Sample Analysis of cropped delta wing under low subsonic flow regime

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Abstract - *The Delta wing is a wing shaped in the form of a triangle. Wing is a type of fin that produces lift, while moving through air or some other fluid. As such, wings have streamlined cross sections that are subject to aerodynamic forces and act as an airfoil. A wing's aerodynamic efficiency is expressed as it's lift-to-drag ratio. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at enough lift and it proves suitable for high-speed subsonic and supersonic flight. This phase of this work is the testing of prototype model by using the subsonic wind tunnel. During the test, the model is placed in the test section of the tunnel and air is made to flow past the model. With the model mounted on the test section we can measure lift, drag, lateral side forces, over a range of angle of attack. This allows one to produce common curves such as lift coefficient versus angle of attack, drag coefficient versus angle of attack. The lift of the airfoil increases linearly with angle of attack and speed. But from the plots, the lift decreases drastically at an angle of attack of 15 degrees. So, the stall angle exists at 15 degrees with maximum coefficient of lift 0.92.*

Key Words: AOA- Angle of Attack, NACA-National Advisory Committee for Aeronautics, NASA- National Aeronautics and Space Administration, AR-Aspect ratio, CG-Center of gravity, CFD- Computational Fluid Dynamics, ANSYS-Analysis Structure.

1.INTRODUCTION

An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Subsonic flight airfoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with a symmetric curvature of upper and lower surfaces. Foils of similar function designed with water as the working fluid are called hydrofoils. Supersonic airfoils are much more angular in shape and can have a very sharp leading edge, which is very sensitive to angle of attack. A supercritical airfoil has its maximum thickness close to the leading edge to have a lot of length to slowly shock the supersonic flow back to subsonic speeds. Generally such transonic airfoils and also the supersonic airfoils have a low camber to reduce drag divergence. Modern aircraft wings may have different airfoil sections along the wing span, each one optimized for the conditions in each section of the wing. Cropped delta wing is a delta wing with sheared tips. Mostly cropped delta wings are used for fighter aircrafts because of high maneuverability under higher speeds and it also promotes higher fuel and weapon carrying capacity. The performance of cropped delta wing is appreciable under sub sonic speeds also, by using cropped delta wing under low speeds drag due to separation is reduced.
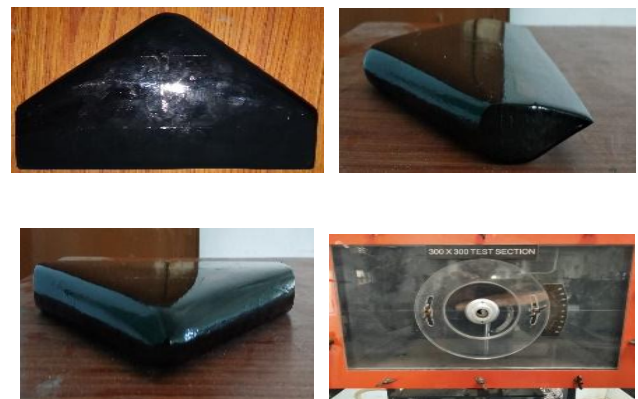
Figure 1: Top view, side view, side view and model in wind tunnel
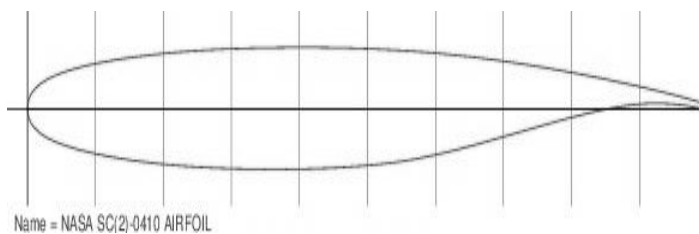
2. Super Critical Airfoil:

Employing a supercritical airfoil would alters the flow separation at the trailing edge and used to reduce the flow separation responsible for drag reduction further. Super critical airfoil contains flat upper surface which accelerates the downstream to higher speeds which reduces the induced drag.

3.NASA SC (2)-0412:

A supercritical airfoil is an airfoil designed primarily to delay the onset of wave drag in the transonic speed range. Supercritical airfoils are characterized by their flattened upper surface, highly cambered ("downward-curved") aft section, and larger leading-edge radius compared with NACA 6 series laminar airfoil shapes.

Standard wing shapes are designed to create lower pressure over the top of the wing. The camber of the wing determines how much the air accelerates around the wing. As the speed of the aircraft approaches the speed of sound the air accelerating around the wing reaches Mach 1 and shockwaves begin to form. The formation of these shockwaves causes wave drag. Supercritical airfoils are designed to minimize this effect by flattening the upper surface of the wing.

The airfoil seleed for this analysis is NASA SC (2) -0410.

Name = NASA SC(2)-0410 AIRFOIL

Figure 2: Super Critical Airfoil

3. METHODLOGY

- Scaling
- Fabrication of model
- Wind tunnel testing
- Calculation of coefficient lift, drag and side force
- Flow analysis using Ansys software

3.1. Fabrication of model

Due to the experimental constrains of wind tunnel experiments were carried out on scaled model with wing span of 25 cm, Root chord of 18cm, Tip chord of 8cmand wing area32.5cm.
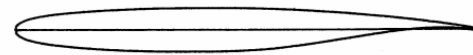
NASA SC (2)-0410
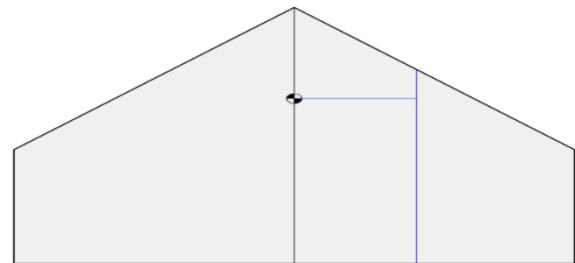
Figure 3: Delta Wing Configuration

And the model was fabricated using the wood, according to the dimensions of NASA SC (2) 0410. The model is shown in the figure3 the tests were conducted in low subsonic wind tunnel.

