INVESTIGATION OF AIRFOIL DESIGN

A thesis Submitted by,

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In partial fulfilment of the requirement
for the award of the degree
of

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in
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Under the guidance of,
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CERTIFICATE

*This is to certify that the Project Report entitled, "***INVESTIGATION OF AIRFOIL DESIGN**" *submitted by* **AVNISH KUMAR (Roll-110CE0444)** *and*

in partial fulfilment for the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering at National Institute of Technology, Rourkela (Deemed university) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matters embodied in the thesis have not been submitted to any other university/Institute for the award of any Degree or Diploma.

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Date:

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I would like to express my deepest appreciation to my respectable guide Prof. Awadesh kumar, an associate professor and our faculty advisor for his support, guidance, care, tutelage, motivation and patience throughout the research period. I appreciate his talent and the encouragement which he provided me throughout this academic year. All credit goes to him who made my project successful. Without his help and contribution my work would not have been able to come to this stage of completeness and fulfilment of my bachelor degree.

Apart from him I would like to thank each and every faculties of my civil engineering department for their knowledge, assistance, motivation and care throughout the study period.

I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hands in successful completion of this project work.

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ABSTRACT

In this project titled “Investigation of airfoil design” an effort has been made to make a detailed study on lift and drag coefficien of various airfoil sections. Airfoil is an important part of any airplane structure whether it may be passenger planes, jet planes or helicopters. The airfoils decide whether the lift force is sufficient to balance the weight of the plane or not and how much drag force is being applied on the plane. Airfoils are basically divided into two categories, I have tried to diffrenciate between the two types i.e Symmetrical and Asymmetrical airoils on the basis of their lift and drag coefficient’s variation with angle of attack, stall angle of attack and magnitude of the coefficients. I have also modelled three commonly used airfoil sections namely BOEING737, MIG21 and BELL 200XV which are of passenger, jet and helicopters respectively and tried to study their lift and drag coefficients and the lift force.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

In the earliest days, when man was yet living in the lap of nature, the only means of locomotion was his legs. Gradually, we have achieved faster and more luxurious ways of travelling, latest being the air transport. Since, its invention aeroplanes have been getting more and more popularity as it is the fastest mode of transportation available. It has also gained popularity as a war machine since world war II. This populariy of air transport has led to many new inventions and research to develope faster and more economical planes. This project is such an attempt to determine how we can derive maximum performance out of an airfoil section.

An airfoil is a cross-section of wing of the plane. It's main job is to provide lift to an aeroplane during take off and while in flight. But, it has also a side effect called Drag which opposes the motion of the aeroplane. The amount of lift needed by a plane depends on the purpose for which it is to be used. Heavier planes require more lift while lighter planes require less lift than the heavier ones. Thus, depending upon the use of aeroplane, airfoil section is determined. Lift force also determines the vertical accelaration of the plane, which in turns depends on the horizontal velocity of the plane. Thus, determining the coefficient of lift one can calculate the lift force and knowing the lift force and required vertical acceleraation one can detremine the required horizontal velocity.

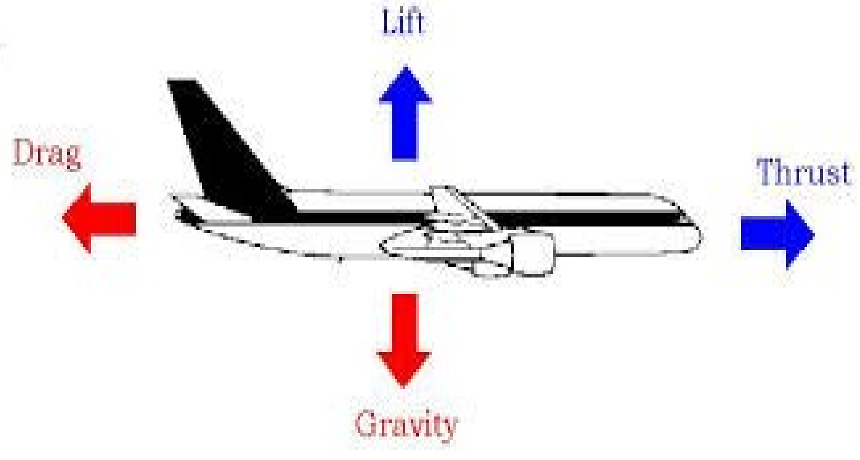


Fig. 1.1(a) : Forces acting on an aeroplane.

1.2 OBJECTIVES

- Modelling of Symmetric and Asymmetric Aerofoils in ANSYS.
- Modelling of airfoils of BOEING737, MIG 21, BELL 200 XV.
- Examine the velocity and surface pressure distribution of various foils.
- Determine the drag and lift coefficient of the various Airfoils and study their variation with angle of attack.
- Calculate lift forces on various foils for each angle of attack.
- Calculate the horizontal velocity required for desired vertical acceleration during take off for the three Airfoils.

1.3 METHODOLOGY

The first step in my project, after deciding the topic, was to do a literature review of the topic. So, I searched for some previous works done in this topic and got myself familiar with the topic.The second step was to gather the required softwares for my project which in this case was ansys- Analysis Systems and Micrsoft excel. The next step was the Data collection. For my project I required coordinates of the three airfoils of the planes namely BOEING 737, MIG 21, BELL 200 XV Helicopters. I also needed the weight, cruising speed, and chord area of the three aeroplanes. Then I went through some textual as well as visual manuals to learn ANSYS. Then, I modelled five models of the airfoil and obtained the coefficient of lift and drag calculated lift force, detremined stall angle of attack, plotted graph between coefficient of lift and drag and the angle of attack and analysed the resuts obtained. I also calculated the required horizontal velocity for desired vertical acceleration and plotted a graph between them.

CHAPTER 2

STUDY AREA

2.1 AERODYNAMICS

Aerodynamics is an extension of science which is concerned with concentrating on the movement of air, especially when associating with an solid object,such as an airfoil. Aerodynamics is a sub-field of fluid progress and gas motion, and numerous parts of aerodynamics hypothesis are regular to these fields. The contrast being that "gas dynamics" applies to the investigation of the movement of all gasses, not constrained to air.formal aerodynamics think about in the cutting edge sense started in the eighteenth century, despite the fact that perceptions of central ideas, for example, aerodynamic drag have been recorded much prior. The vast majority of the early exertions in aerodynamics worked towards attaining heavier-than-air flight, which was initially exhibited by Wilbur and Orville Wright in 1903. From that point forward, the utilization of aerodynamics through scientific examination, observational estimates, wind tunnel experimentation, and workstation recreations has framed the investigative premise for progressing improvements in heavier-than-air flight and various different advances. Late work in aerodynamics has concentrated on issues identified with compressible stream, turbulence, and limit layers, and has gotten to be progressively computational in nature.

An airfoil (in American English) or aerofoil (in British English) is the state of a wing or edge or cruise as seen in cross-area.

An airfoil-formed body traveled through a fluid handles an aerodynamic energy. The segment of this power perpendicular to the course of movement is called lift. The segment parallel to the bearing of movement is called drag. Subsonic flight airfoils have a trademark shape with an adjusted heading edge, emulated by a sharp trailing edge, regularly with uneven camber. Foils of comparative capacity composed with water as the working fluid are called hydrofoils.

The lift on an airfoil is fundamentally the consequence of its approach and shape. At the point when arranged at a suitable edge, the airfoil diverts the approaching air, bringing about an energy on the airfoil in the heading inverse to the diversion. This power is known as aerodynamic drive and could be determined into two parts: Lift and drag. Most thwart shapes oblige a positive approach to produce lift, however cambered airfoils can create lift at zero approach. This "turning" of the air in the region of the airfoil makes bended streamlines which brings about more level weight on one side and higher weight on the other. This weight contrast is joined by a speed distinction, through Bernoulli's standard, so the ensuing stream field about the airfoil has a higher normal speed on the upper surface than on the more level surface. The lift power might be connected specifically to the normal top/base speed contrast without registering the weight by utilizing the idea of flow and the Kutta-Joukowski hypothesis.

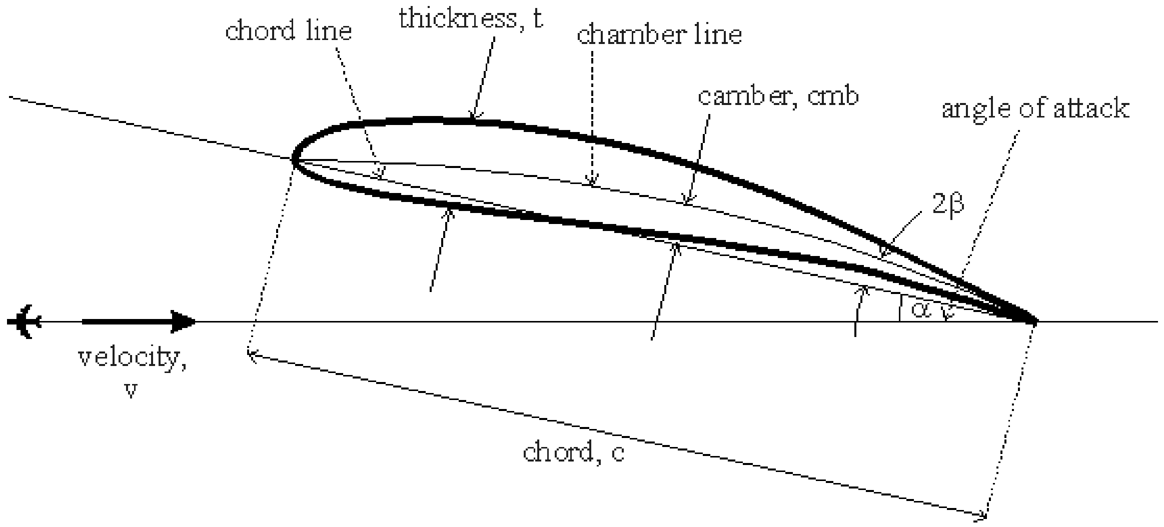


Fig. 2.1(a) : General section of an airfoil.

Some terms related to Airfoil are :

Leading edge :- It is the edge of the airfoil facing the direction of motion of plane. It is generally roundish in shape and deflects the air in such a way that the velocity of air on upper surface of the airfoiol is more than velocity on the lower surface.

Trailing edge :- It is the edge of the airfoil which is pointed in nature. It is located at the back side of the airfoil.

Chord line :- It is a straight line joining the leading edge to the trailing edge. It bisects the airfoil into two parts for an symmetric airfoil but may not do so for an asymmetric airfoil. It defines another important parameter Angle of attack.

Angle of attack :- It is the angle which the chord line makes with the direction of motion of plane. It is an important parameter which affects the coefficient of lift and drag.

Chamber line :- It is a line joining leading edge and trailing edge and dividing the airfoil into two symmetrical parts.It may or may not be a straight line.

Lift coefficient :- It is a dimensionless coefficient that relates the lifting force on the body to its velocity, surface area and the density of the fluid in which it is lifting.

Drag coefficient :- It is a dimensionless coefficient that relates the draging force on the body to its velocity, surface area and the density of the fluid in which it is moving.

Stall angle of attack :- It is the angle of attack at which the lift coefficient is maximum and after which the lift coefficent starts to decrease.

2.2 ANSYS, offers engineering simulation solution sets in engineerig simulation that a design process requires. Companies in a wide variety of industries use ANSYS software. It uses CFD and FEM and various other programming algorithms for simulating and optimising various design problems.ANSYS has many sub parts out of which I will use FLUENT. ANSYS Fluent uses CFD for analysis and is mainly used for simulation of fluid mechanics and thermodynamics problems. Data of various fluid and solid materials are already fed into the ANSYS database which we use.

CHAPTER 3

LITERATURE REVIEW

T .Gultop, (2005) [1] studied the impact of perspective degree on Airfoil peformance. The reason for this study was to focus the ripple conditions not to be kept up throughout wind tunnel tests. These studies indicate that aeroelastic insecurities for the changing arrangements acknowledged showed up at Mach number 0.55, which was higher than the wind tunnel Mach number point of confinement velocity of 0.3.

Sanjay Goel,(2008)[3] devised a method of optimization of Turbine Airfoil using Quansi – 3D analysis codes. He solved the complexity of 3D modelling by modelling multiple 2D airfoil sections and joining their figure in radial direction using second and first order polyonmials that leads to no rouhness in the radial direction.

Mr. Arvind (2010)[4] researched on NACA 4412 airfoil and analysed its profile for consideration of an airplane wing .The NACA 4412 airfoil was created using CATIA V5 And analysis was carried out using commercial code ANSYS 13.0 FLUENT at an spped of 340.29 m/sec for angles of attack of 0˚, 6, 12 and 16˚. k-ε turbulence model was assumed for Airflow. Fluctuations of static pressure and dynamic pressure are plotted in form of filled contour.

By J. Fazil and V. Jayakumar, (2011)[5] concluded that despite the fact that it is less demanding to model and make an airfoil profile in CAD environment utilizing camber cloud of focuses, after the making of vane profile it is exceptionally troublesome to change the state of profile for dissection or improvement reason by utilizing billow of focuses. In the paper, they examined and depicted the making of airfoil profile in CAD environment utilizing the control purpose of the camber profile. By method for changing the qualities of control focuses the state of the profile could be effectively changed and additionally the outline of the cambered airfoil is created without influencing the essential airfoil geometry. In the said paper, the Quintic Reverse Engineering of Bezier bend recipe is utilized to discover the camber control focuses the current camber cloud of focuses.

Mr. Mayurkymar kevadiya (2013)[2] studied the NACA 4412 airfoil profile and recognized its importance for investigation of wind turbine edge. Geometry of the airfoil is made utilizing GAMBIT 2.4.6. Also CFD investigation is done utilizing FLUENT 6.3.26 at different approaches from 0˚ to 12˚.

CHAPTER 4

INVESTIGATION OF SYMMETRIC AIRFOIL DESIGN

4.1 MODELLING AND MESHING

A symmetric airfoil is the one in which both the camber line and the chord line is the same i.e a straight line joining the leading edge and the trailing edge bisects the airfoil into two symmetric sections.

