© June 2022| IJIRT | Volume 9 Issue 1 | ISSN: 2349-6002

Design and Analysis of NASA SC (2)-0606 Airfoil

E.Roshan[1], V.Sethuraman[2], S.Vijayasarathi[3], S.R.Arun[4], M.G.Rajagopal[5]

[1,2,3] *UG Student, Department of Aeronautical Engineering, Excel Engineering College, Namakkal, India.*

[4,5]*Assistant Professor, Department of Aeronautical Engineering, Excel Engineering College, Namakkal.*

***Abstract*—Airfoil is an important part of any aeroplane structure whether it may be passenger aeroplanes, jet aeroplanes or helicopters. The airfoils decide whether the lift force is sufficient to balance the weight of the aeroplane or not and how important drag force is being applied on the aeroplane. Airfoils are principally divided into two orders, I've tried to differentiate between the two type-site Symmetrical and Asymmetrical airfoils on the base of their lift and drag measure's variation with angle of attack, stall angle of attack and magnitude of the coefficients. Literal background says that various development of airfoil development took place till now. Before wing design testing was done with the help of wind tunnel testing styles but now days with advancement of computer technology the task has come veritably easier than before one. Design of wing and its optimization is done in different CAD software package and their analysis in some analytical software like ANSYS. In this design named a DESIGN AND ANALYSIS OF NASA SC (2) – 0606 AIRFOIL trouble has been made to make a detailed study on lift and drag measure of various conditions. The aerodynamics characteristics are acquired veritably directly with the help of these CAD and CFD analysis. In current age of technology we've the most advanced aerodynamics in the field of aviation. In our design, the performance of NASA SC (2) – 0606 airfoil experimentally under the condition of subsonic, supersonic and hypersonic condition analyze by the ANSYS software and also analyze by the wind tunnel test. The reason for Why We Take This Airfoil Means, This Airfoil Used in Airbus a380 at the wingtip (approximated). Because Airbus a380 is the most successful running aircraft in the aviation field. Then only we would like to decide to Analyze NASA SC (2)-0606 AIRFOIL.**

Index Terms: ANSYS, AIRFOIL, AEROPLANE

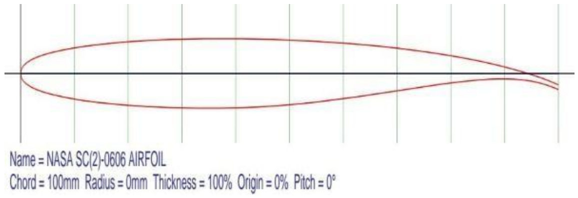


Fig 1 NASA SC (2)-0606 AIRFOIL

I. INTRODUCTION

In the initial days, when man was yet living in the stage of nature, the only means of locomotion was his legs. Gradationally, we've achieved quickly and more luxurious ways of travelling, latest being the air transport. Since, its invention aeroplanes have been getting further and further fashion ability as it's the fastest mode of transportation available. It has also gained fashion ability as a war machine since World War II. This popularity of air transport has led to many new inventions and exploration to develop faster and more economical aeroplanes. This design is such an attempt to determine how we can decide maximum performance out of an airfoil section.

An airfoil is a cross-section of wing of the aeroplane. Its main job is to give lift to an aeroplane during takeoff and while in flight. But, it has also a side effect called Drag which opposes the stir of the aeroplane. The quantum of lift demanded by a aeroplane depends on the purpose for which it's to be used. Heavier aeroplanes bear further lift while lighter aeroplanes bear lower lift than the heavierones. Therefore, depending upon the use of aeroplane, airfoil section is determined. Lift force also determines the perpendicular acceleration of the aeroplane, which in turns depends on the horizontal velocity of the aeroplane. Therefore, determining the coefficient of lift one can calculate the lift force and knowing the lift force and needed vertical acceleration one can determine the needed horizontal velocity.

II. OBJECTIVE

- Designing of Asymmetric Airfoil in CATIA.
- Modelling of airfoil of NASASC (2) 0606.
- Examine the velocity and surface pressure distribution of our airfoil.
- Determine the drag and lift coefficient of the Airfoils at the condition of subsonic, supersonic

and hypersonic and also study their variation with angle of attack by ANSYS SOFTWARE.
- Calculate lift and Drag forces on airfoil for each angle of attack.