3.2. TESTING

The lift, drag and side forces are obtained from the wind tunnel testing and the coefficients are calculated using the formulae results are depicted in the tables.

Coefficient of lift $= \frac{2L}{\rho * V^2 * A}$

Drag coefficient $= \frac{2}{\rho * V^2 * A}$

Coefficient of side force $= \frac{2S}{\rho * V^2 * A}$

3.3. Results and Discussion:

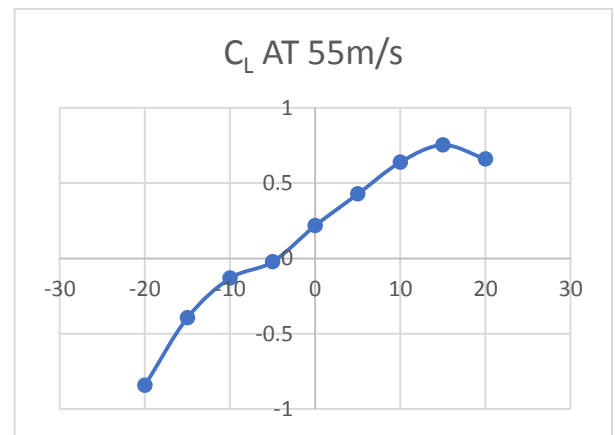| TABLE 1: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=35m/s:						
A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	-2.3	-0.9253	0.61	0.2454	0.01	0.00402
-15	-1.23	-0.4948	0.29	0.11667	0.03	0.01207
-10	-0.38	-0.1529	0.18	0.07241	0.01	0.00402
-5	-0.05	-0.0201	0.16	0.06437	-0.01	-0.004
0	0.45	0.18103	0.15	0.06034	0	0
5	1.06	0.42643	0.23	0.09253	-0.02	-0.008
10	1.54	0.61953	0.48	0.1931	-0.01	-0.004
15	1.74	0.69999	0.68	0.27356	0	0
20	1.4	0.56321	0.74	0.2977	-0.01	-0.004

TABLE 2: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=40m/s:

A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	2.89	-0.89	0.76	0.02341	0.02	0.0062
-15	-1.41	-0.434	0.33	0.1016	0.03	0.0092
-10	-0.47	-0.145	0.21	0.0647	0.01	0.0031
-5	-0.08	-0.025	0.19	0.0585	-0.01	-0.003
0	0.59	0.1817	0.2	0.0616	0	0
5	1.32	0.4066	0.25	0.077	-0.02	-0.006
10	1.91	0.5883	0.58	0.1786	-0.01	-0.003
15	2.25	0.693	0.91	0.2803	0	0
20	1.77	0.5452	0.95	0.2926	-0.01	-0.003

TABLE 3: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=45m/s:

A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	-3.74	-0.91	0.95	0.2312	0.02	0.0049
-15	-1.73	-0.421	0.42	0.1022	0.04	0.0097
-10	-0.6	-0.146	0.28	0.0681	0.01	0.0024
-5	-0.11	-0.027	0.24	0.0584	-0.01	-0.002
0	0.75	0.1825	0.24	0.0584	0	0
5	1.74	0.4235	0.32	0.0779	-0.03	-0.007
10	2.47	0.6011	0.77	0.1874	-0.02	-0.005
15	2.71	0.6595	1.1	0.2677	0	0
20	2.36	0.5743	1.23	0.2993	-0.01	-0.002

TABLE 4: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=50m/s:

A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	-4.96	-0.978	1.09	0.2149	0.04	0.0079
-15	-2.02	-0.398	0.5	0.0986	0.04	0.0079
-10	-0.71	-0.14	0.34	0.067	0.01	0.002
-5	-0.13	-0.026	0.29	0.0572	-0.01	-0.002
0	0.95	0.1873	0.29	0.0572	0	0
5	2.14	0.4218	0.37	0.0729	-0.03	-0.006
10	3.14	0.619	0.97	0.1912	-0.03	-0.006
15	3.51	0.6919	1.37	0.2701	0.02	0.0039
20	3.03	0.5973	1.58	0.3115	-0.02	-0.004

TABLE 5: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=55m/s:

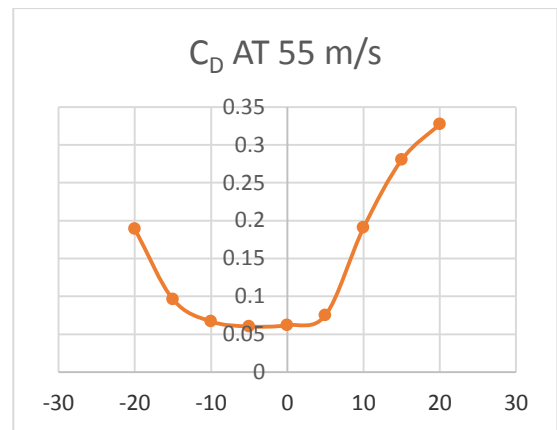| A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	-5.18	-0.84389	1.16	0.189	0.06	0.0098
-15	-2.42	-0.39425	0.59	0.0961	0.04	0.0065
-10	-0.81	-0.13196	0.41	0.0668	0.01	0.0016
-5	-0.14	-0.02281	0.37	0.0603	-0.01	-0.002
0	1.33	0.21667	0.38	0.0619	-0.02	-0.003
5	2.62	0.42683	0.46	0.0749	-0.03	-0.005
10	3.92	0.63862	1.17	0.1906	-0.04	-0.007
15	4.62	0.75266	1.72	0.2802	-0.01	-0.002
20	4.05	0.6598	2.01	0.3275	-0.02	-0.003