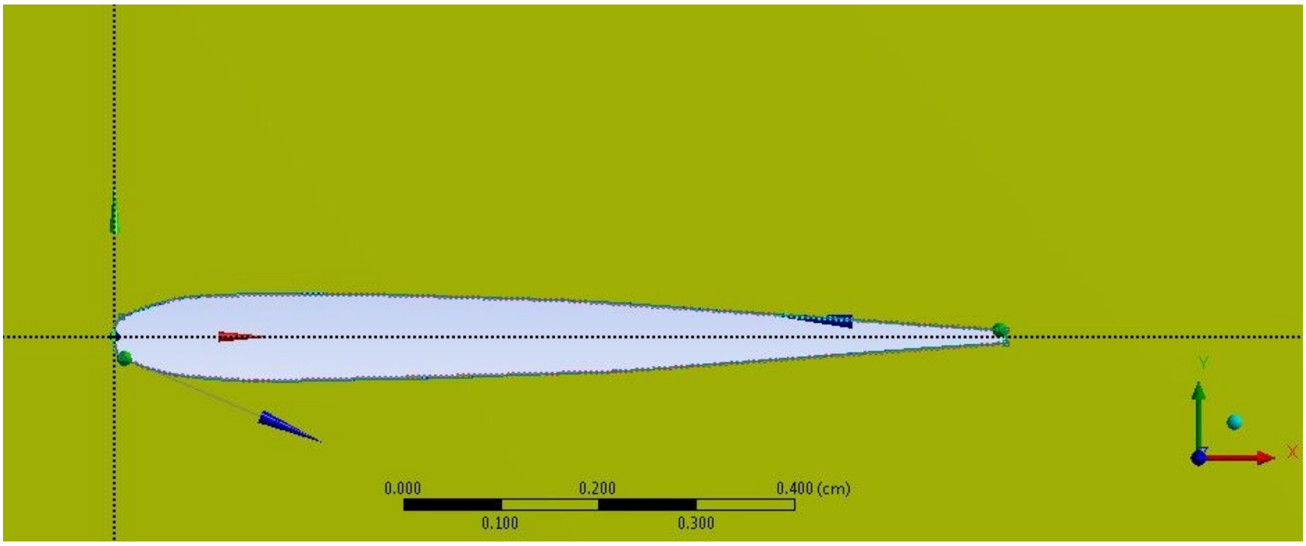


Fig. 4.1(a) : Geometry of the symmetrical airfoil section.

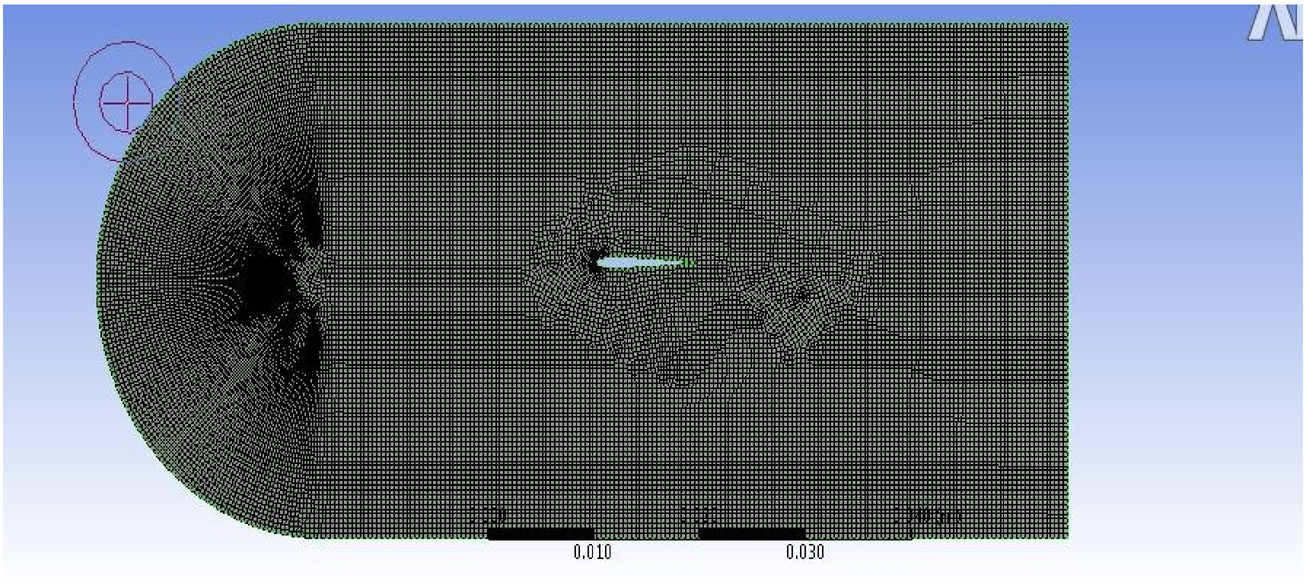


Fig. 4.1(b) : Meshing of air profile around the symmetrical airfoil

4.2 PRESSURE AND VELOCITY DISTRIBUTION

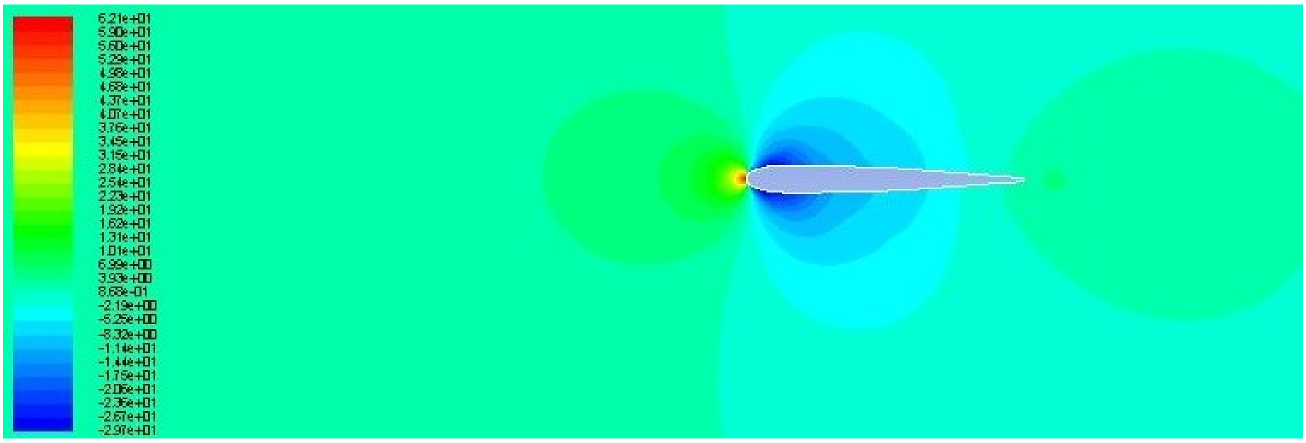


Fig. 4.2(a) : Pressure distribution around the symmetrical airfoil at 0° Angle of attack.

At 0^0 Angle of attack the wind particles collide with the airfoil headon.Since it is symmetric in nature. Velocity of the wind is same on both upper and lower layer of the airfoil. Since, the velocity is same the pressure on the upper and lower layer will also be same or the difference will be very much negligible.

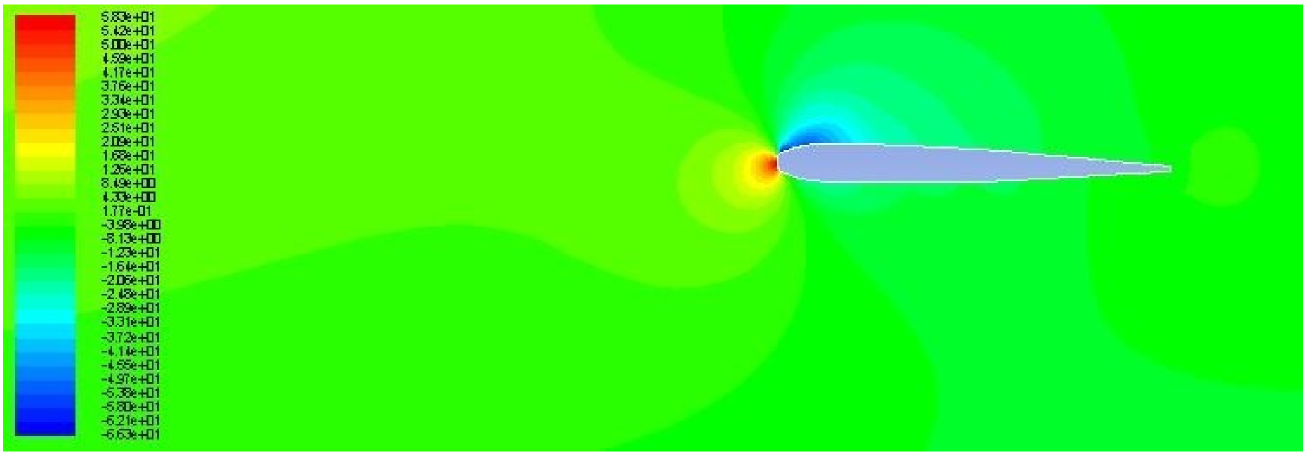


Fig. 4.2(b) : Pressure distribution around the symmetrical airfoil at stall Angle of attack.

At stall angle of attack i.e the angle of attack at maximum coefficient of lift, we can see that the zone of low pressure is much more on the upper layer than on the lower layer. Thus there is a zone of high pressure created on bottom side of airfoil resulting in a force acting on the airfoil. The vertical component of this force gives us lift and the horizontal component drag.

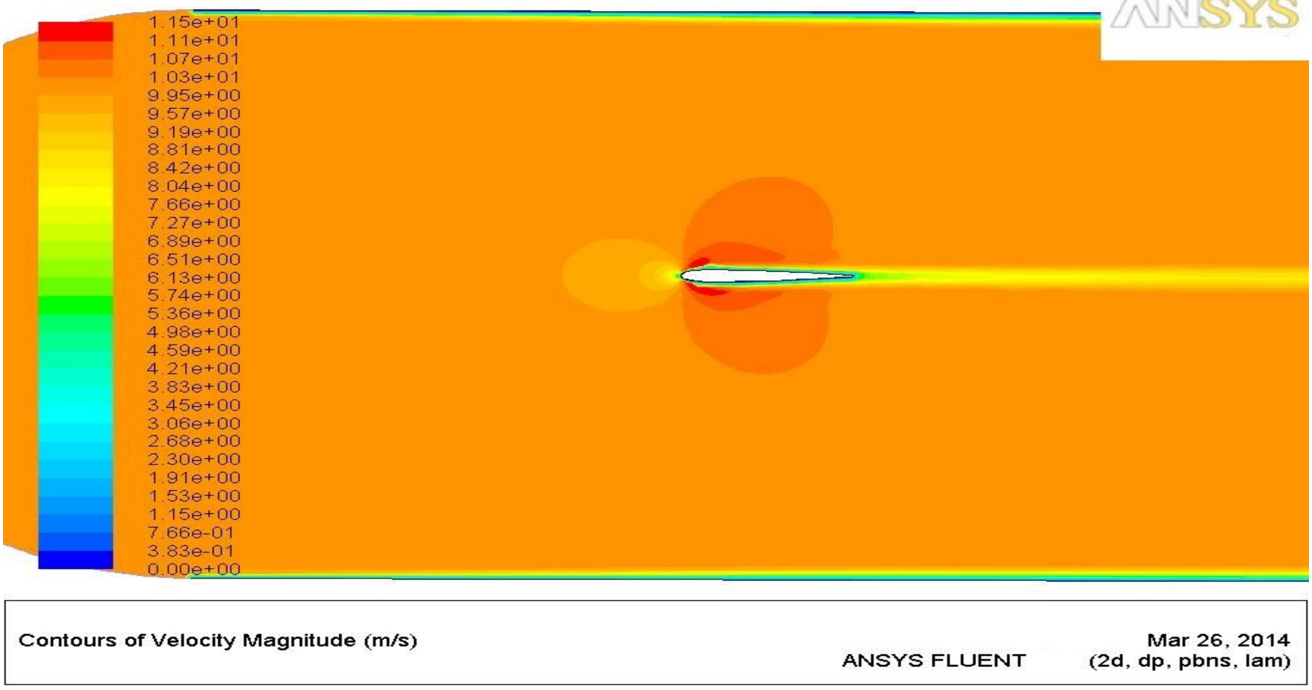


Fig. 4.2(c) : Contours of velocity magnitude in m/s at 0^0 angle of attack.

Velocity distribution at zero angle of attack can be seen very as similar on both upper and lower layer of airfoils. Which gives rise to same pressure on both the surface of airfoil.

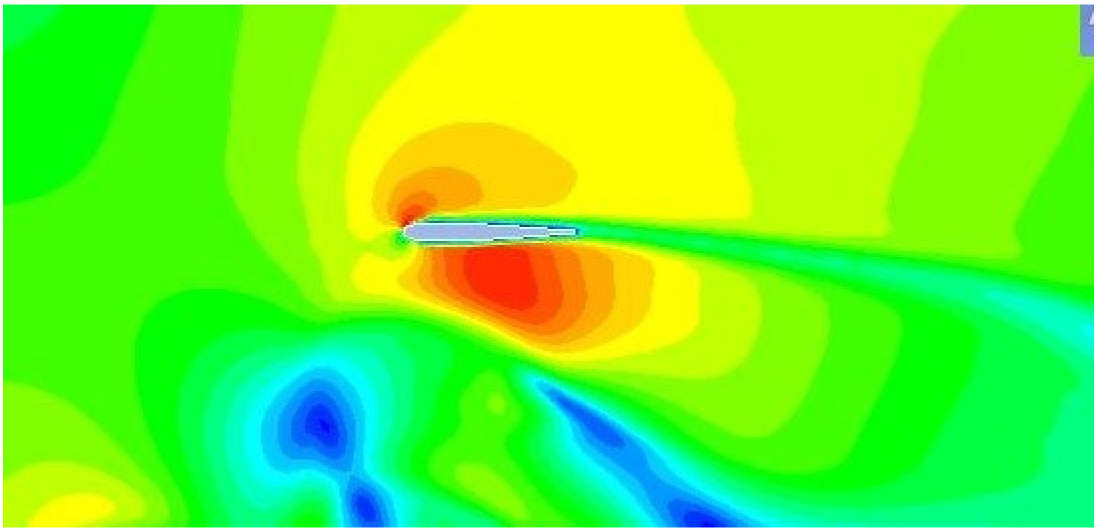


Fig. 4.2(d) :Enlarged view of contours of velocity magnitude in m/s at an angle of attack greater than stall angle of attack.

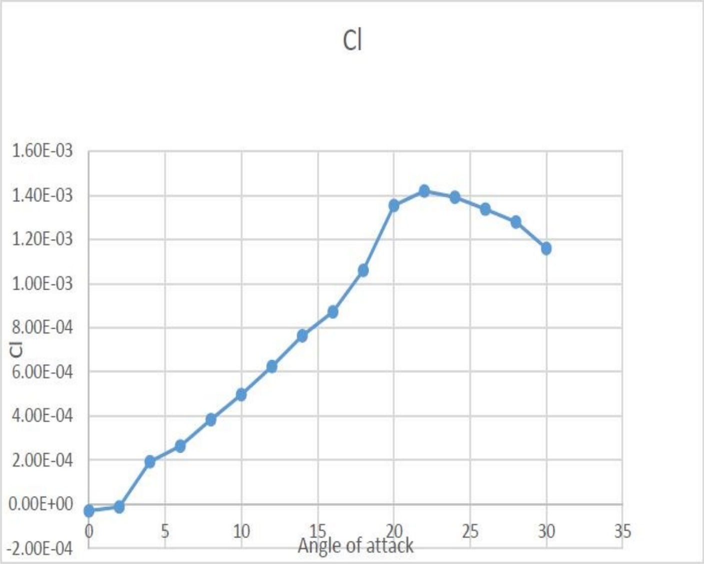
At higher angle of attack air flow separates from upper layer of flow thus leading to increase in pressure in upper layer of flow and decrease in value of lift coefficient.