III. METHODOLOGY

The first step in our project, after deciding the topic, was to do a literature review of the topic. So, we searched for some previous works done in this topic and got our self-familiar with the topic. The second step was to gather the required software's for our project which in this case was CATIA for designing, ANSYS- Analysis Systems and Microsoft excel. The next step was the Data collection. For our project we required coordinates of the airfoil of the NASA SC (2) 0606. We also needed the area, velocity at all the three conditions and pressure. Then we went through some textual as well as visual manuals to learn ANSYS. Then, we modelled NASA SC(2) 0606 airfoil and obtained the coefficient of lift and drag calculated lift and drag force, determined stall angle of attack, plotted graph between coefficient of lift and drag and the angle of attack and analyzed the results obtained. WE Also Calculated The Pressure Distribution for This Airfoil at 12 Stagnation Points and Using by This We Obtained a Pressure Co-Efficient On Each Point.

IV. AERODYNAMICS

Aerodynamics is an extension of science which is concerned with concentrating on the movement of air, especially when associating with a 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 limits layers, and has gotten to be progressively computational in nature.

An airfoil (in American English) or airfoil (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 headingedge, 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 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 and base speed contrast without registering the weight by utilizing the idea of flow and the Kutta-Joukowski hypothesis.

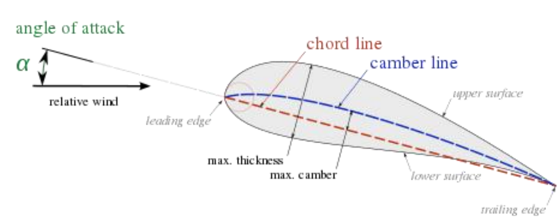


Fig 2 relative wind moving on airfoil

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 airfoil 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 dragging 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 coefficient starts to decrease.

V. CATIA

CATIA is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), 3D modeling and Product lifecycle management (PLM), developed by the French company Dassault Systems.

Since it supports multiple stages of product development from conceptualization, design and engineering to manufacturing, it is considered a CAx-software and is sometimes referred to as a 3D Product Lifecycle Management software suite. Like most of its competition it facilitates collaborative engineering through an integrated cloud service and have support to be used across disciplines including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

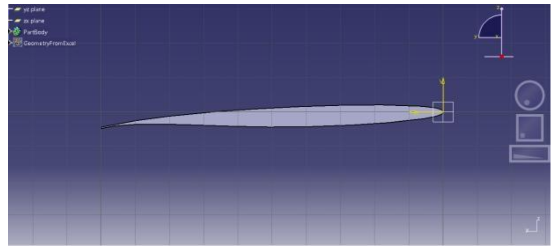


*Fig3*NASA SC (2) 0606 AIRFOIL DESIGN BY CATIA

Besides being used in a wide range of industries from aerospace and defense to packaging design, CATIA has been used by architect Frank Gehry to design some of his signature curvilinear buildings and his company Gehry Technologies was developing their Digital Project software based on CATIA.

The software has been merged with the company's other software suite 3D XML Player to form the combined Solid works Composer Player.

VI. ANSYS

Offers engineering simulation solution sets in engineering 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 optimizing 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.

VII. LITERATURE REVIWE

T .Gultop, (2005) [1] studied the impact of perspective degree on Airfoil performance. The reason for this study was to focus the ripple conditions not to be kept up throughout wind tunnel tests. These studies indicate that aero elastic 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 polynomials that leads to no roughness in the radial direction.

Mr. Arvind (2010)[4] researched on NACA 4412 airfoil and analyzed 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 speed 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. Mayurkymarkevadiya (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˚.

VIII.RESULTS PRESSURE DISTRIBUTION

We are testing pressure distribution for our model airfoil in the subsonic wind tunnel and Ansys. wemake a 12 stagnation point on the airfoil and each point has a different pressure co efficient in varying angle of attack.