TABLE 6: ANALYTICAL RESULTS FOR THE FLOW VELOCITY V=60m/s:

A	LIFT	Cl	DRAG	Cd	SIDE	Cs
-20	-0.89	-0.122	0.46	-0.002	0.01	0.0013
-15	-0.89	-0.122	0.46	-0.017	0.01	0.0014
-10	-0.89	-0.122	0.46	-0.017	0.01	0.0014
-5	-0.14	-0.019	0.42	0.003	-0.02	-0.003
0	1.57	0.214	0.43	0.0294	-0.02	-0.003
5	4.08	0.558	0.87	0.0765	-0.22	-0.03
10	4.9	0.670	1.46	0.0918	-0.14	-0.019
15	5.67	0.776	2.07	0.1063	-0.1	-0.014
20	5.23	0.715	2.52	0.098	-0.02	-0.003

Lift coefficient

C_L AT 35m/s

C_L AT 50 m/s

C_L AT 40m/s

C_L AT 55m/s

C_L AT 45M/S

C_L AT 60 m/s
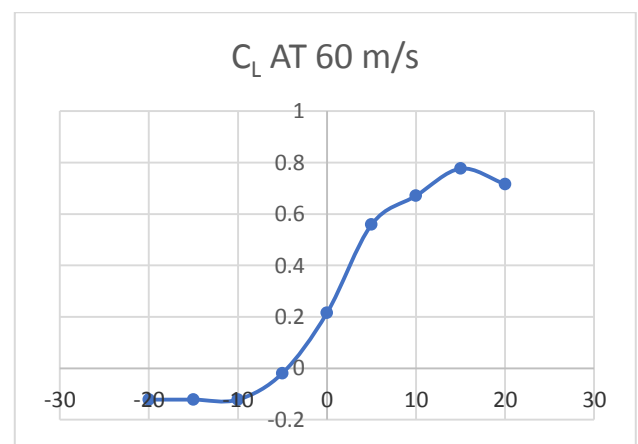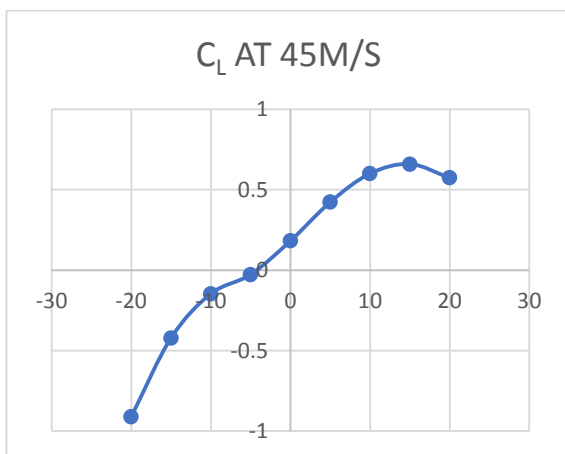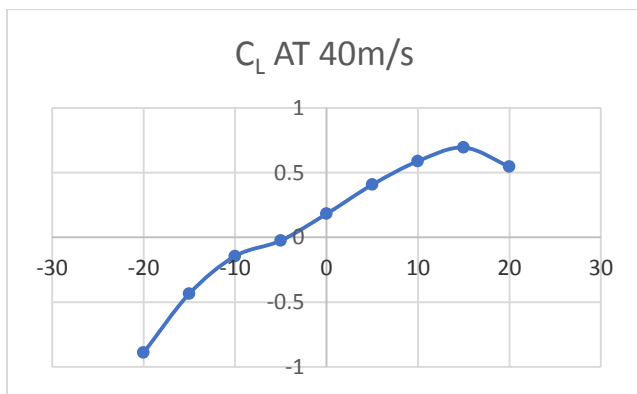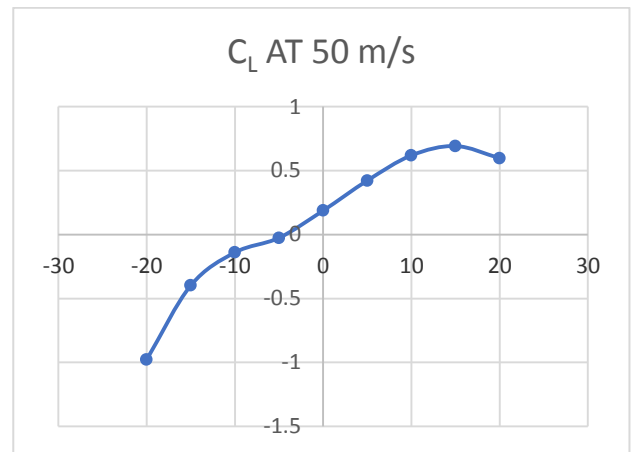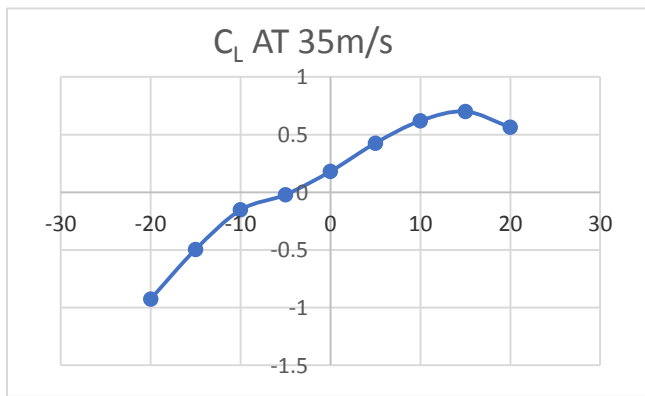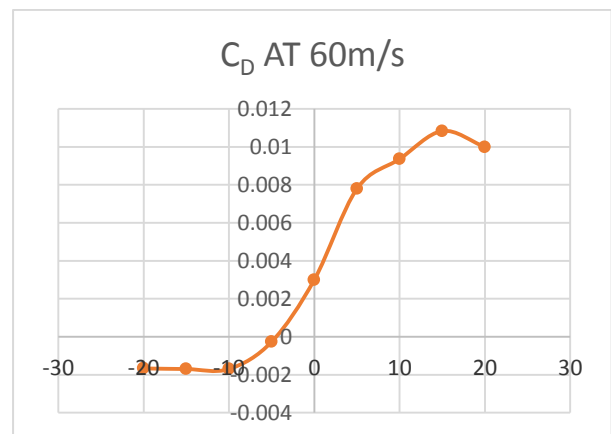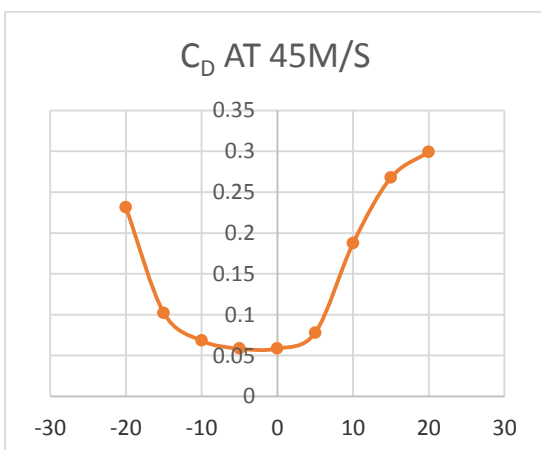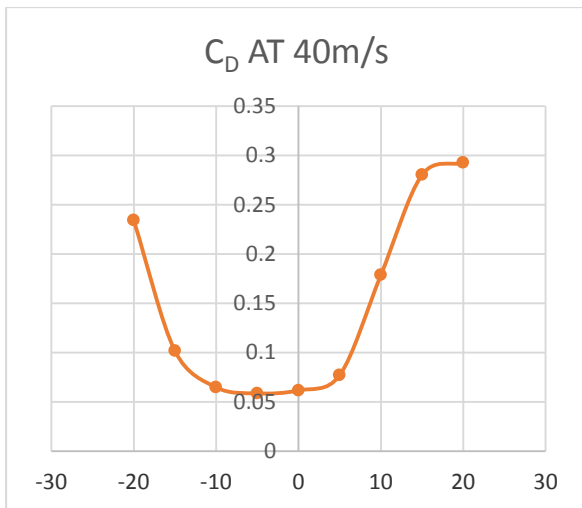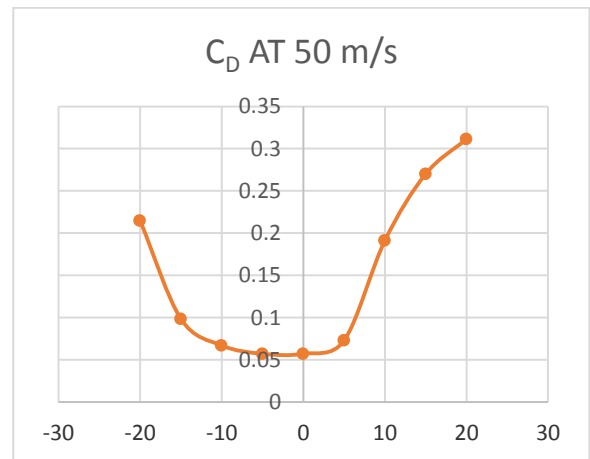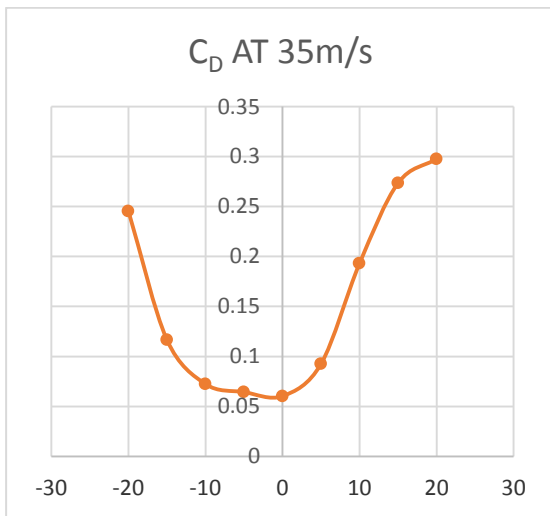
Drag coefficient