4.3 RESULTS

Table 4.3 (a) Variation of lift and drag coefficient with angle of atack.

A.O.A(degrees)	**Cl**	**Cd**
0	-2.95E-05	4.22E-04
2	-1.21E-05	4.23E-04
4	1.93E-04	4.28E-04
6	2.64E-04	4.38E-04
8	3.83E-04	4.51E-04
10	4.97E-04	5.20E-04
12	6.25E-04	6.18E-04
14	7.64E-04	6.96E-04
16	8.72E-04	7.29E-04
18	1.06E-03	8.00E-04
20	1.36E-03	9.14E-04
22	1.42E-03	1.81E-03
24	1.39E-03	3.21E-03
26	1.34E-03	5.61E-03
28	1.28E-03	8.31E-03
30	1.16E-03	1.42E-02

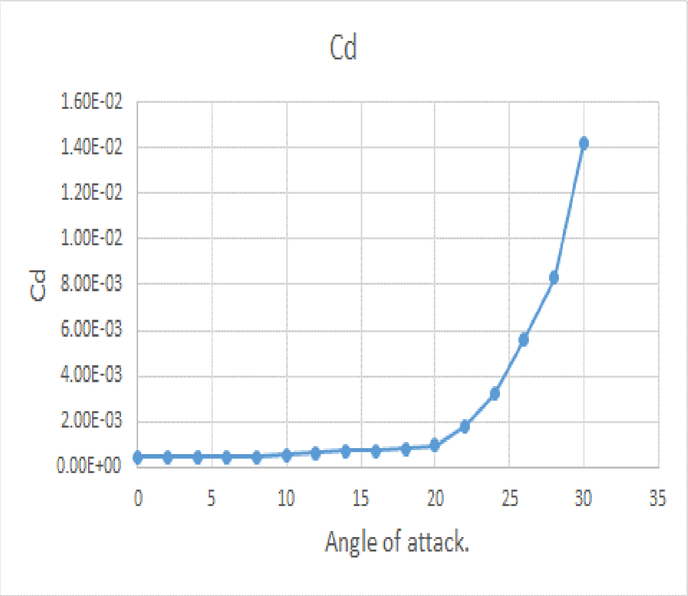
Stall angle of attack = 22^0



Graph 4.3(b) : Variation of lift coefficient with angle of attack.

From, the graph it is seen that first the lift coefficient increases with increase in angle of attack. But as the angle crosses 22^0 it again starts to decrease.

In the case of drag coefficient we can see that first the drag increseas ever so slightly with angle of attack but after 20^0 the rate of increase of drag increaseas.



4.3(c) : Variation of drag coefficient with angle of attack.

CHAPTER 5

INVESTIGATION OF ASYMMETRIC AIRFOIL DESIGN

5.1 MODELLING AND MESHING

Asymmetric airfoils are those in which the chord line does not bisect the Airfoil into two symmetric halves.The curved surface of the upper and lower layer is dissimilar in geometry.

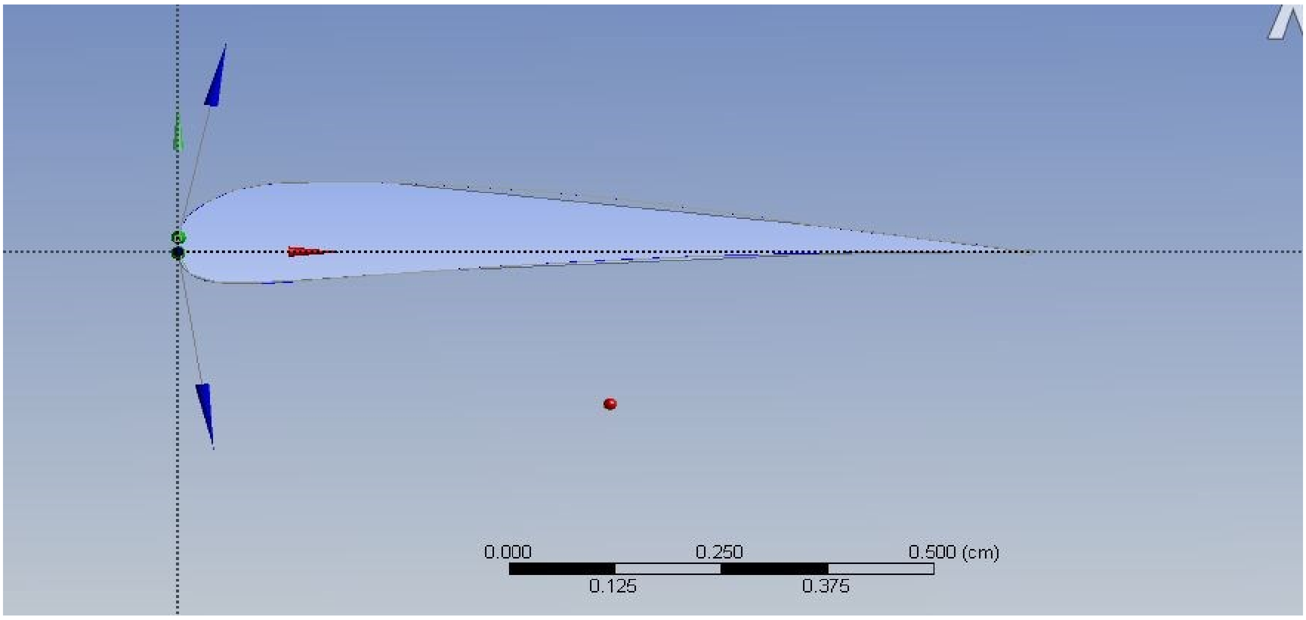


Fig. 5.1(a) : Geometry of the Asymmetrical airfoil section.

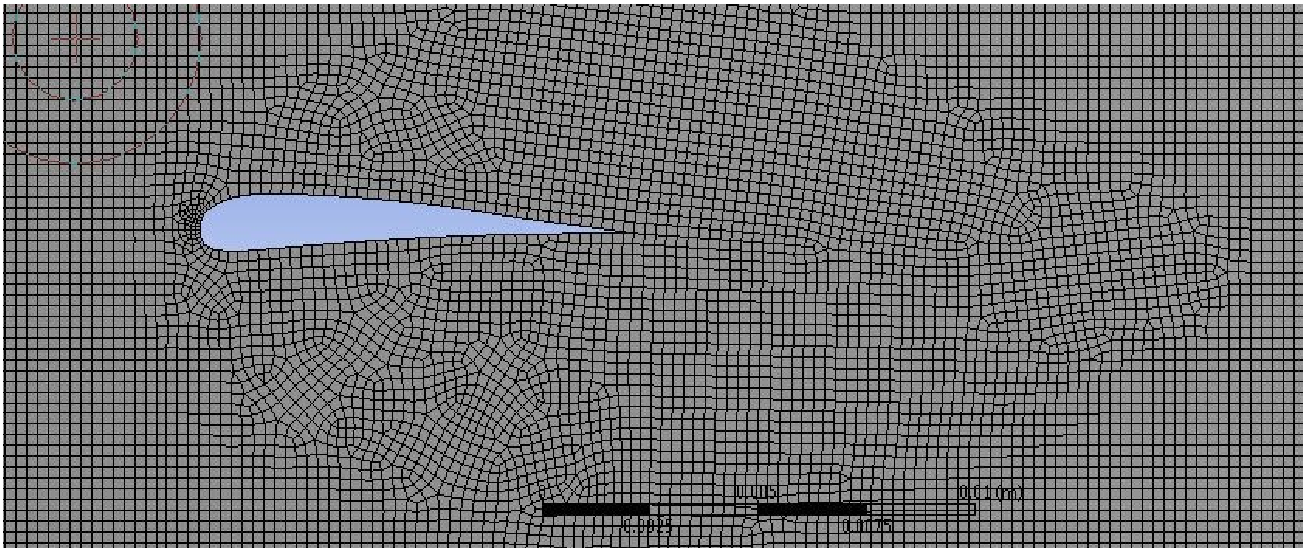


Fig. 5.2(b) : Close up of mesh around the airfoil.

5.2 PRESSURE AND VELOCITY DISTRIBUTION

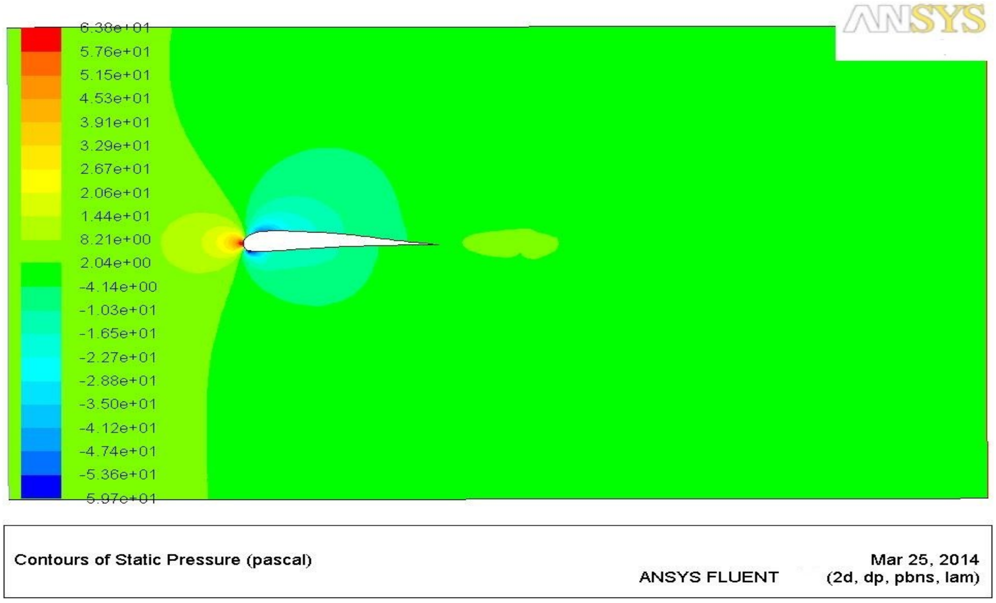


Fig. 5.2(a) Contours of static pressure at 0° angle of attack for asymmetrical airfoil.

In case of asymmetrical bending we can see that the zone of low pressure is more above the top surface of airfoil even at zero angle of attack. It also behaves like symmetrical airfoil in the sense that first the lift value increases and then it decreases.

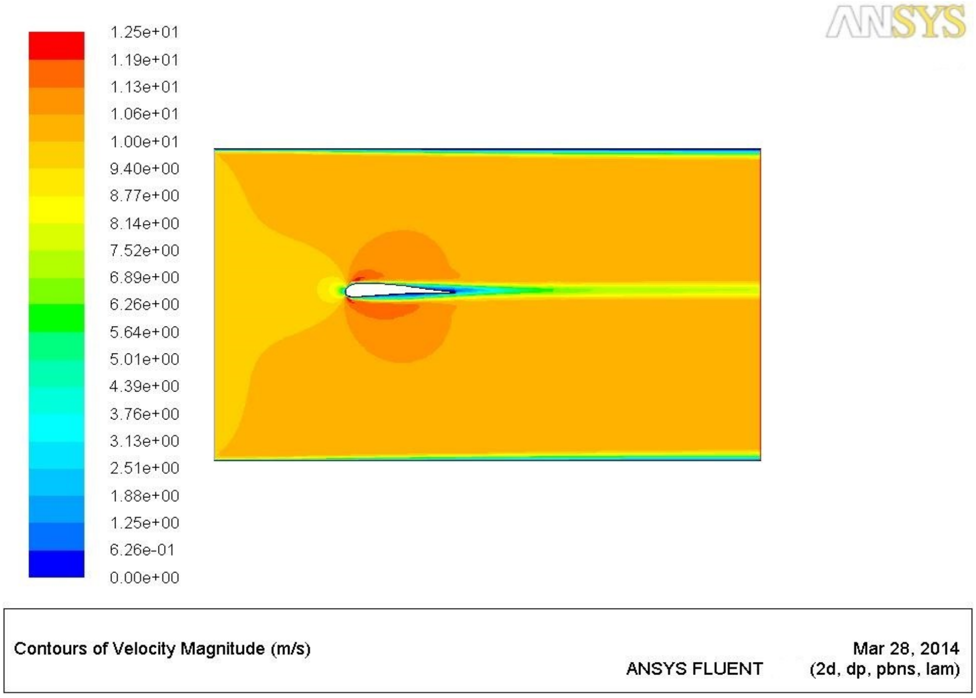


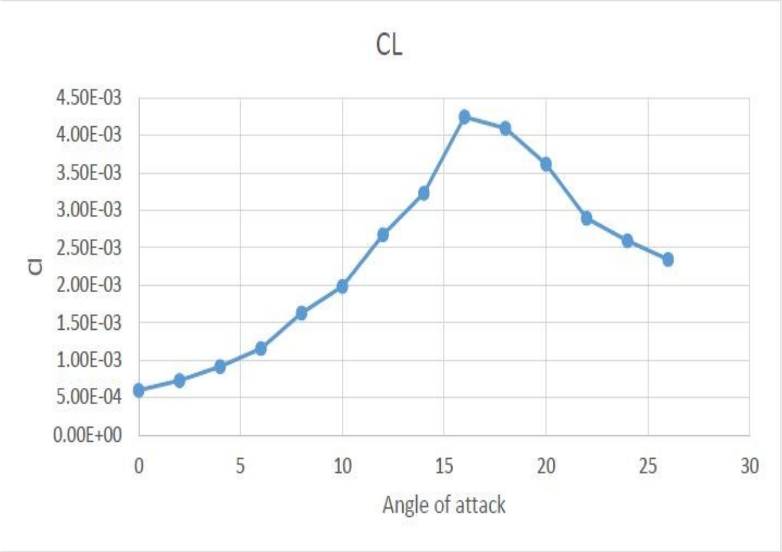
Fig. 5.2(b) Contours of velocity magnitude at 0° angle of attack for asymmetrical airfoil.