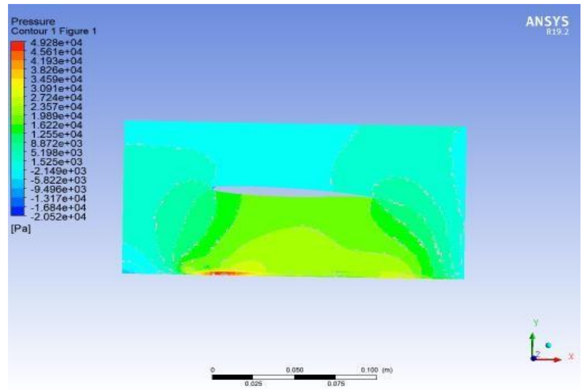


Fig 4 pressure at subsonic condition

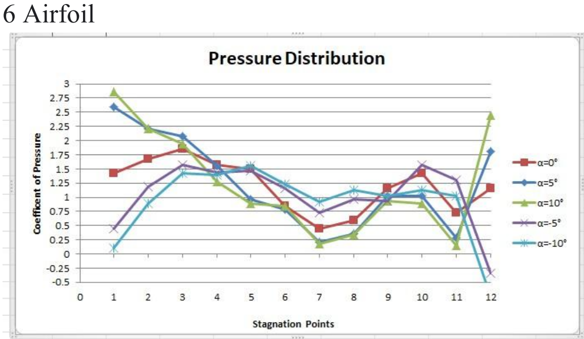
CO EFFICIENT OF PRESSURE; The Pressure Coefficient is the ratio of pressure forces to inertial forces.

Angle of Attack	Δhx10²m	Pressure distribution in Manometer, h(x10⁻²m)											
		1	2	3	4	5	6	7	8	9	10	11	12
0	3.8	22.5	23.5	24.2	23.1	22.8	20.3	18.8	19.4	21.5	22.5	19.9	21.5
5	3.8	27	25.5	25	23	20.8	20.1	17.9	18.5	21	21	18.2	24
10	3.8	28.5	26	24.5	22	20.5	20.3	17.8	18.4	20.7	20.5	17.7	26.4
-5	3.8	18.8	21.6	23.1	22.6	22.7	21.5	19.9	20.8	20.7	23.1	22.1	15.8
-10	3.8	17.5	20.5	22.4	22.4	23	21.8	20.6	21.4	21	21.4	21	14.2

*Table 1*Pressure distribution on the stagnation point on NASA SC(2)

Angle of Attack	Δh x10⁻²m	Coefficient of pressure for the various position of pressure tapping's, $Cp = \frac{\pm h}{\Delta h}$											
		1	2	3	4	5	6	7	8	9	10	11	12
0	3.8	1.42	1.68	1.86	1.57	1.5	0.84	0.44	0.60	1.15	1.42	0.73	1.15
5	3.8	2.6	2.21	2.07	1.55	0.97	0.78	0.21	0.36	1.02	1.02	0.28	1.81
10	3.8	2.86	2.21	1.94	1.28	0.89	0.84	0.18	0.34	0.94	0.89	0.15	2.44
-5	3.8	0.44	1.18	1.57	1.44	1.47	1.15	0.73	0.97	0.94	1.57	1.31	-0.34
-10	3.8	0.10	0.89	1.42	1.39	1.55	1.23	0.92	1.13	1.02	1.13	1.03	-0.76

*Table 2*Co efficient of pressure for NASA SC (2)060 6 Airfoil



*Graph 1*For co efficient of pressure in each stagnation point of on NASA SC (2) 0606 Airfoil.

VELOCITY DISTRIBUTION

SUBSONIC SPEED:

A subsonic condition aircraft with a maximum speed less than the speed of sound (Mach 1). The term technically describes an aircraft that flies below its critical Mach number, typically around≤250 m/s and Mach 0.8.