Side coefficient
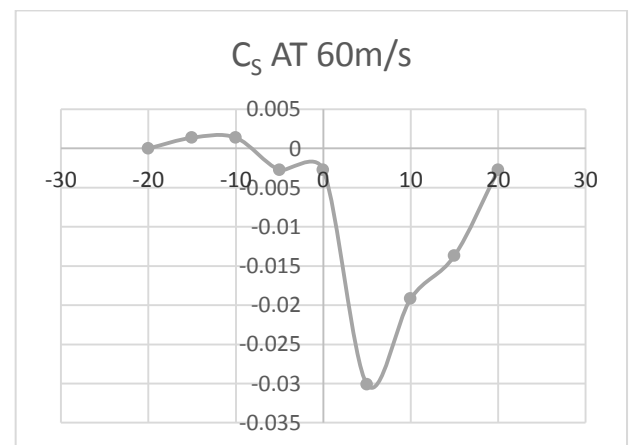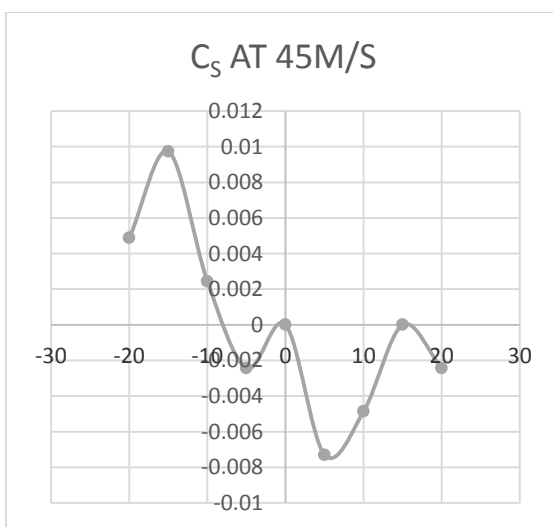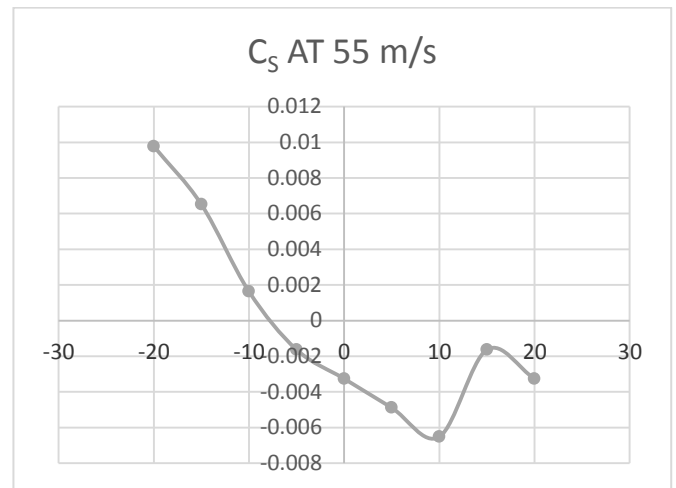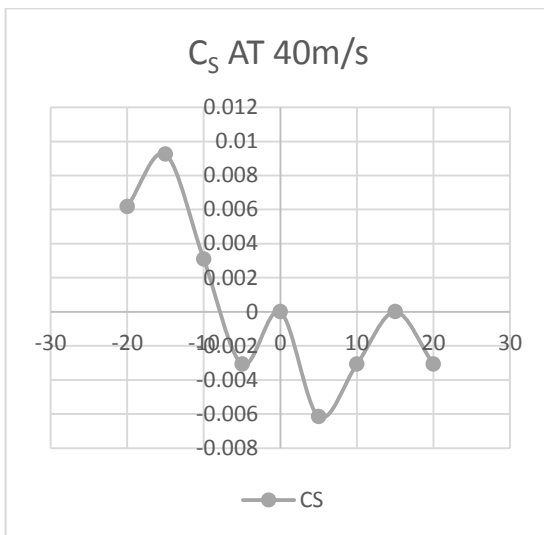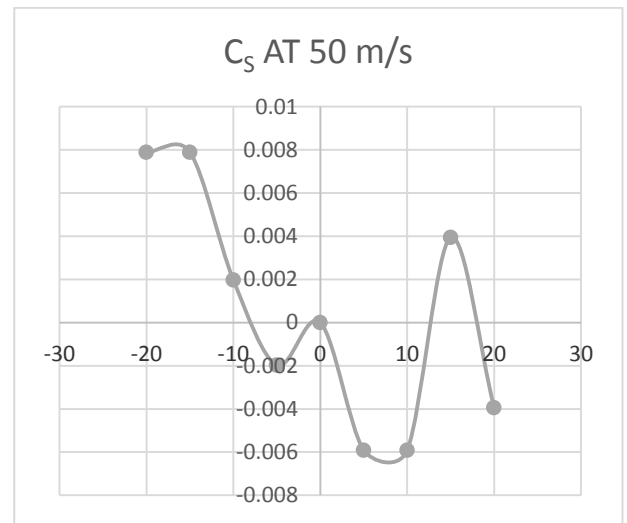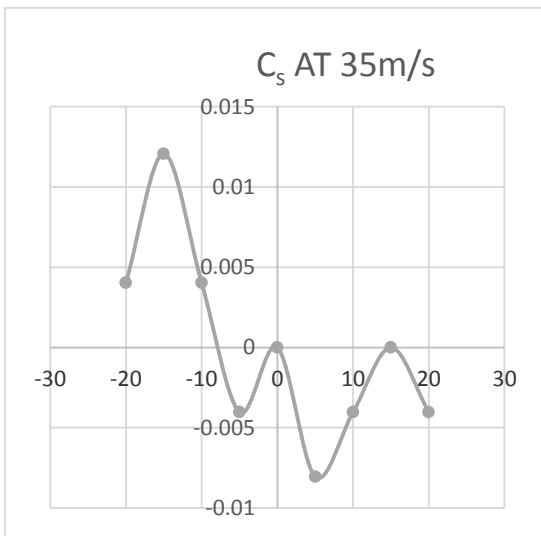
Coefficient of lift, drag and side force