5.3 RESULTS

Table 5.3 (a) Variation of lift and drag coefficient with angle of attack

A.O.A	Cd	CL
0	4.62E-04	5.98E-04
2	4.73E-04	7.29E-04
4	4.98E-04	9.14E-04
6	5.38E-04	1.15E-03
8	5.91E-04	1.63E-03
10	6.40E-04	1.98E-03
12	6.98E-04	2.67E-03
14	7.96E-04	3.23E-03
16	9.49E-04	4.25E-03
18	1.45E-03	3.80E-03
20	2.75E-03	3.12E-03
22	3.45E-03	2.79E-03
24	4.61E-03	2.59E-03
26	ll5.91E-03	2.34E-03

Stall angle of attack = 16^0



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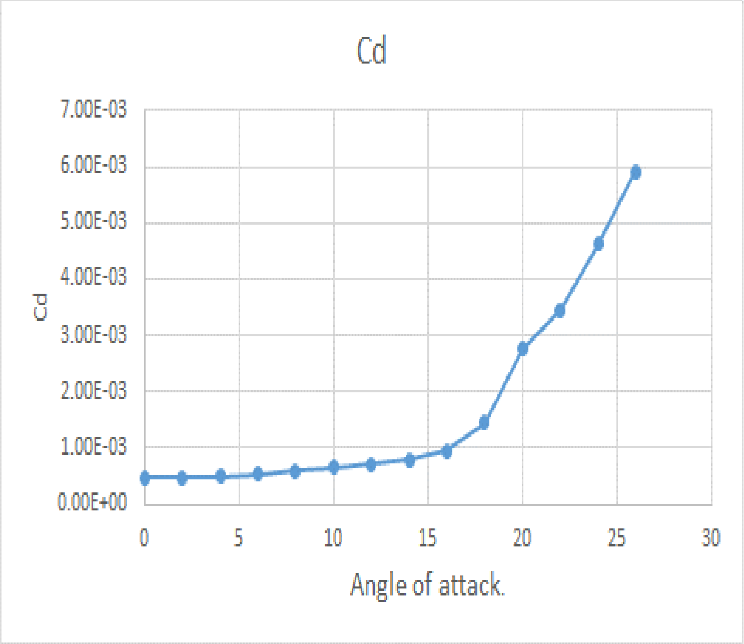
From, the graph it is seen that first the lift coefficient increases with increase in angle of attack. But as the angle crosses 16^0 it again starts to decrease due to separation of velocity profile from upper surface of the body.

Graph 5.3(b) : Variation of lift coefficient with angle of attack

In the case of drag coefficient we can see that first the drag increseas ever so slightly with angle of attack but after 16^0 the rate of increase of drag increaseas rapidly.



Graph 5.3(c) : Variation of drag coefficient with angle of attack.

CHAPTER 6

INVESTIGATION OF AIRFOIL DESIGN OF BOEING 737.

Boeing 737 is a narrow body jet airliner. It is the plane mostly used by Air India has a passenger plane. It was developed in 1965 by the american compnay boeing.Some specifications for the plane are

- wing span = 34.32 mt.
- Gross area of wings = 124.58m^2
- max. weight = 70080 kg.
- length = 33.60mt.

6.1 MODELLING AND MESHING

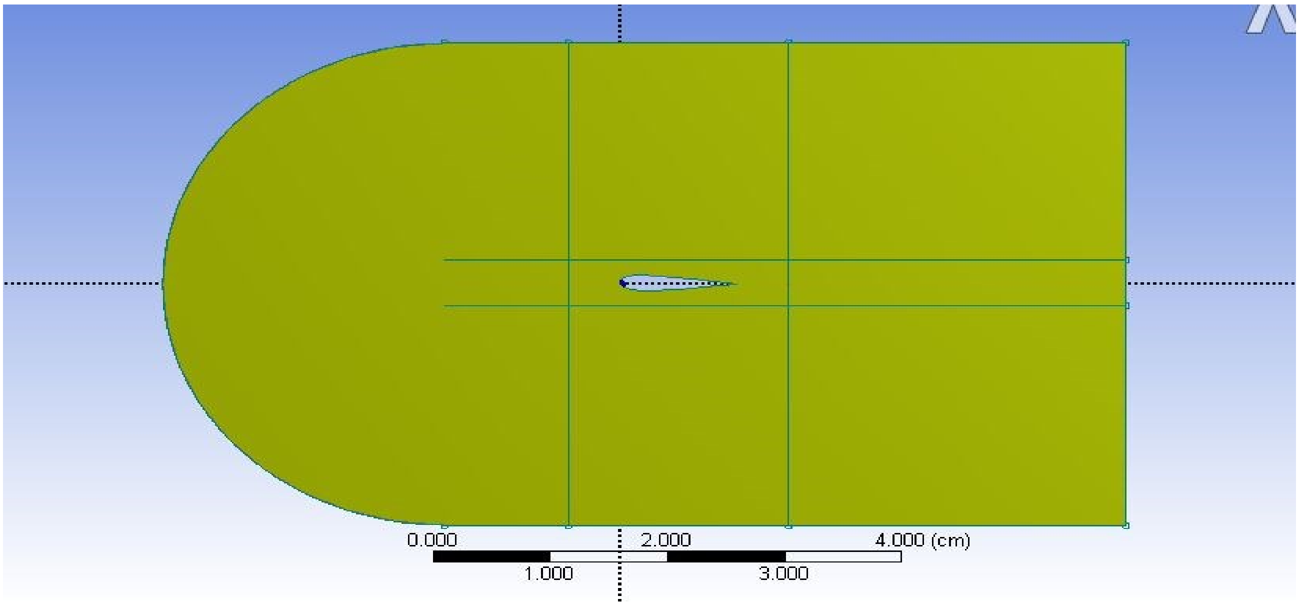


Fig. 6.1(a) : Geometry of boeing 737 airfoil with air profile drawn around it.

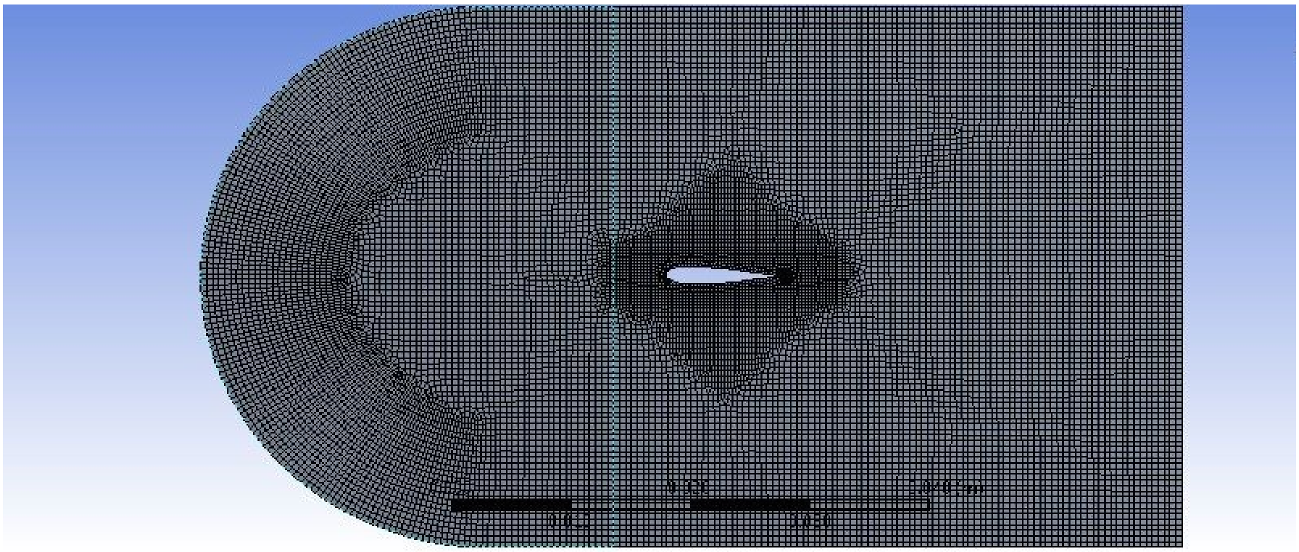


Fig. 6.1(b) : Meshing of air profile around the boeing737 airfoil

6.2 PRESSURE AND VELOCITY DISTRIBUTION

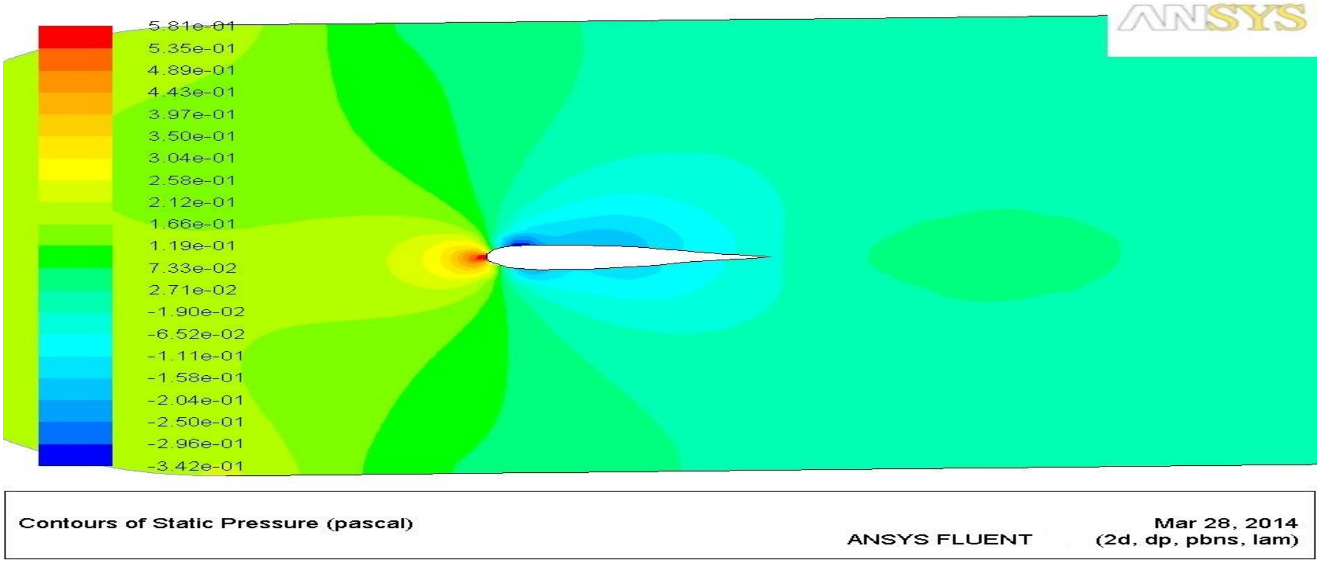


Fig. 6.2(a) : Contours of static pressure for boeing 737 airfoil at 0^0 A.O.A.

At zero angle of attack it can be seen that the static pressure is little higher on the lower surface than on the upper surface. This generates a pressure gradient which causes a force on the total surface area of the airfoil.

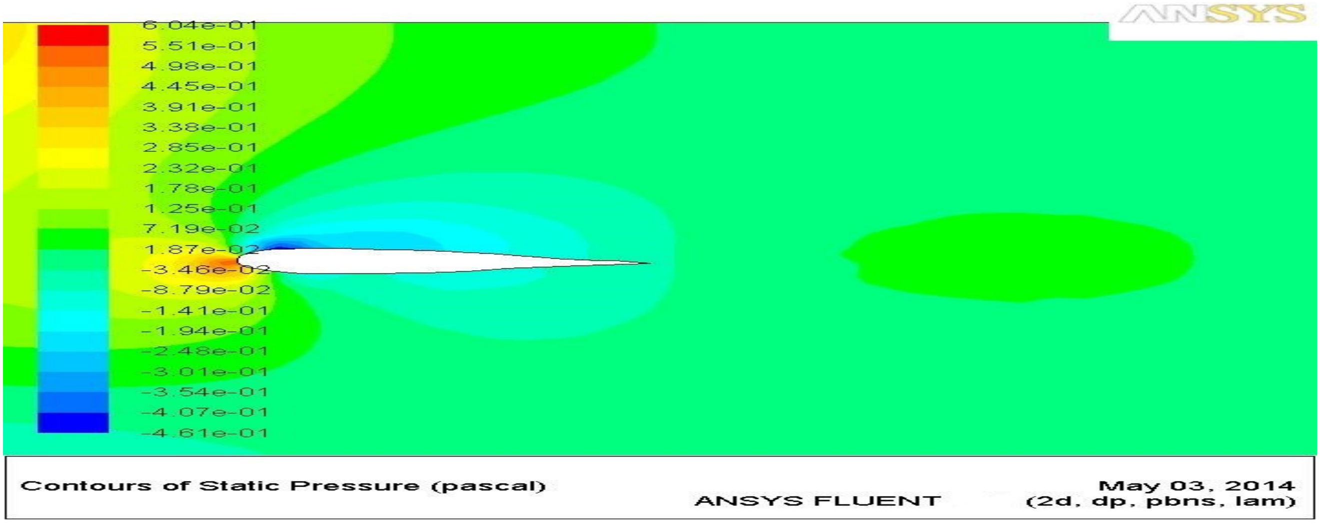


Fig. 6.2(b) : Contours of static pressure for boeing 737 airfoil at stall A.O.A

As the angle of attack increaseas the pressure difference between the upper surface and the lower surface increases thus causing an increase in the force which causes increase in lift and drag coefficient.