Angle of Attack	Co-efficient of lift(CoL)	Co-efficient of Drag(CoD)	Lift force	Drag force
0	0.45094	0.010041	378.1	154.3
5	0.6068	0.0123	778.7	463.5
10	0.084309	0.016252	317.4	611.9
15	0.034876	0.093410	313	863.7
20	0.023579	0.111519	297.8	1361.2

*Table 3*for Subsonic Flow Condition

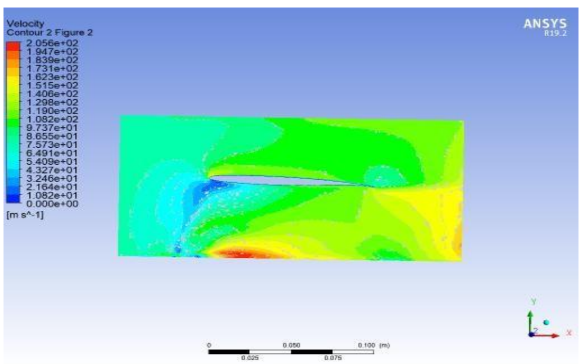
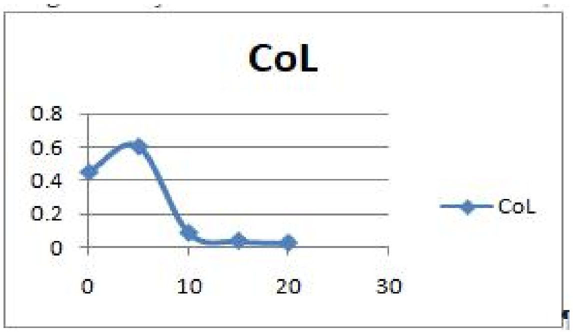
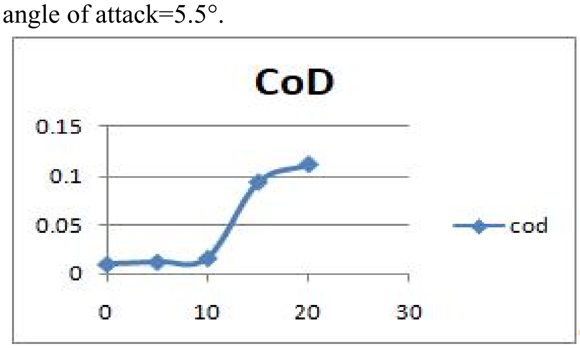


*Fig 5*Velocity Distribution in Subsonic Condition



*Graph 2*It can be observed from the graph of lift coefficient increases with angle of attack till 5.5° after which it begins to decrease. Therefore, stall angle of attack=5.5°.



*Graph 3*Coefficient of drag is an undesired force and should be avoided. Its value is seen to be increasing with Angle of Attack.

SUPERSONIC SPEED:

For aircraft speeds which are greater than the speed of sound, the aircraft is said to be supersonic. Typical speeds for supersonic aircraft are 412-1715 m/s and the Mach number M is greater than one, 1 < M < 3.

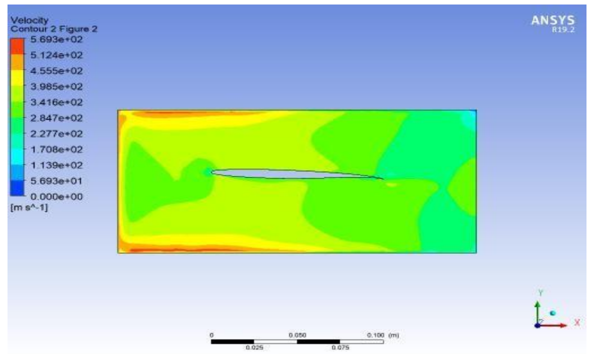
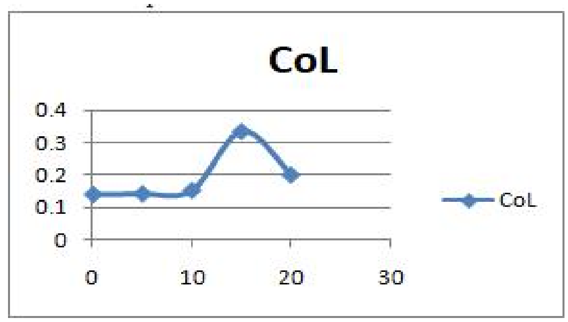