C_D AT VARIOUS VELOCITIES

- CD AT 35M/S
- CD AT 40M/S
- CD AT 45M/S
- CD AT 50M/S
- CD AT 55M/S
- CD AT 60M/S

C_S AT VARIOUS VELOCITIES

- CS AT 35M/S
- CS AT 40M/S
- CS AT 45M/S
- CS AT 50M/S
- CS AT 55M/S
- CS AT 60M/S
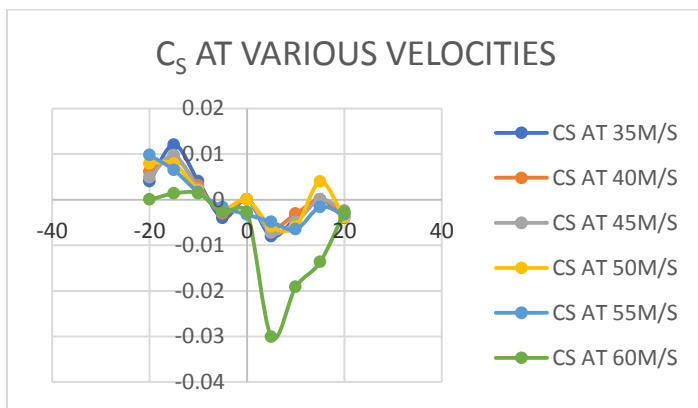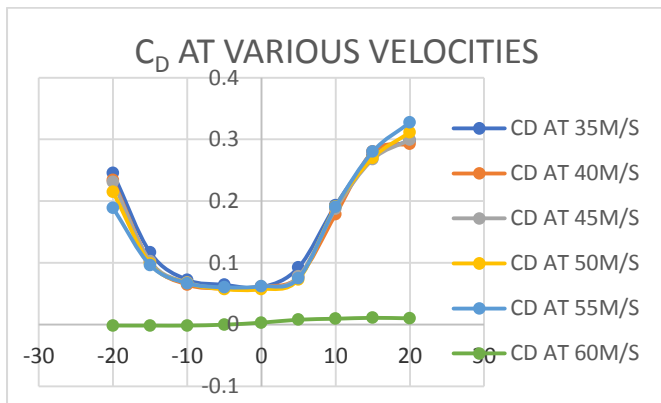
For all the wings the lift increases linearly with angle of attack and speed. But from the plots the lift decreases drastically at an angle of attack 15 degrees. So, the angle of stalling exists at 15 degrees with maximum lift coefficient 0.8. The performance of a cropped delta wing is quite appreciable, and the max drag obtained is 0.12. There is no effect of side forces observed

3.4. Flow Analysis using Ansys

The aim of this research is to analyze the behavior of the air flow at the internal cavity of the NASA SC (2)-0410 airfoil and predict possible zones of flow separation at the suction surface of this airfoil. A two-dimensional numerical simulation by using CFD will be performed to obtain velocity fields, pressure fields, temperature, density and streamlines of the flow. ANSYS workbench is the numerical type of engineering problem solving software. Used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. Air foil geometry of NASA SC (2)-0410 is derived from the CSV file of coordinates. These coordinates of the respective airfoil are imported to the ANSYS FLUID FLOW (FLUENT)
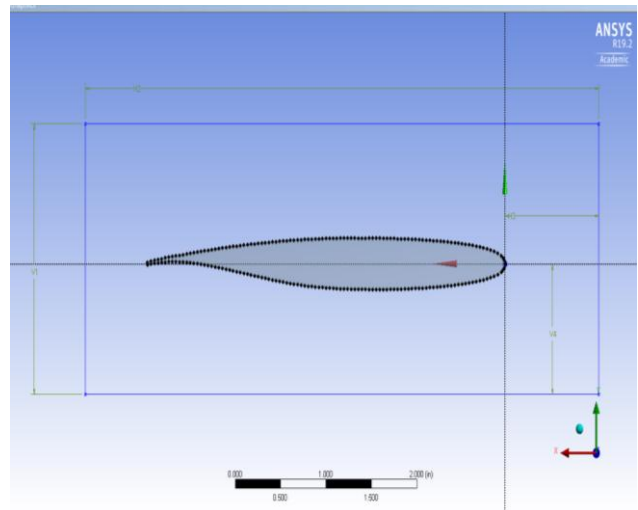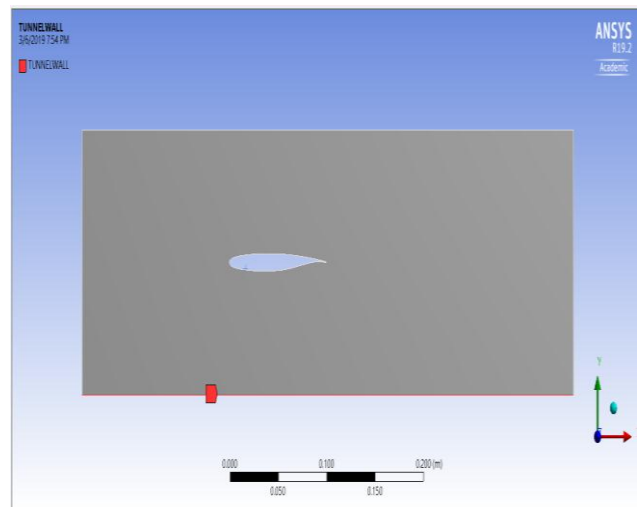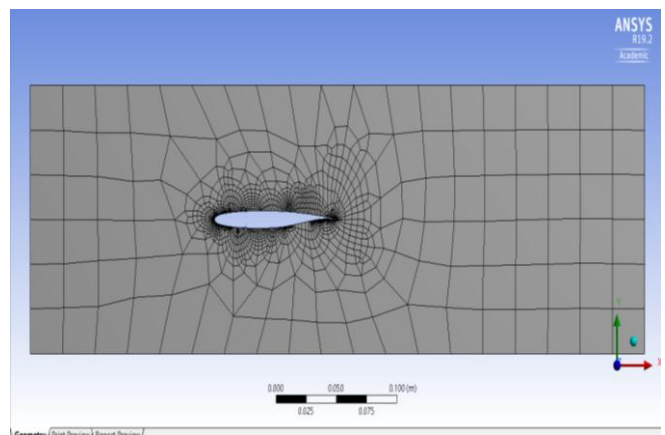