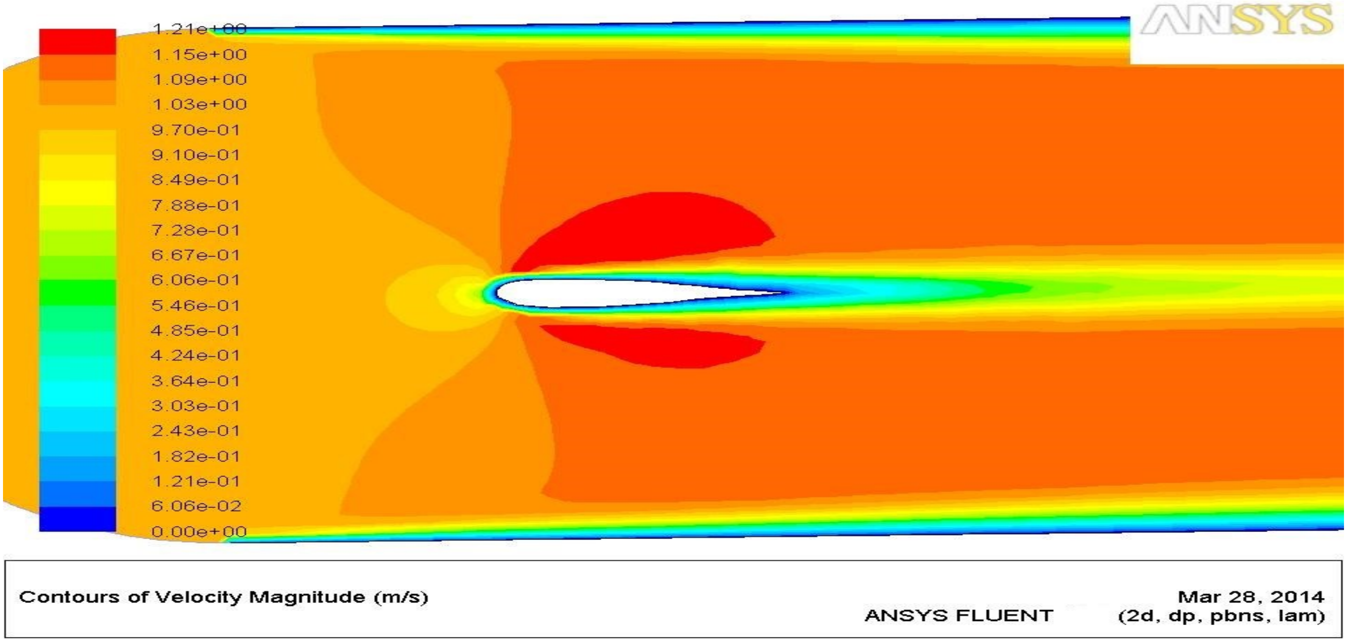


Fig. 6.2(c) : Contours of velocity magnitude for boeing 737 airfoil at 0^0 A.O.A

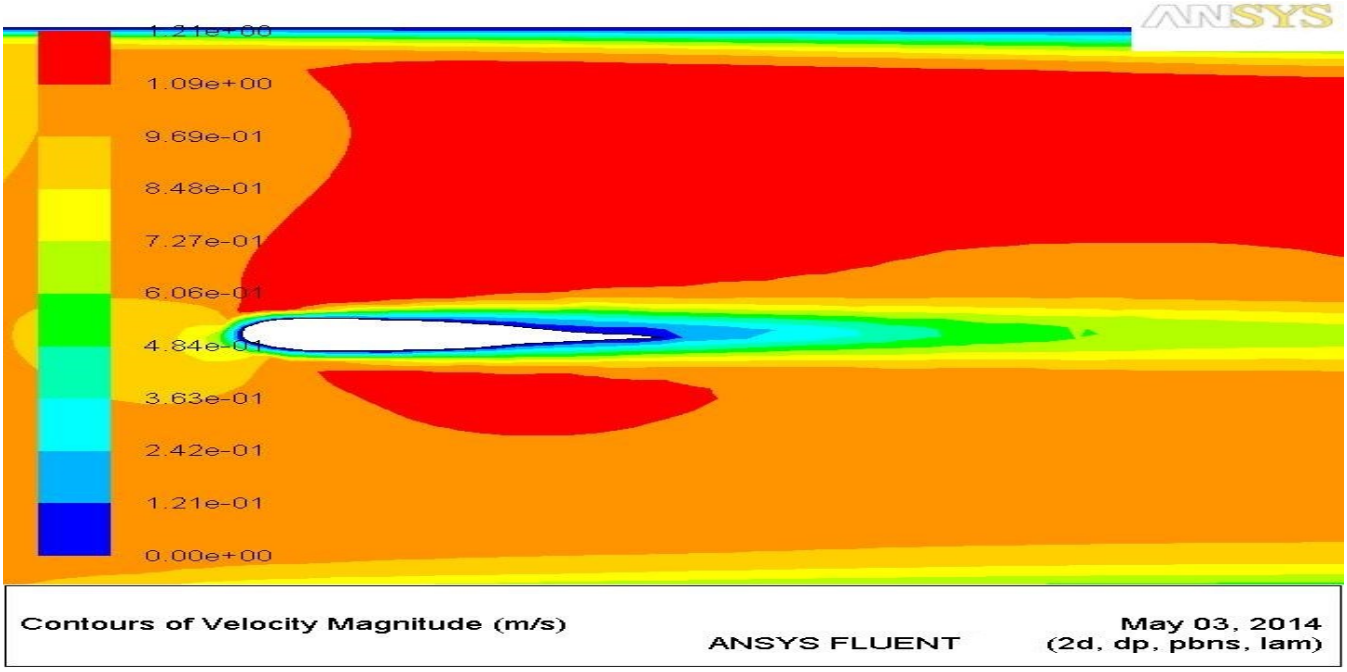


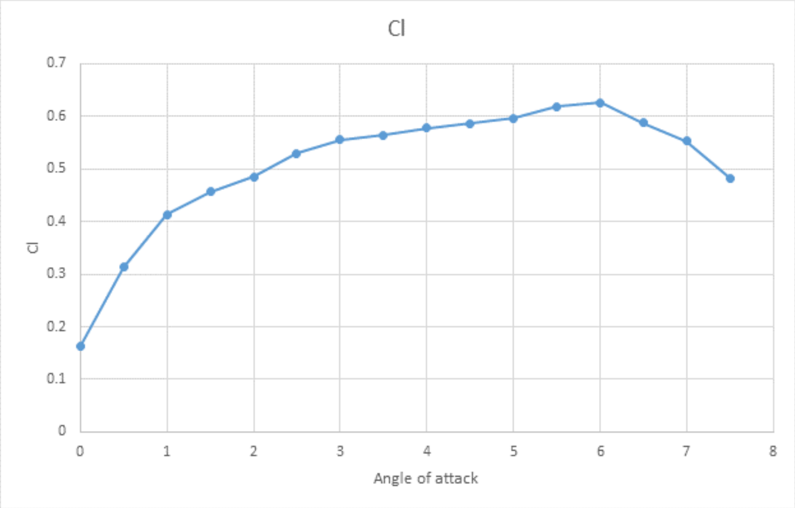
Fig. 6.2(d) : Contours of velocity magnitude for boeing 737 airfoil at stall A.O.A

6.3 RESULTS

Table 6.3 (a) Variation of lift and drag coefficient and lift force with angle of attack.

A.O.A	Cl	Cd	lift force
0	0.1628	0.02566	79503.97
0.5	0.3128	0.02594	152757
1	0.4132	0.02669	201787.7
1.5	0.4569	0.03119	223128.8
2	0.4852	0.03841	236949.2
2.5	0.5294	0.04452	258534.4
3	0.5562	0.04926	271622.3
3.5	0.5643	0.05442	275577.9
4	0.5782	0.06114	282366.1
4.5	0.5864	0.06701	286370.6
5	0.5971	0.07332	291595.9
5.5	0.6188	0.07932	302193.2
6	0.6257	0.08756	305562.8
6.5	0.5878	0.09028	287054.2
7	0.5528	0.09354	269961.9
7.5	0.4829	0.10698	235826

Stall angle of attack = 6^0.



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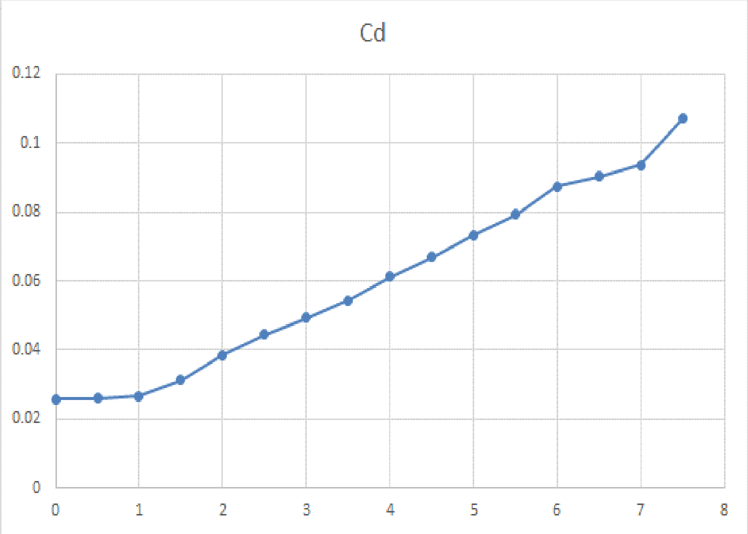
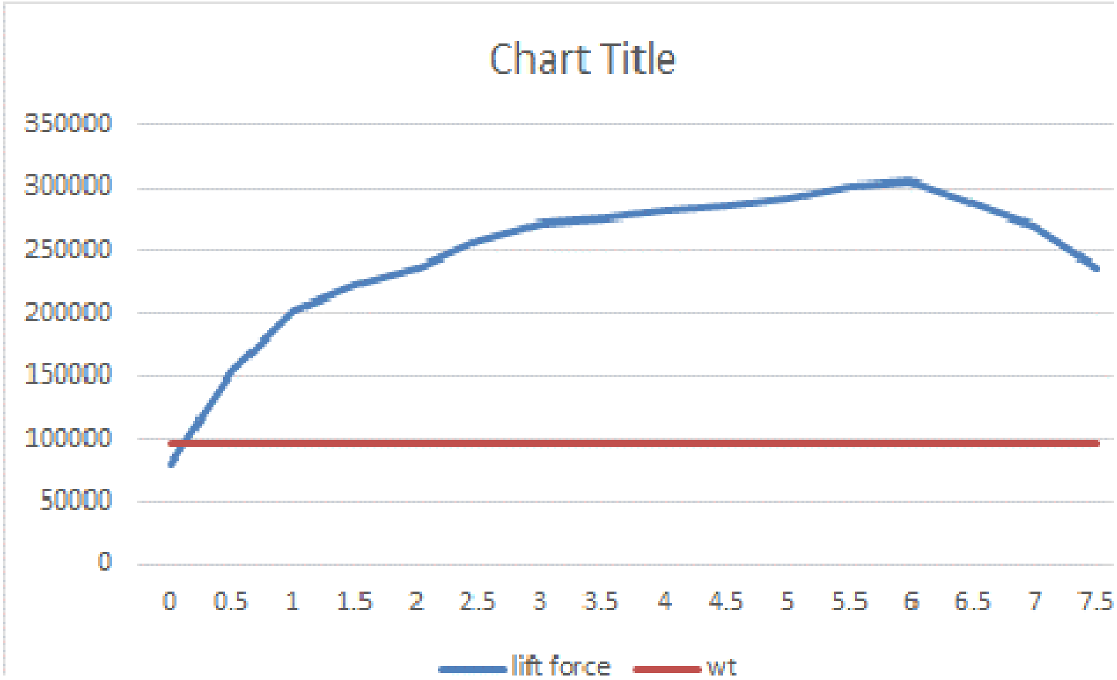
It can be observed from the graph that lift coefficient increaseas with angleof attack till 6^0 after which it begins to decrease.Therfore, Stall angle of attack= 6^0.

Graph 6.3(b) : Variation of lift coefficient with angle of attack

Coefficient of drag is an undesired force and should be avoided. Its value is seen to be increasing with Angle of Attack.



Graph 6.3(c) : Variation of drag coefficient with angle of attack.



Graph 6.3(d) : Variation of lift force with angle of attack.

Here the lift force was calculated using the lift coefficient and plotted against the angle of attack.The speed of plane was assumed as 80 m/s for the calculation of lift force The brown line marks the weight of the plane. From this diagram we can find out which angle of attack is sufficient to maintain lift force equal to the weight of the plane at cruising speed i.e at 80 m/s.

CHAPTER 7

INVESTIGATION OF AIRFOIL DESIGN OF MIG 21.

The Mikoyan-Gurevich MiG-21 is a supersonic jet fighter aircraft, designed by the Mikoyan-Gurevich Design Bureau in the Soviet Union.The airfoil of this supersonic jet is named as TsAGI S-12 airfoil. India bought these planes from soviet in 1960 and were in service for 50 years. Some specifications for the plane are

- wing span = 7.154 mt.
- wing area = 23.0 m2.
- max weight = 10400 kg
- take off speed = 340-370 km/h.
- criuise speed = 800 km/h

7.1 MODELLING AND MESHING

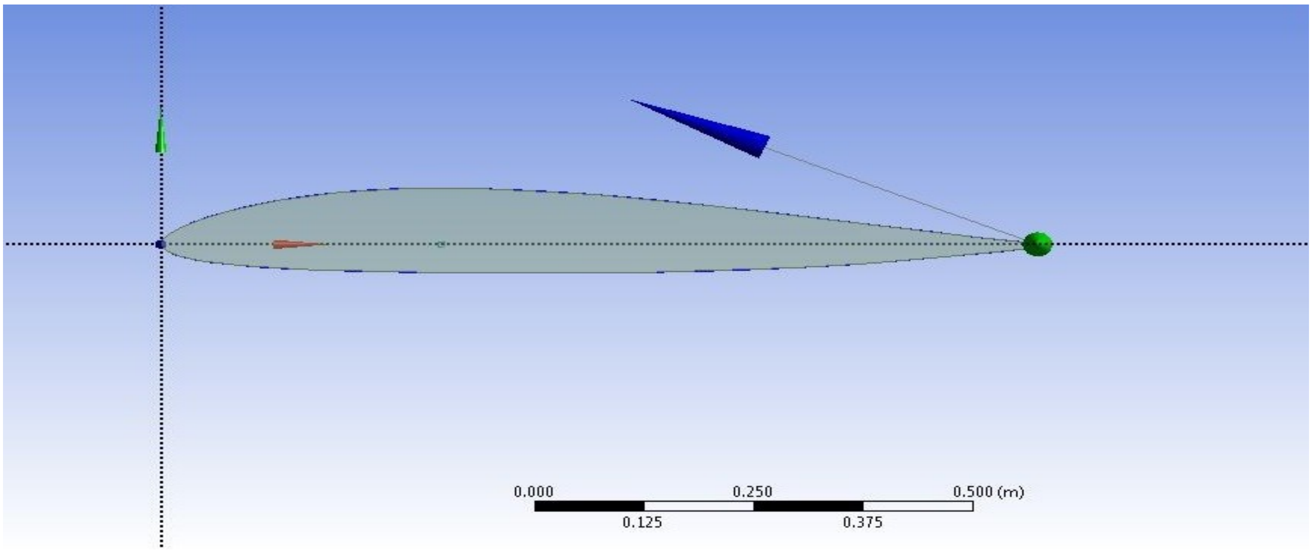


Fig. 7.1(a) : Geometry of the MIG 21 Airfoil

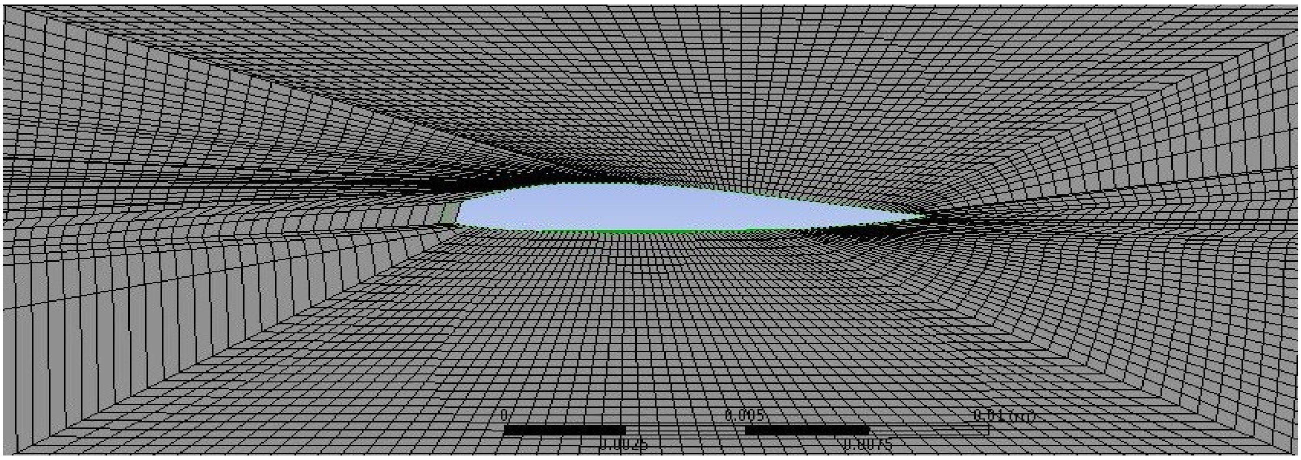


Fig 7.1(b) : Closeup of mesh drawn around the airfoil.

