Pressure Distribution over an Aerofoil

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1. Aim :-

The objectives of the experiment are to examine the surface pressure distribution and to compute the :

(i) To measure Coefficient of Pressure distribution.

(ii) To find the Coefficient of Lift of the airfoil E-340.

A stationary airfoil mounted in the test section of a wind tunnel. The airfoil being considered is positive cambered and assumed to be of an infinite wing ,hence tip effects are neglected.

2. Introduction :-

When a body is immersedd in a fluid (here air), it is exposed to various kinds of force.

a. Lift : - The sum of forces that act normal to the free-stream direction is clled Lift.

b. Drag:- The sum that acts parallel to the free-stream direction is called Drag.

The geometric and dynamic characteristics of airfoils are shown in Figure 1.

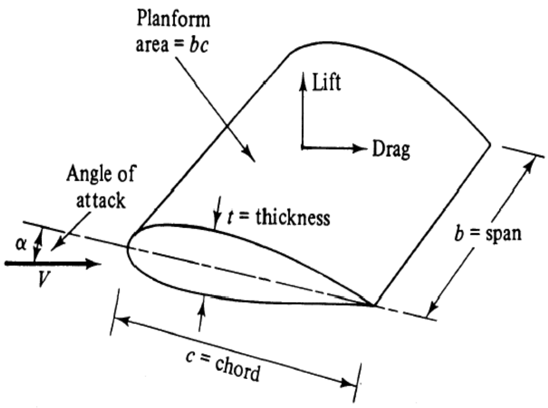
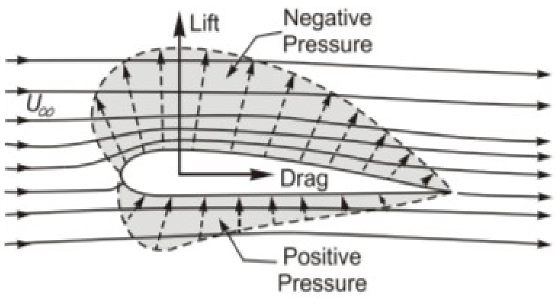


Figure 1. Geometric and dynamic parameters of airfoils

c. Pressure Difference between upper and lower surfaces :-

As free stream velocity move through the airfoil, there will be pressure difference between the upper surface and bottom surface.

“ The upper surface has lower pressure than lower surface, thus producing lift force. ”



d. Pressure Transducer :-

In the below experiment, pressure was measured with **DSA-3217**. Since, it is an electronic device, it provides greater accuracy than mechanical devices like manometer.

How it works :-

The basic function of a transducer is to convert energy in one form to another. In this case, pressure energy to change in voltage. This can be done either by using piezoelectric materials or by changing resistance of one of the wires in a wheat stone bridge during the application of pressure and hence changing the voltage difference.

This is called a **strain gauge**. Strain gauge is a sensor whose resistance varies with applied force. The signal received from this setup was then amplified and values noted using a data acquisition system. Pressure was measured at different points across the airfoil using automated data acquisition system.

3. Theory :-

a. Coefficient of Pressure (C_p):-

The pressure distribution on the airfoil is expressed in dimensionless form by the pressure coefficient C_P which describes the relative pressures throughout a flow field in fluid dynamics, Every point in a fluid flow field has its own unique pressure coefficient.

$$C_P = \frac{P - P_\infty}{\frac{1}{2}\rho V_\infty^{\ 2}}$$

From Bernoulli’s equation

$$P_0 = P_\infty - \frac{1}{2}\rho V_\infty^{\ 2}$$

Therefore , we get

$$C_P = \frac{P - P_\infty}{P_0 - P_\infty}$$

where V_∞ - free-stream velocity of fluid

P_0 - total pressure from settling chamber

P_∞ - free-stream pressure from inlet section p - Pressure at a point on the circular cylinder surfaace

ρ - Density of fluid

Assumptions:-

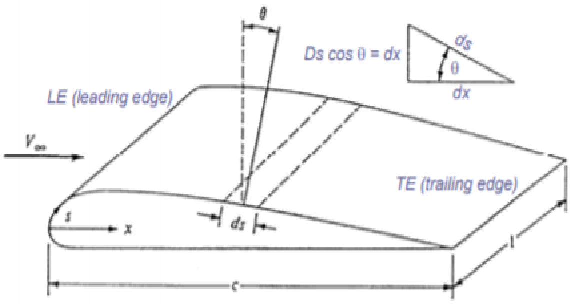
The relationship is valid for the flow of incompressible fluids only. As variations in speed and pressure are small enough to make the fluid density negligible.