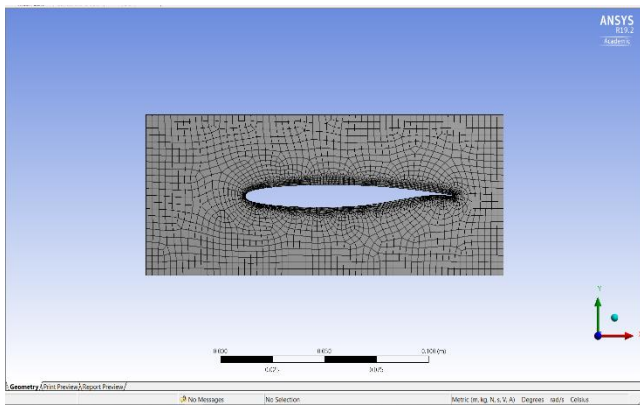**Figure 4. Generation of all keypoints and edges of airfoil**

Figure 5. Mesh Generation

The first phase 'Geometry' is to import the coordinates of the airfoil into the ANSYS Fluid Flow and to generate the airfoil. The new Geometry is opened, and the points are created respectively. The coordinates are imported from the coordinates file and the coordinates units are changed to Millimeters. The airfoil is generated successfully as shown in figure4.The outline of the airfoil which is formed in the Geometry process is appeared in this section. Here the four sides of the rectangle are named. The left side of the rectangle is named as the inlet. The right side of the rectangle is named as outlet. The upper and lower sides are named as the Tunnel Wall. The airfoil outline is selected and named as the airfoil wall as depicted in the figure5.
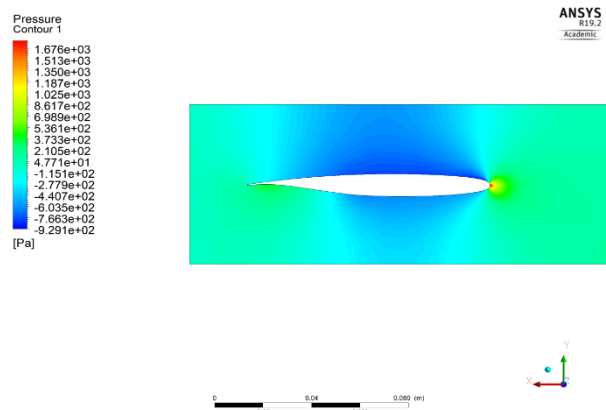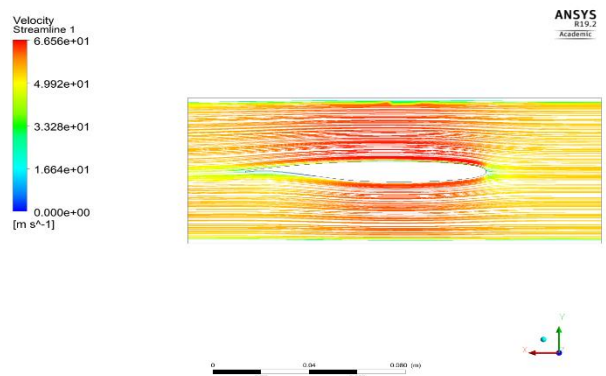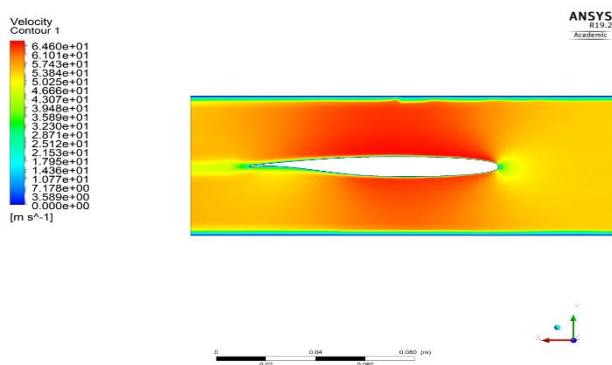