7.2 PRESSURE AND VELOCITY DISTRIBUTION

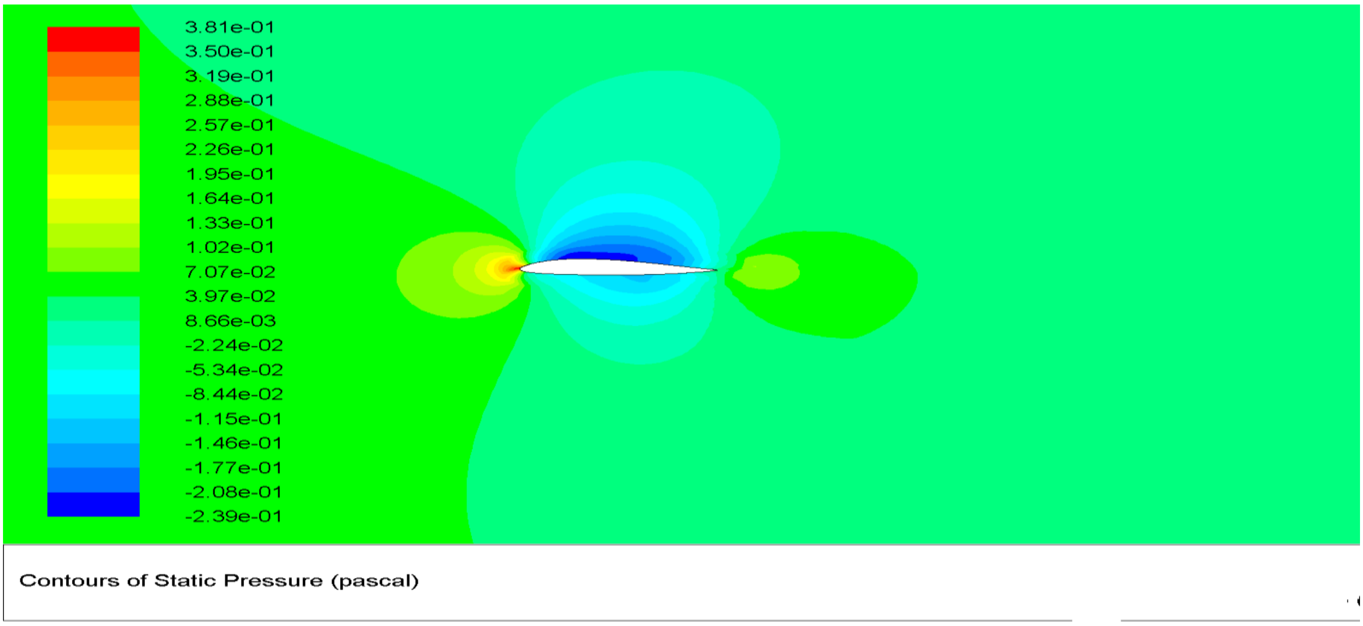


Fig. 7.2(a) : Contours of static pressure for MIG21 airfoil at 0^0 A.O.A.

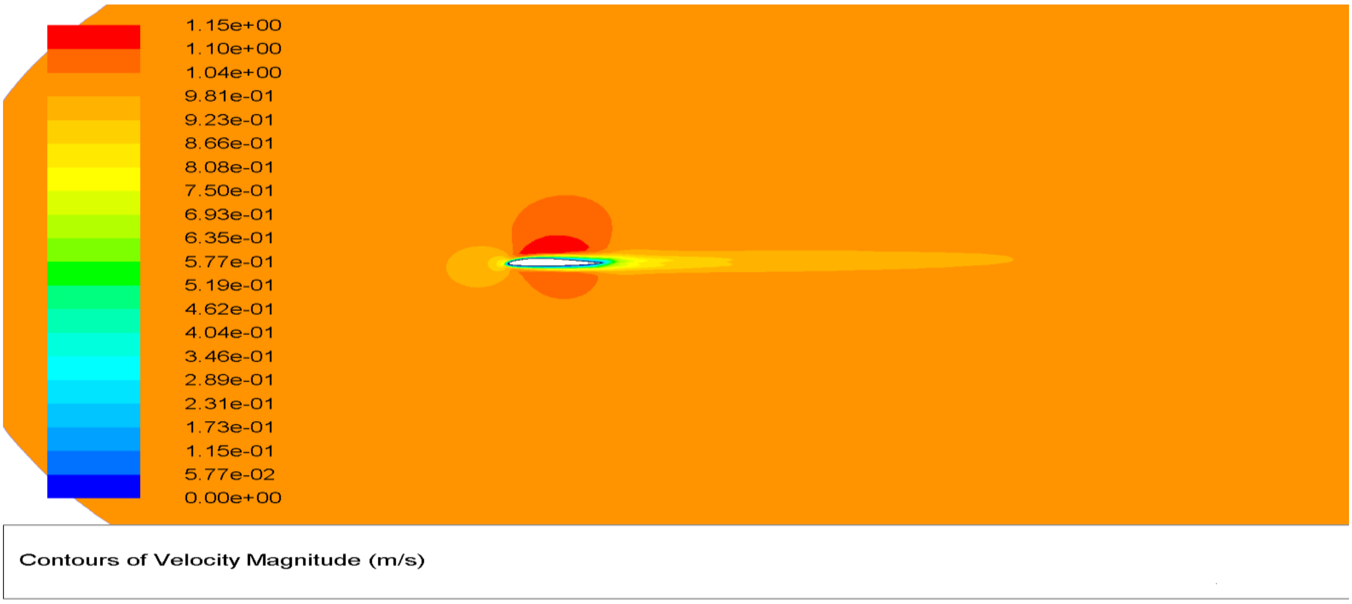


Fig. 7.2(b) : Contours of veloity magnitude for MIG21 airfoil at 0^0 A.O.A.

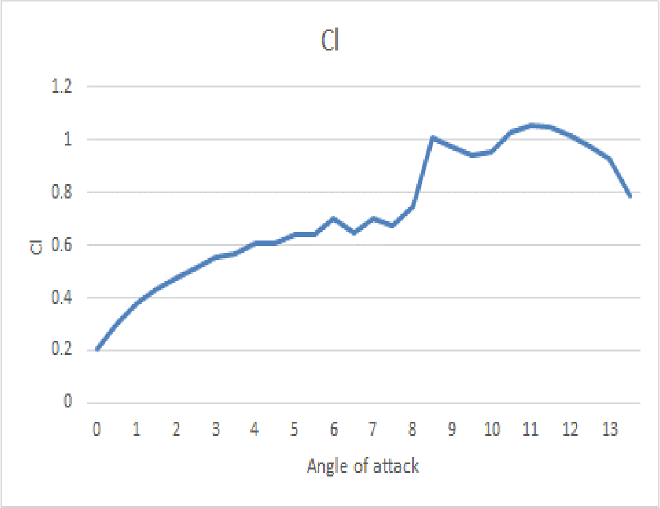
In both these diagram we can clearly see that even at zero angle of attack, the airfoil of MIG 21 shows considerable variation in pressure and velocity variation between upper surface and lower surface.

7.3 RESULTS

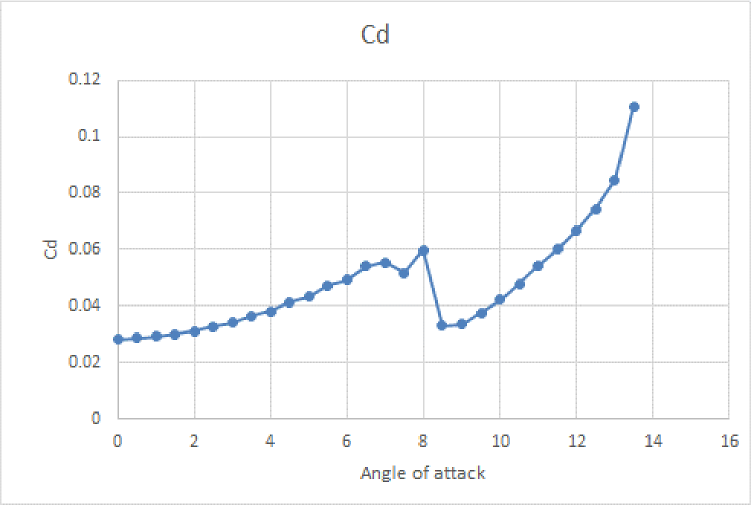
Table 7.3 (a) Variation of lift and drag coefficient with angle of attack

A.O.A	**Cl**	**Cd**	**liftforce**
0	0.2053	0.02816	28921.64
0.5	0.3019	0.02852	42530.16
1	0.3784	0.02911	53307.1
1.5	0.4351	0.03001	61294.71
2	0.4765	0.03112	67126.94
2.5	0.5138	0.03254	72381.58
3	0.5563	0.03391	78368.76
3.5	0.5691	0.03657	80171.96
4	0.6091	0.03811	85806.96
4.5	0.6101	0.04129	85947.84
5	0.6432	0.04326	90610.8
5.5	0.6378	0.04718	89850.08
6	0.6985	0.04927	98401.19
6.5	0.6472	0.05412	91174.3
7	0.7001	0.05542	98626.59
7.5	0.6757	0.05174	95189.24
8	0.7482	0.05982	105402.7
8.5	1.0102	0.03294	142311.9
9	0.9751	0.03351	137367.2
9.5	0.9432	0.03755	132873.3
10	0.9582	0.04218	134986.4
10.5	1.0265	0.04775	144608.2
11	1.0574	0.05421	148961.2
11.5	1.0472	0.06013	147524.3
12	1.0162	0.06668	143157.2
12.5	0.9732	0.07452	137099.6
13	0.9264	0.08465	130506.6
13.5	0.7885	0.11075	111079.9

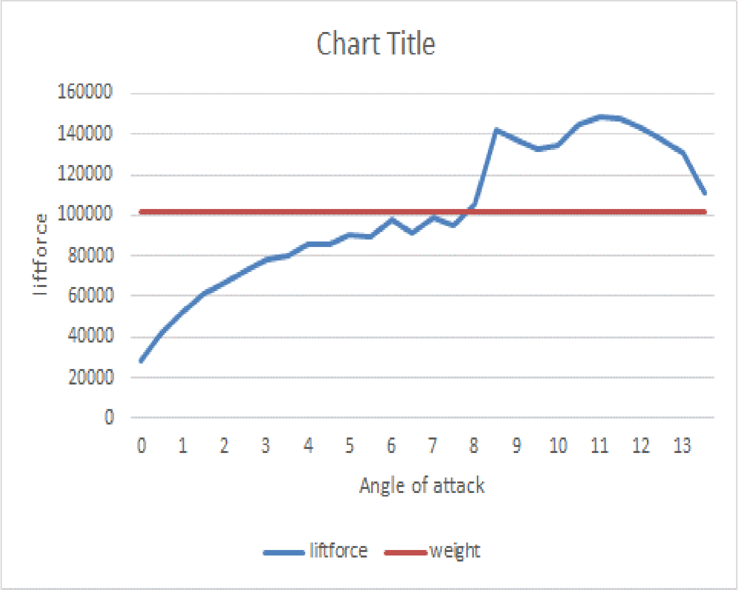
Stall angle of attack = 11^0



Graph 7.3(b) : Variation of lift coefficient with angle of attack.



Graph 7.3(c) : Variation of drag coefficient with angle of attack.



Graph 7.3(d) : Variation of lift force with angle of attack.

CHAPTER 8

INVESTIGATION OF AIRFOIL DESIGN OF BELL 200XV.