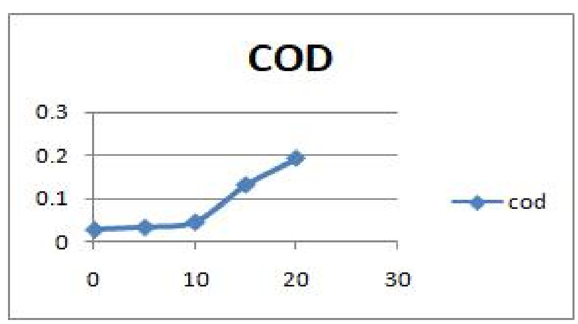
*Fig 6*Velocity Distribution for supersonic Condion

Angle of Attack	Co-efficient of lift	Co-efficient of Drag	Lift force	Drag force
0	0.139955	0.027149	20526	3993.2
5	0.141148	0.032606	20810	4794.8
10	0.152058	0.044942741	22365.4	6610.3
15	0.33551	0.13127	49349	19307
20	0.200214	0.19293263	29419.9	22721

*Table 4*ForSupersonic Flow Condition



*Graph 4*It can be observed from the graph that lift coefficient increases with angle of attack till 16°after which it begins to decrease. Therefore, Stall angle of attack= 16°.



*Graph 5*Coefficient of drag is an undesired force and should be avoided. Its value is seen to be increasing with Angle of Attack.

HYPERSONIC SPEED:

A hypersonic speed is one that exceeds 5 times the speed of sound, often stated as starting at speeds of Mach 5 and above.

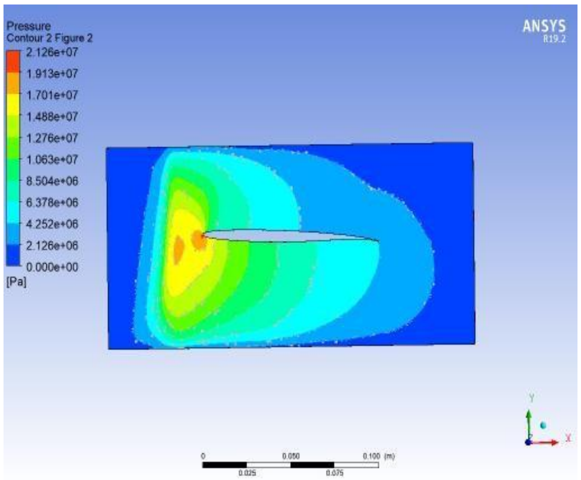
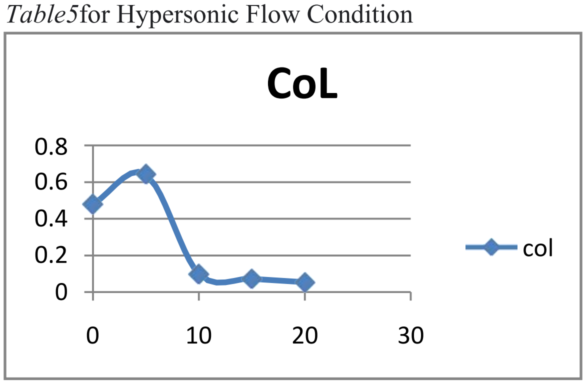


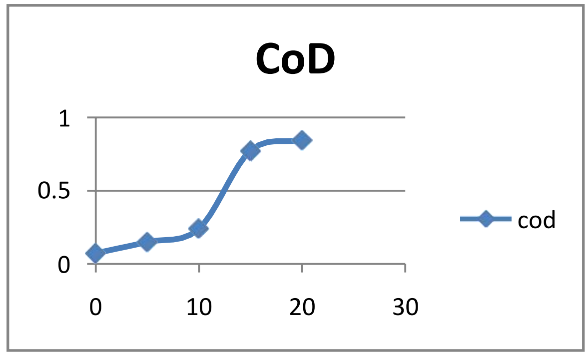
*Fig 7*Velocity Distribution for Hypersonic Condition

Angle of Attack	Co-efficient of lift	Co-efficient of Drag	Lift force	Drag force
0	0.47912	0.073352	913310	139800
5	0.64159	0.14978	1019300	198200
10	0.098202509	0.23987103	103521.2	317531
15	0.0719377	0.77228	656500	410223
20	0.0537116	0.844917392	12405.1	594597

*Table5*for Hypersonic Flow Condition



*Graph 6*It can be observed from the graph that lift coefficient increases with angle of attack till 6° after which it begins to decrease. Therefore, Stall angle of attack= 6°.



