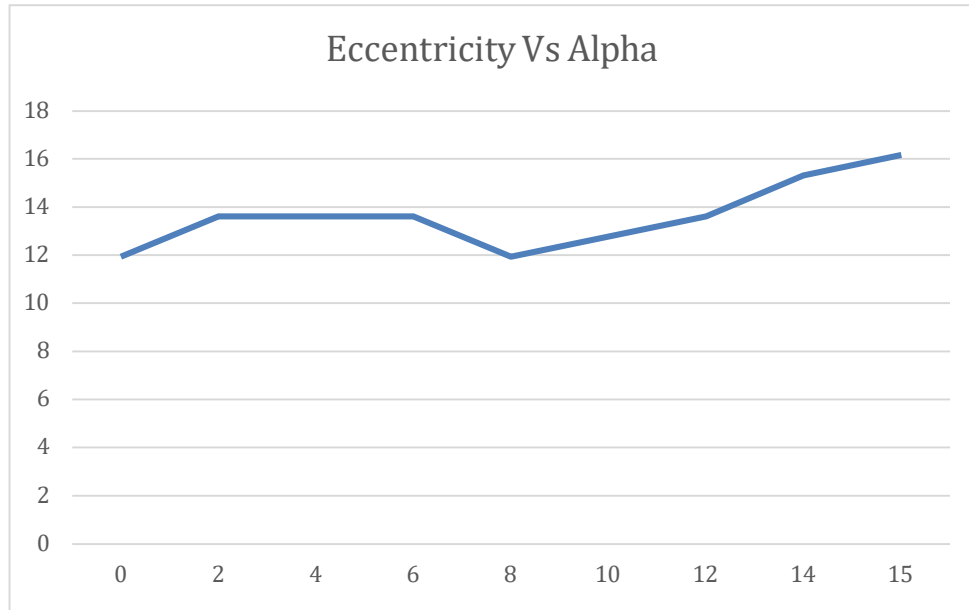


Figure 5.5- E vs AOA experimental

Here the Eccentricity is increasing from 11.943 at 0° AOA to 16.17 at 15° AOA

To proceed for the neutral point calculations, we need c_l and c_m of the wing so we considered a NACA5 series aerofoil that suits with the tail plane. We combined the computational analysis of the wing with the experimental analysis of tail plane to get the neutral point derivation solved.

The computational analysis of the wing is as follows

Table 5.6- wing c_l and c_m

C_{lwing}	c_{mwing}
0.5945	-0.83834
0.6667	-0.58745
0.8247	-0.70065
0.8854	-0.55735
0.9935	-0.55877
1.0054	-0.42358
1.0433	-0.40387
1.12852	-0.32689
1.11285	-0.28698



Figure 5.6- geo tag

Coefficient of lift (overall) $C_L = C_{LW} + C_{Lt} = 0.934542146 + 1.555886232 = 2.490428378$

5.4 Neutral point calculations

This is the point which decides the stability of an airplane. If the neutral point is located beyond the centre of gravity point then it is said to be more stable. Our tail plane is the new model which is unique from the other existing models. For derivation purpose we named our model as “wing body- twin horizontal tail configuration”. So, we derived a formula for calculating the neutral point.

$$X_{np}/c = X_{ac}/c + 2 \cdot \eta V_H C_{Lat} / C_L \alpha (1 - d\epsilon/d\alpha) - 2 \cdot C_{mat} / C_m \alpha$$

$$\text{Induced velocity } (d\epsilon/d\alpha) = C_{Lawing} / (\pi e A R)$$

Table 5.7- Induced velocity

pi	E	AR	Clw	induced
3.141593	11.943116	0.45	1.11285	1.903780693
3.141593	13.616498	0.45	1.12852	2.201087604
3.141593	13.616498	0.45	1.0433	2.034872839
3.141593	13.616498	0.45	1.0054	1.960951934
3.141593	11.943116	0.45	0.9935	1.699605638
3.141593	12.77571	0.45	0.8854	1.620269302
3.141593	13.616498	0.45	0.8247	1.6085111
3.141593	15.315012	0.45	0.6667	1.462548994
3.141593	16.1703	0.45	0.5945	1.376995678

Tail volume ratio (V_H) = $I_t \cdot s_t / c \cdot s$

Neutral point values

condition for static stability is that neutral point should always be beyond the centre of gravity

Chapter 6

RESULTS AND DISCUSSION

The result of our work is being discussed here, our I shaped tail model is producing stability up to certain angle of attack. stability is determined by comparing the cg and X_{np} values if $X_{np} > cg$ it is said to be stable. The centre of gravity is determined as the point through which the weight of the airplane is concentrated. The centre of pressure is determined as the position of centre of mass where the aircraft would be neutrally stable. When we run the wind tunnel by fixing the model at 0° AOA the $X_{NP} = 17.66$ and the $C_g = 10$ (which is constant) at 2° AOA the $X_{NP} = 10.99$ at 4° AOA the $X_{NP} = 13.72$ at 6° AOA the $X_{NP} = 10.29$ at 8° AOA the $X_{NP} = 11.821$ up to the 8° AOA the neutral point is beyond the center of gravity this producing stability. When we further increase the angle of attack at 10° AOA the $X_{NP} = 6.73$ at 12° AOA the $X_{NP} = 4.10$ at 14° AOA the $X_{NP} = -5.61$ at 15° AOA the $X_{NP} = -12.58$.

If we talk about the lift produced, we can see that the lift curve is increasing gradually. For the 0° AOA the lift produced is 1.3071 for 2° AOA lift produced is 1.544 for 4° AOA the lift is 1.544 for 6° AOA the lift is 1.544 for 8° AOA the lift is 1.3071 for 10° AOA the lift is 1.4259 for 12° AOA the lift is 1.5447 for 14° AOA the lift is 1.7824 for 15° AOA the lift is 1.90123. here we can see that the lift has increased from 0° AOA to 2° AOA and from 2° AOA to 6° AOA it remained constant with the value of 1.54475 and it decreased for 8° AOA. From 12° AOA to 15° AOA the lift is gradually increased upto 1.90123.

Chapter 7

CONCLUSION

From the past few years stability of the airplane is concerned as the most priority. In the aircraft industry many inventions of new models took place and the improvement is still taking place. The tail of the aircraft produces stability in level flight it also corrects any deviation upto certain angle. The model which we named as I shaped tail is designed using catia v5 the design is then simulated in solid works to get the analytical values then our model is inserted into fusion 360 software and divided into parts to get the fabrication done. After fabricating the model, it is then tested in wind tunnel to obtain the experimental values. Using the manometer readings for the angle of attack of 0° , 2° , 4° , 6° , 8° , 10° , 12° , 14° , 15° we calculated the neutral point values with the help of an equation i.e; $X_{np}/c = X_{ac}/c + 2 \cdot \eta V_H C_{Lat}/C_{La} (1 - d_e/d_\alpha) - 2 \cdot C_{mat}/C_{ma}$. The I shaped tail we designed is producing stability upto certain deviation in the angle of attack of upto 8° AOA if the deviation in the angle of attack is less than 8° then the neutral point is obtained beyond the center of gravity. The maximum location of neutral point at 8° AOA is 11.821. If the deviation is more than 8° AOA the stability is reduced and stalling is prone to occur with this, we are concluding that our design is helpful but with limitations further developments are needed to break the limits.

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