8.1 MODELLING AND MESHING

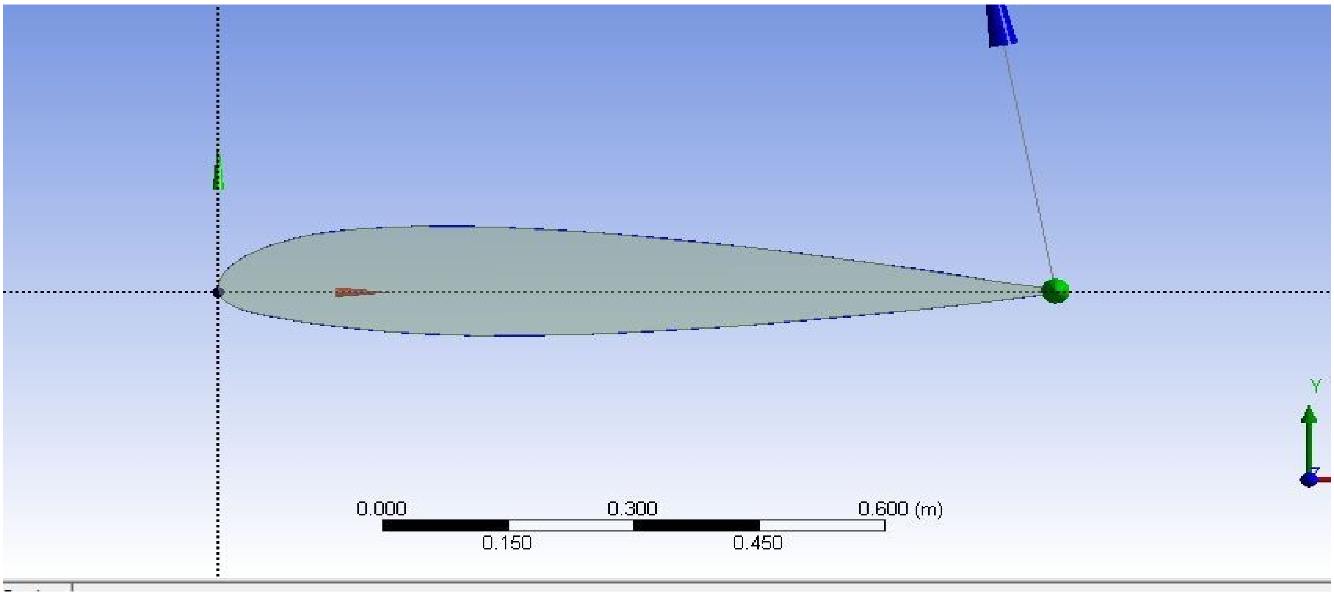


Fig. 8.1(a) : Geometry of the BELL 200XV Airfoil

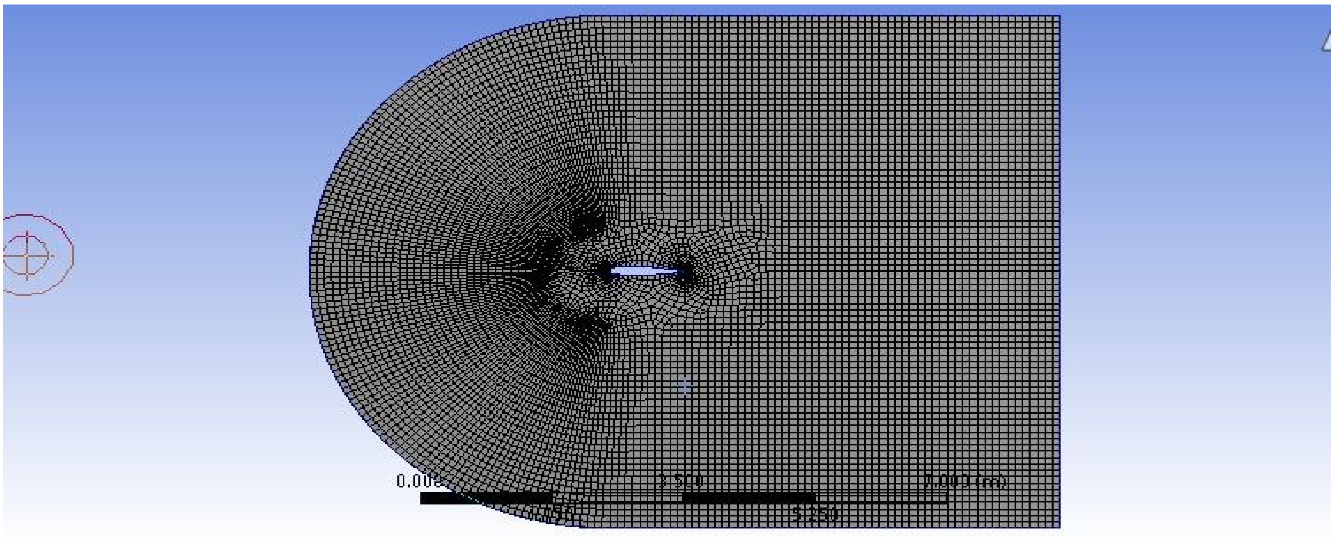


Fig. 8.1(b) : Meshing of the BELL 200XV Airfoil

8.2 PRESSURE AND VELOCITY DISTRIBUTION.

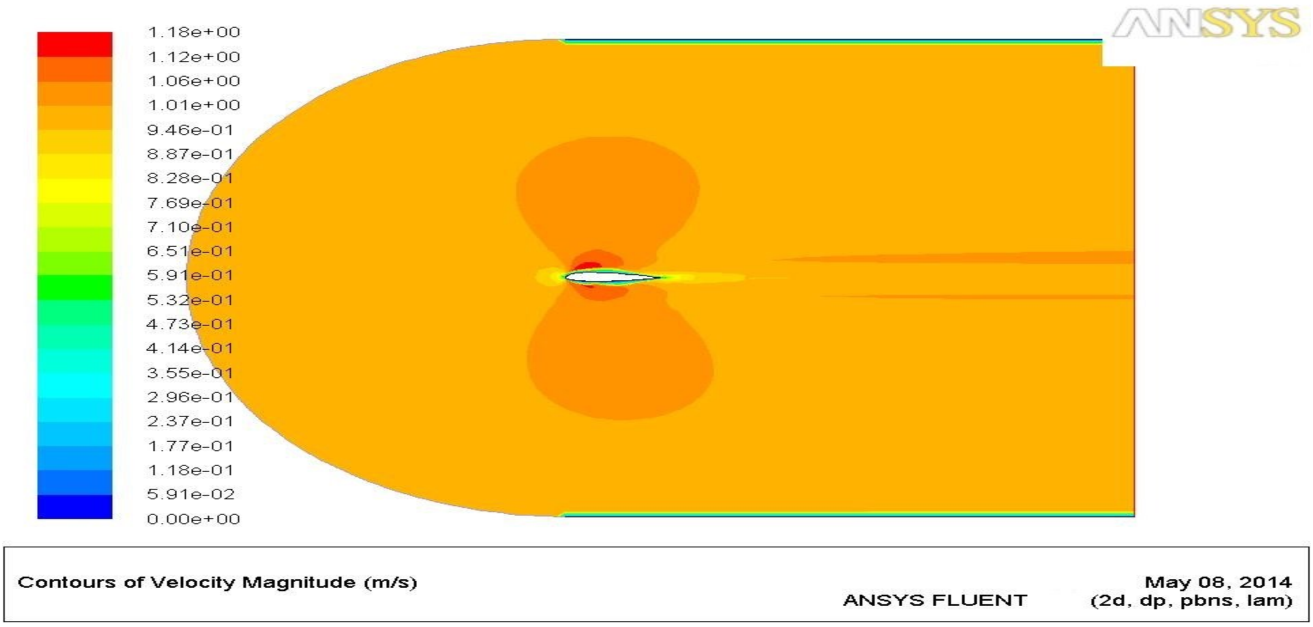


Fig. 8.2(a) : Contours of velocity magnitude for BELL200 XV airfoil at 0^0 A.O.A.

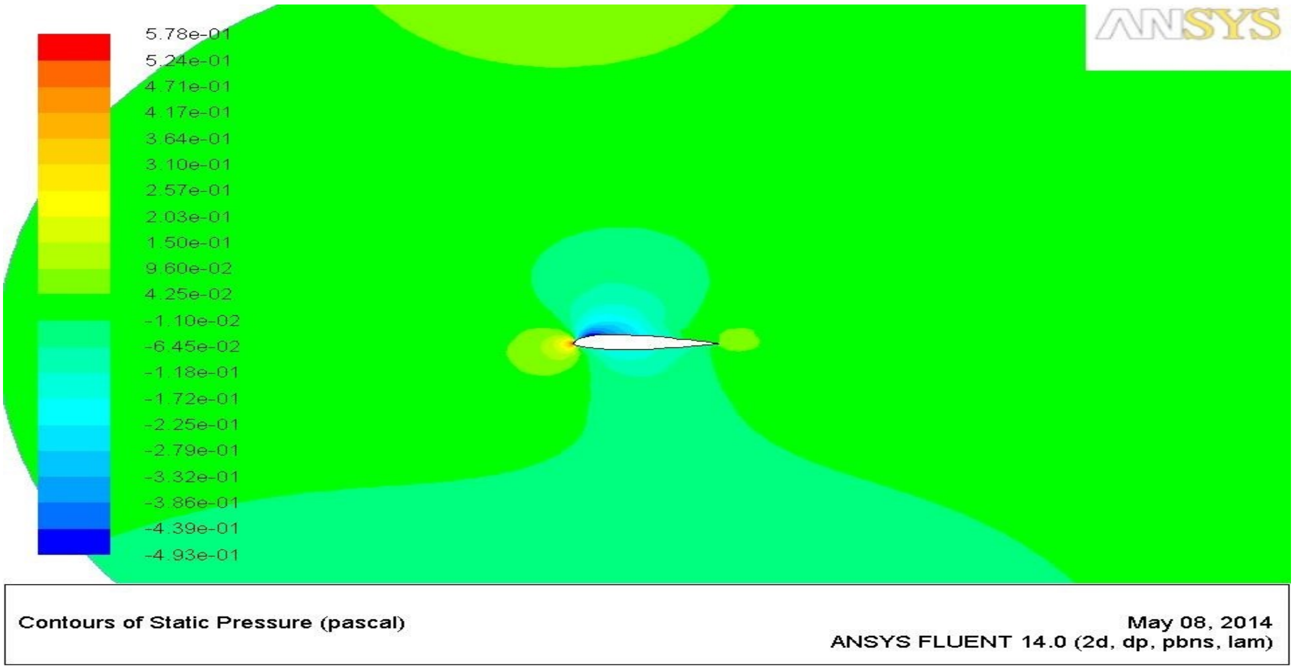
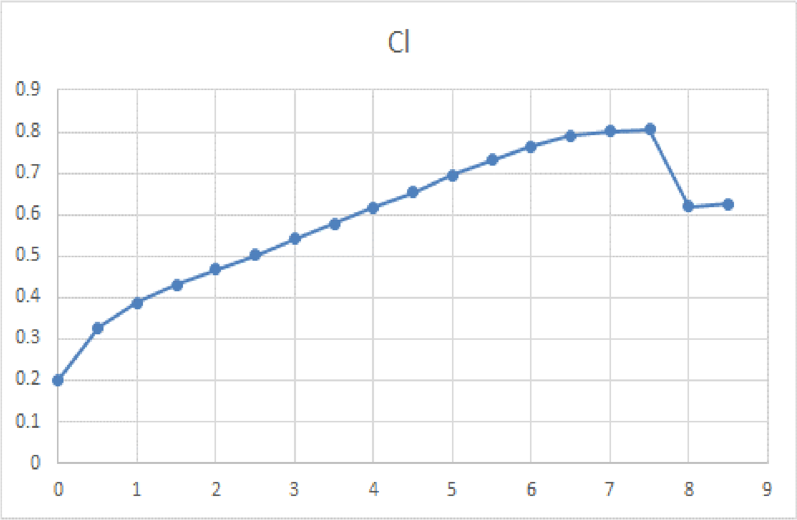


Fig. 8.2(b) : Contours of static pressure for BELL200 XV airfoil at stall A.O.A.

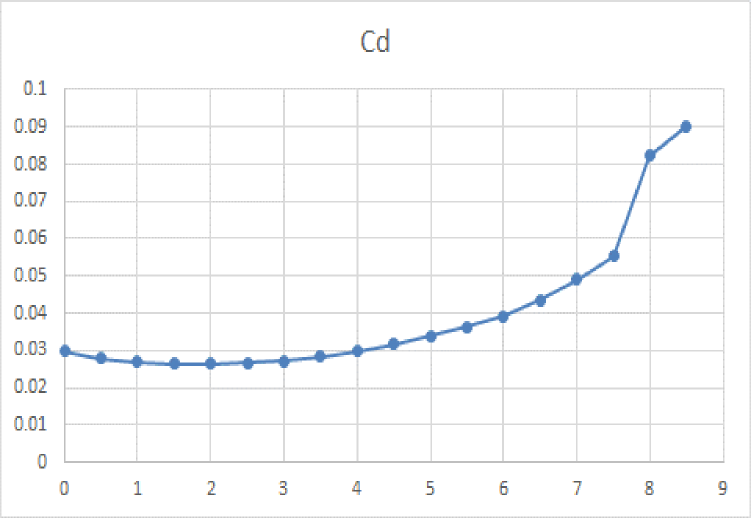
8.3 RESULTS

Table 8.3 (a) Variation of lift and drag coefficient with angle of attacK’

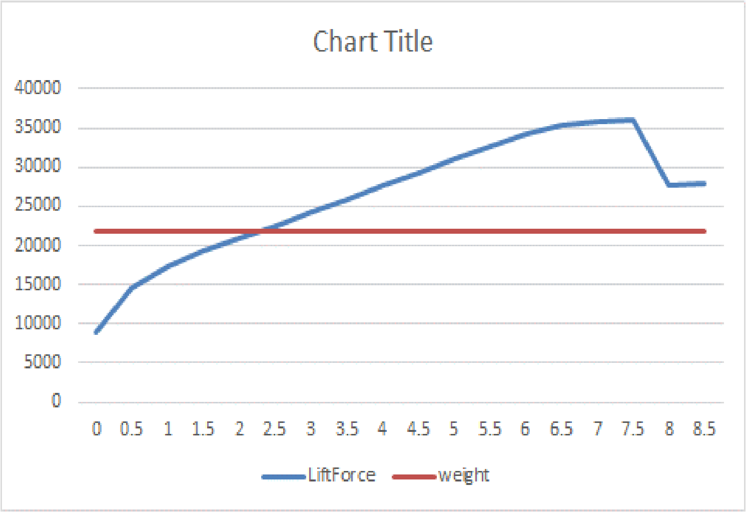
A.O.A	Cl	Cd	liftforce
0	0.2053	0.02816	28921.64
0.5	0.3019	0.02852	42530.16
1	0.3784	0.02911	53307.1
1.5	0.4351	0.03001	61294.71
2	0.4765	0.03112	67126.94
2.5	0.5138	0.03254	72381.58
3	0.5563	0.03391	78368.76
3.5	0.5691	0.03657	80171.96
4	0.6091	0.03811	85806.96
4.5	0.6101	0.04129	85947.84
5	0.6432	0.04326	90610.8
5.5	0.6378	0.04718	89850.08
6	0.6985	0.04927	98401.19
6.5	0.6472	0.05412	91174.3
7	0.7001	0.05542	98626.59
7.5	0.6757	0.05174	95189.24
8	0.7482	0.05982	105402.7
8.5	1.0102	0.03294	142311.9
9	0.9751	0.03351	137367.2
9.5	0.9432	0.03755	132873.3
10	0.9582	0.04218	134986.4
10.5	1.0265	0.04775	144608.2
11	1.0574	0.05421	148961.2
11.5	1.0472	0.06013	147524.3
12	1.0162	0.06668	143157.2
12.5	0.9732	0.07452	137099.6
13	0.9264	0.08465	130506.6
13.5	0.7885	0.11075	111079.9



Graph 8.3(b) Lift coefficient vs. Angle of attack.



Graph 8.3(c) Drag coefficient vs. Angle of attack



Graph 8.3(d) Lift force vs. Angle of attack

CHAPTER 9

ANALYSIS OF RESULTS.