Figure 6: Velocity contour

figure 7. pressure contour
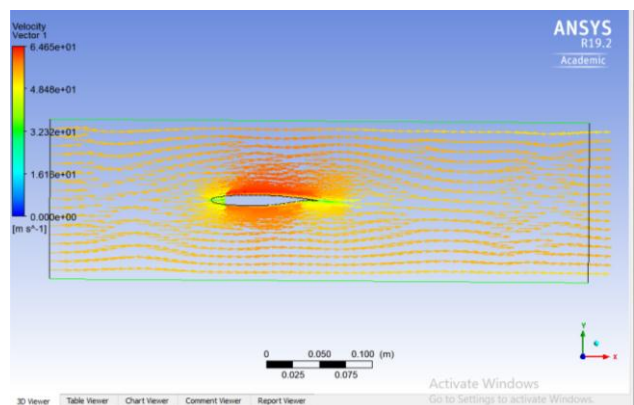

Figure 8: Streamlines
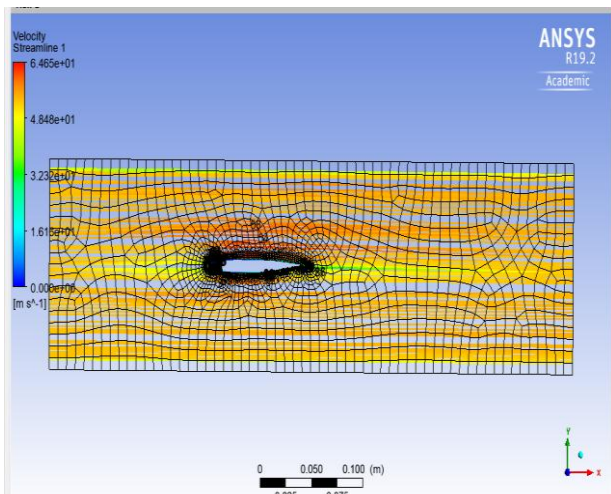

Figure 9: Tunnel Wall

Figure10: Mesh view of streamlines
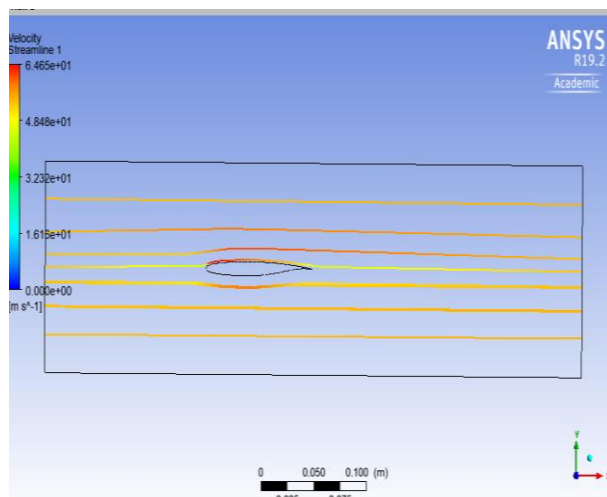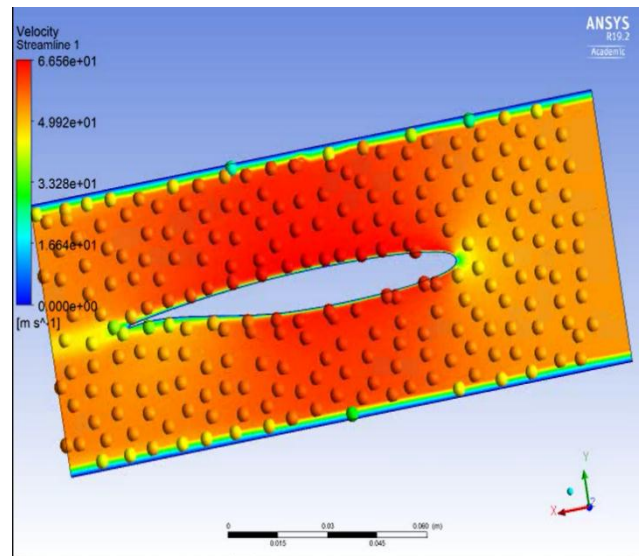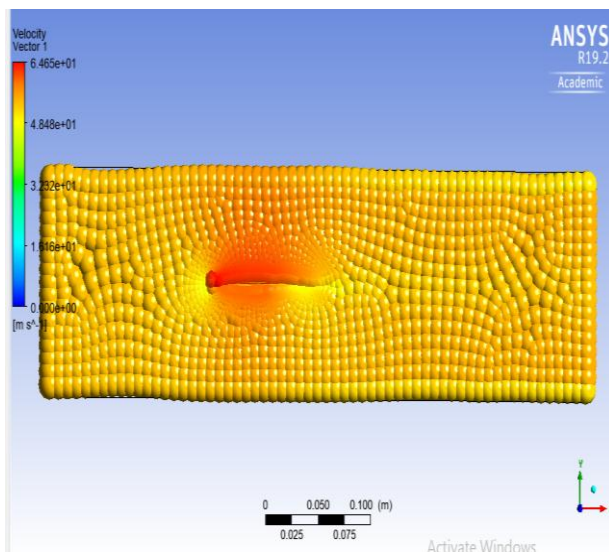

Figure11: Streamlines at 10contour points

Figure 12:   Velocity in Ball Streamlines

4.Conclusion:

The lift of the airfoil increases linearly with angle of attack and speed. But from the plots, the lift decreases drastically at an angle of attack of 15 degrees. So, the stall angle exists at 15 degrees with maximum coefficient of lift 0.92.

According to experimentation and computational analysis the performance of a cropped delta wing is quite appreciable, and the maximum drag obtained is 0.2, since there is no effect of side forces observed. The maximum lift on the cropped delta wing under the supersonic flow and subsonic flow are similar at 15 degrees angle of attack.

There is a possibility of using cropped delta wings for civil aircrafts, that having higher maneuverability at lower speeds. The velocity fields, pressure fields, temperature, density and streamlines of the flow and graphs have been plotted, and the flow patterns are captured necessarily.

5.Future work:

❖ Since the results presented in this work for lift calculation are only through basic formulae which only depend on are of the delta wing, a flow analysis could be done in order to determine the lift-off performances, vortices reduction.

❖ The pressure distribution can be done by using the pressure tapings.

❖ The distribution of laminar and turbulent flow in the boundary layer of a delta wing is difficult to resolve experimentally and to predict computationally even for sharp-edged wing.

❖ Pressure distribution on delta wing should be done and a finite element analysis could be performed to calculate structural integrity using Finite Element Analysis tools like ANSYS or CATIA.

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