*Graph 7*Coefficient of drag is an undesired force and should be avoided. Its value is seen to be increasing with Angle of Attack.

REFERENCES

[1] Jacobs, Eastman N.; Ward, Kenneth E.; and Pinkerton, Robert M.: The Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Wind Tunnel. NACA Rep. 460, 1933

[2] Jacobs, Eastman N.; and Pinkerton, Robert M.: Tests in the Variable-Density Wind Tunnel of Related Airfoils Having the Maximum Camber Unusually far Forward. NACA Rep. 537, 1935

[3] Jacobs, Eastman N.; Pinkerton, Robert M.; and Greenberg, Harry: Tests of Related Forward-Camber Airfoils in the Variable-Density Wind Tunnel. NACA Rep. 610, 1937.

[4] Abbott, Ira H.; Von Doenhoff, Albert E.; and Stivers, Louis S., Jr.: Summary of Airfoil Data. NACA Rep. 824, 1945. (Supersedes NACA WR L-560.

[5] Abbott, Ira H.; and Von Doenhoff, Albert E.: Theory of Wing Sections. Dover Publ., Inc., c.1959.

[6] McGhee, Robert J.; Beasley, William D.; and Whitcomb, Richard T.: NASA Low- and Medium-Speed Airfoil Development. NASA TM-78709, 1979

[7] Eppler, Richard; and Somers, Dan M.: A Computer Program for the Design and Analysis of Low-Speed Airfoils. NASA TM-8021O, 1980.

[8] Eppler, Richard; and Somers, Dan M.: Supplement To: A Computer Program for the Design and Analysis of Low-Speed Airfoils. NASA TM-81862, 1980.

[9] Somers, Dan M.: The S809 through S813airfoils. Airfoils, Inc., 1988. [proprietary to NREL]
[10] van Ingen, J. L.; Boermans, L. M. M.; and Blom, J. J. H.: Low-Speed Airfoil Section Research at Delft University of Technology. ICAS-80-1O.1, Munich, Oct. 1980.
[11] Wortmann, F. X.: Experimental Investigations on New Laminar ProfIles for Gliders and Helicopters. TILlT.4906, British Minist.Aviat., Mar. 1960. (Translated from Z. Flugwissenschaften, Bd. 5, Heft 8, Aug. 1957, S. 228-243.)
[12] The.Cambridge University Aeronautics Laboratory: The Measurement of Profile Drag by the Pitot-Traverse Method. R. & M. No. 1688, British A.R.C., 1937.
[13] Allen, H. Julian; and Vincenti, Walter G.: Wall Interference in a Two-Dimensional-Flow Wind Tunnel, With Consideration of the Effect of Compressibility. NACA Rep. 782, 1944. (Supersedes NACA WR A-63.)
[14] Hoerner, Sighard F.: Fluid-Dynamic Drag. Published by the author (Midland Park, New Jersey), 1965.
[15] Braslow, Albert L; and Knox, Eugene C.: Simplified Method for Determination of Critical Height of Distributed Roughness Particles for Boundary-Layer Transition at Mach Numbers From 0 to 5. NACA TN 4363, 1958.
[16] Loving, Donald L.; and Katzoff, S.: The Fluorescent-Oil Film Method and Other Techniques for Boundary-Layer Flow Visualization. NASA MEMO 3-17-59L, 1959.
[17] Pfenninger, Werner: Investigations on Reductions of Friction on Wings, in Particular by Means of Boundary Layer Suction. NACA TM 1181, 1947.
[18] van Ingen, J. L.; and Boermans, L. M. M.: Research on Laminar Separation Bubbles at Delft University of Technology in Relation to Low Reynolds Number Airfoil Aerodynamics. Proceedings of the Conference on Low Reynolds Number Airfoil Aerodynamics, UNDAS-CP-77BI23, Dniv.of Notre Dame, June 1985, pp. 89-124
[19] 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.
[20] 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
[21] Goel S.,(2008) “Turbine Airfoil Optimization Using Quasi-3D Analysis Codes.” International Journal of Aerospace Engineering ISSN/EISSN: 16875974 16875974 Volume: 2009, 2008
[22] 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)
[23] 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.