9.1 SYMMETRIC VS. ASYMMETRIC

Fig. 9.1(a) : Comparison of lift coefficient

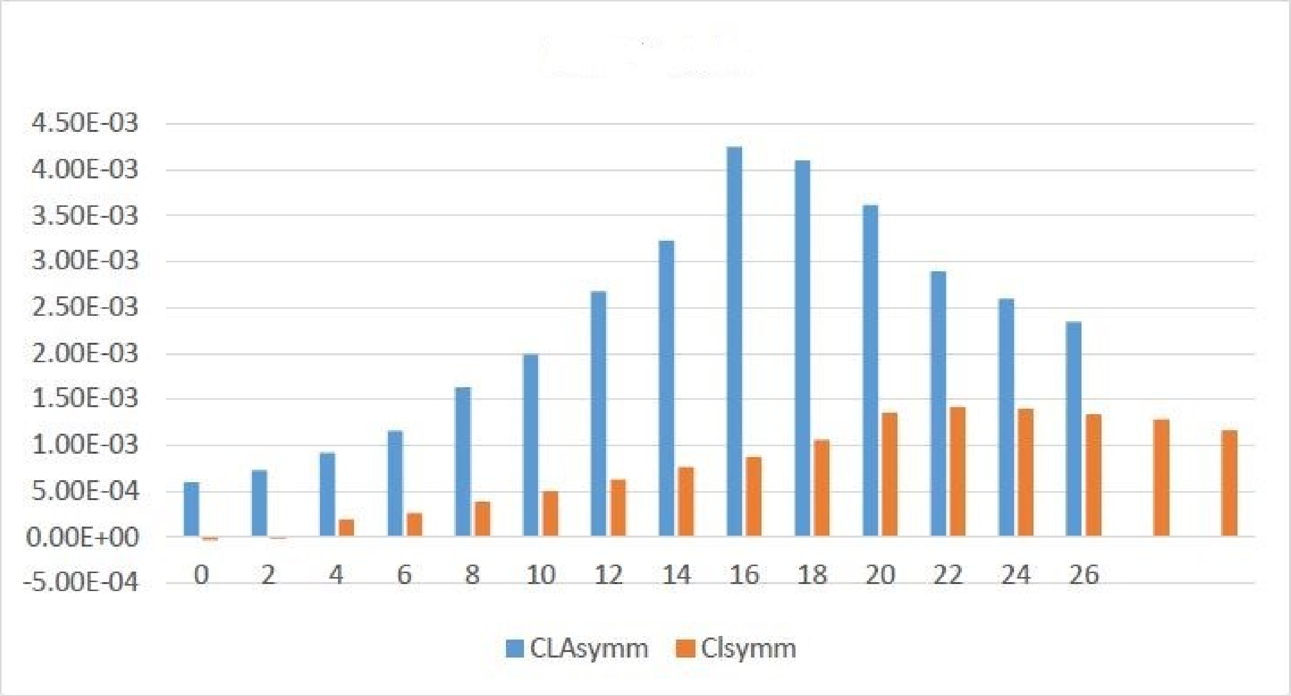
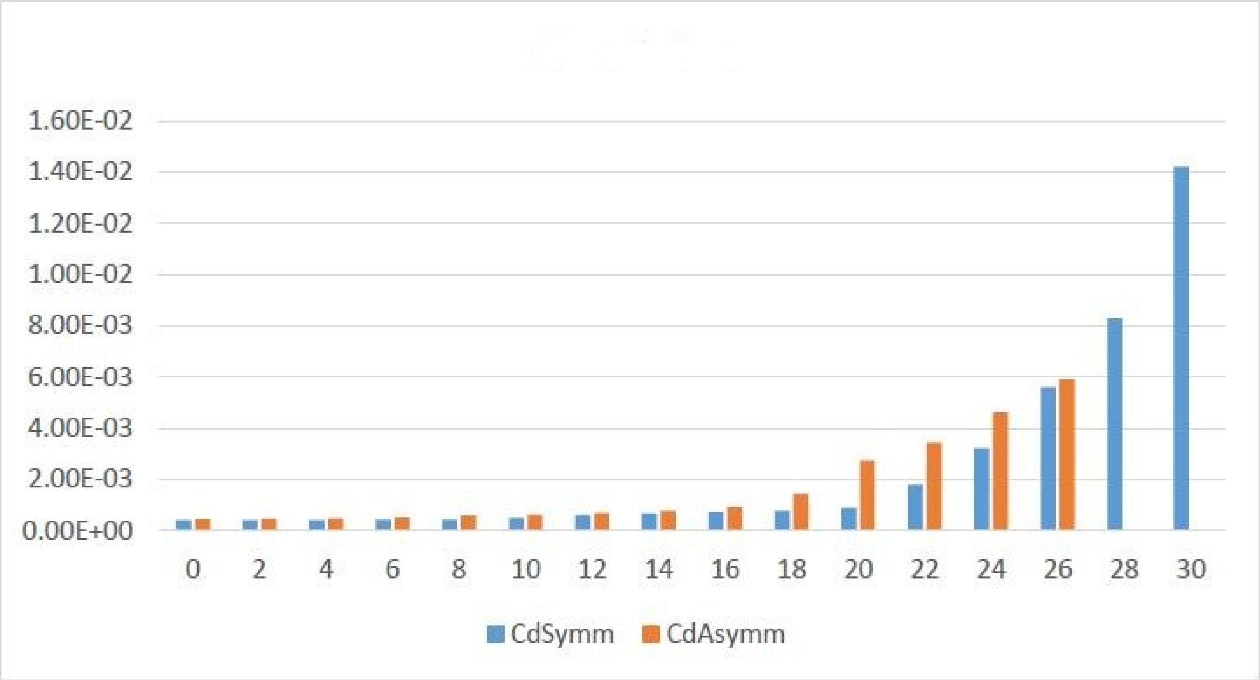
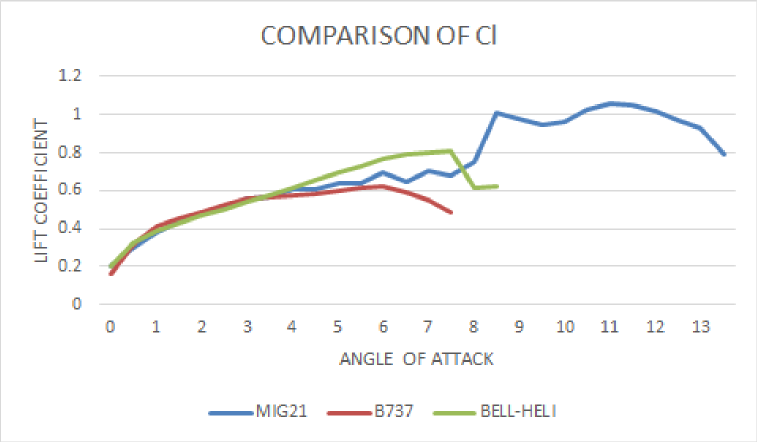


Fig. 9.1(b) : Comparison of drag coefficient.



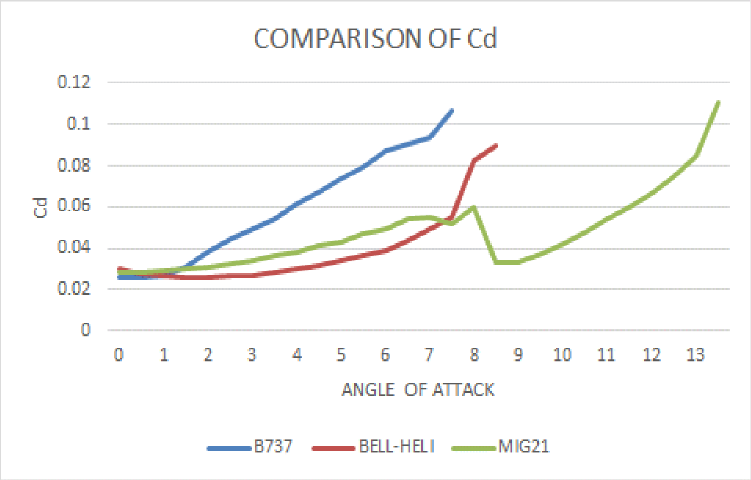
9.2 COMPARISON OF BOEING 737, MIG 21 AND BELL 200XV



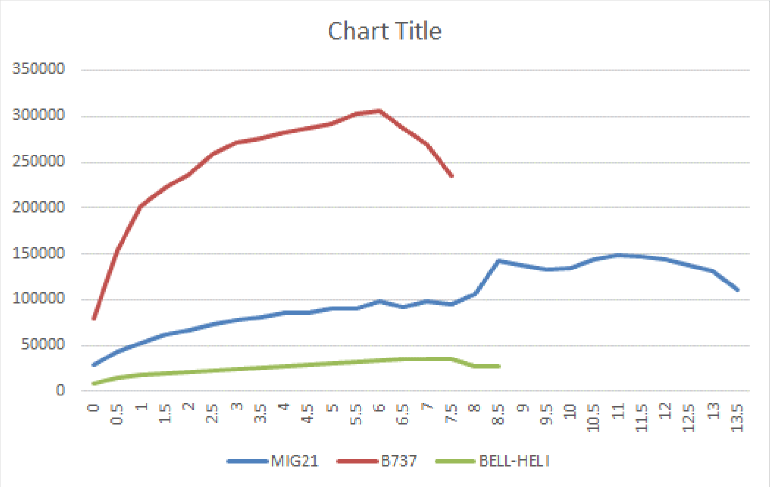
We can see from the graph that at the starting lift coefficient is nearly same for all the three airfoils but with increase in angle of attack bell 200 xv shows higher lift coefficient while MIG21 has higher stall angleof attack.

Graph 9.2(a) Lift coefficient vs. Angle of attack.

It is clear from the graph that B737 has a higher intial value of drag coefficient while MIG21 takes over due to its wide range of angle of attack.



Graph 9.2(b) Drag coefficient vs. Angle of attack



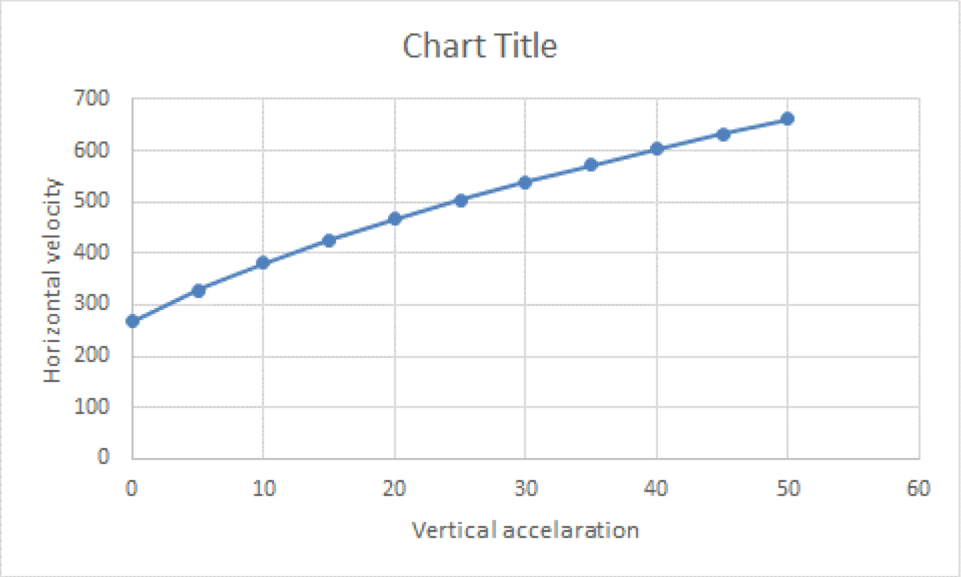
From the graph we can conclude that B737 can generate very high amount of lift force as compared to MIG 21 and BELL 200XV.While MIG21 comes second and BELL.

Graph 9.3(c) Lift force vs. Angle of attack

9.3 VELOCITY VS. ACCELERATION

Table 9.3(a) : Vertical accelration vs. horizontal velocity for B737 at stall angle of attack.

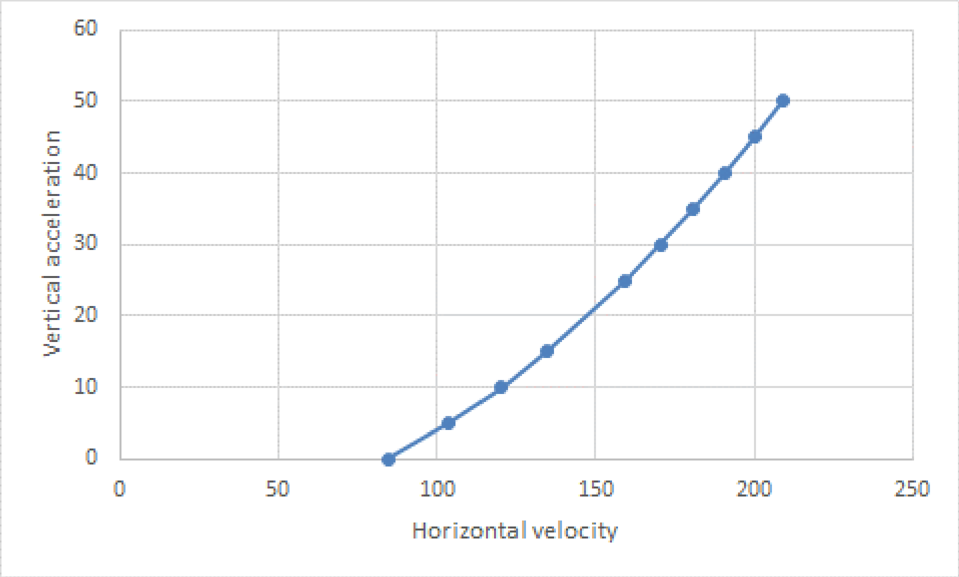
Vertical accelaration(m/s^2)	**Horizontal velocity(m/s)**
0	267.7444
5	328.9753
10	380.4767
15	425.7937
20	466.7312
25	504.3567
30	539.3639
35	572.2335
40	603.315
45	632.8718
50	661.1085



Graph 9.3(b) Vertical accelration vs. horizontal velocity for B737 at stall angle of attack.

Table 9.3(C) : Vertical accelration vs. horizontal velocity for B737 at stall angle of attack

Accelaration (m/s^2)	**velocity (m/s)**
0	84.635401
5	104.00875
10	120.301658
15	134.637134
25	159.488231
30	170.561322
35	180.958099
40	190.789157
45	200.137881
50	209.068985



Graph 9.3(d) Vertical accelration vs. horizontal velocity for MIG21 at stall angle of attack.

CHAPTER 10

CONCLUSION

CONCLUSION

- Lift coefficient was found to be higher for Asymmetric airfoil than the Symmetric airfoil for same chord length and maximum camber of the airfoil at same angle of attack.

- Stall angle of attack of asymmetric airfoil was found to be lower than that of Symmetric airfoil for same length and camber of the airfoil.

- Drag force of Asymmetric airfoil was found to be marginally more than that of Symmetric airfoil for same length and camber of airfoil.

- Out of the three airfoils namely MIG21, BOEING 737 AND BELL 200XV airfoils MIG21 was found to have highest stall angle of attack.

- While all the three airfoils MIG21, BOEING 737 AND BELL 200XV have nearly same lift coefficient for smaller angle of attack MIG21 shows the highest lift coefficient owing to its greater stall angle of attack.

- Drag coefficient of BOEING 737 is higher than that of MIG21 AND BELL 2OOXV for the same angle of attack.

- The lift force is highest for BOEING 737 followed by MIG 21 and then BELL 200XV helicopters.

REFERENCES

1. Gultop T., "An Investigation of the effect of aspect ratio on Airfoil performance." Gazi : American Journal of Applied Sciences ISSN/EISSN: 15469239 15543641, Volume: 2, Issue: 2 ,Pages: 545-549 ,1995.

2. Kevadiya M. (2013) CFD "Analysis of Pressure Coefficient for NACA 4412" International Journal of Engineering Trends and Technology ISSN/EISSN: 22315381 Volume: 4 Issue: 5 Pages: 2041-2043, 2013

3. Goel S.,(2008) " Turbine Airfoil Optimization Using Quasi-3D Analysis Codes." International Journal of Aerospace Engineering ISSN/EISSN: 16875974 16875974 Volume: 2009, 2008

4. Arvind M. "CFD ANALYSIS OF STATIC PRESSURE AND DYNAMIC PRESSURE FOR NACA 4412" International Journal of Engineering Trends and Technology ISSN/EISSN: 22315381 Volume: 4 Issue: 8 Pages: 3258-3265,(2010)

5. . By J. Fazil and V. Jayakumar, "Investigation of airfoil profile design using reverse engineering Bezier curve" Journal of Engineering and Applied Sciences ISSN/EISSN: 18196608 Year: 2011 Volume: 6 Issue: 7 Pages: 43-52, 2011.

WEB REFERENCES

1. http://www.airfoiltools.com
2. http://www.boeing.com/boeing/commercial/737family/
3. http://www.dcs-mig21.com/
4. http://www.aviastar.org/helicopters_eng/bell_xv-3.php
5. http://aerospace.illinois.edu/m-selig/ads/coord_database.html