"Fluid is considered incompressible if the Mach Number is less than 0.3"

b. Coefficient of lift (C_l):-

The lift coefficient relates the lift generated by a lifting body to the fluid density around the body,, the fluid velocity and an associated reference area.

$$C_l = \frac{L}{\frac{1}{2}\rho V_\infty^2 S} = \frac{L}{q_\infty S}$$



$$C_l = \frac{1}{c}\int_0^c \left(C_{p,l} - C_{p,u}\right) dx$$

S – Wing Planform area

x – Distance of pressure port from leading edge

C_{pl}– Cp lower surface

C_{pu} – Cp upper surface

4. Procedure :-

1. We placed the airfoil inside the test section of the wind tunnel with an Angle of attack -3 degree.

2. Set the signal conditioning amplifier at 0mv to avoid the error and start the tunnel.

3. For this AOA the corresponding differential pressure at the lower and upper surface are noted.

4. Above Steps are repeated for AOA 0,5,10,15 degrees.

5. Finally the positions of Pressure ports on the airfoil surface are noted along with the chord length.

5. Observations & Calculations:-

Reynolds number =154737

V∞ =17.077m/s

Chord = 150 mm

a. At Angle of Attack (-3^0):-

Sl.No.	x/c	P-P∞ (Pa)	P0-P∞ (Pa)	Cp
1	0	56.85	175.05	0.325
2	0.08	184.47	175.05	1.054
3	0.15	-164.02	175.05	-0.937
4	0.26	-144.8	175.05	-0.827
5	0.33	-147.4	175.05	-0.842
6	0.41	-146.13	175.05	-0.835
7	0.53	-142.51	175.05	-0.814
8	0.59	-133.79	175.05	-0.764
9	0.67	-122.75	175.05	-0.701
10	0.73	-110.46	175.05	-0.631
11	0.83	-86.69	175.05	-0.495
12	0.88	-60.06	175.05	-0.343
13	0.02	122.32	175.05	0.699
14	0.12	-81.39	175.05	-0.465
15	0.25	-140.95	175.05	-0.805
16	0.37	-123.47	175.05	-0.705
17	0.49	189.45	175.05	1.082
18	0.62	-78.09	175.05	-0.446
19	0.71	-46.24	175.05	-0.264
20	0.86	-37.17	175.05	-0.212

b. At Angle of Attack (0^0):-

Sl.No.	x/c	P-P∞ (Pa)	P0-P∞ (Pa)	Cp
1	0	164.535	169.008	0.974
2	0.08	178.018	169.008	1.053
3	0.15	-87.213	169.008	-0.516
4	0.26	-88.786	169.008	-0.525
5	0.33	-97.656	169.008	-0.578
6	0.41	-103.805	169.008	-0.614
7	0.53	-102.545	169.008	-0.607
8	0.59	-103.593	169.008	-0.613
9	0.67	-84.755	169.008	-0.501
10	0.73	-76.971	169.008	-0.455
11	0.83	-73.731	169.008	-0.436
12	0.88	-73.421	169.008	-0.434
13	0.02	37.539	169.008	0.222
14	0.12	-164.837	169.008	-0.975
15	0.25	-185.807	169.008	-1.099
16	0.37	-152.591	169.008	-0.903
17	0.49	186.229	169.008	1.102
18	0.62	-76.65	169.008	-0.454
19	0.71	-59.41	169.008	-0.352
20	0.86	-49.002	169.008	-0.29

c. At Angle of Attack (5^0):-

Sl.No.	x/c	P-P∞ (Pa)	P0-P∞ (Pa)	Cp
1	0	52.081	160.849	0.324
2	0.08	169.701	160.849	1.055
3	0.15	-7.158	160.849	-0.045
4	0.26	-25.55	160.849	-0.159
5	0.33	-44.542	160.849	-0.277
6	0.41	-56.621	160.849	-0.352
7	0.53	-64.371	160.849	-0.4
8	0.59	-66.766	160.849	-0.415
9	0.67	-61.89	160.849	-0.385
10	0.73	-55.693	160.849	-0.346
11	0.83	-46.626	160.849	-0.29
12	0.88	-44.892	160.849	-0.279
13	0.02	-257.846	160.849	-1.603
14	0.12	-275.803	160.849	-1.715
15	0.25	-264.629	160.849	-1.645
16	0.37	-223.348	160.849	-1.389
17	0.49	171.734	160.849	1.068
18	0.62	-106.99	160.849	-0.665
19	0.71	-83.727	160.849	-0.521
20	0.86	-65.913	160.849	-0.41

d. At Angle of Attack (10^0):-

Sl.No.	x/c	P-P∞ (Pa)	P0-P∞ (Pa)	Cp
1	0	-287.42	158.809	-1.81
2	0.08	167.512	158.809	1.055
3	0.15	38.944	158.809	0.245
4	0.26	9.598	158.809	0.06
5	0.33	-16.684	158.809	-0.105
6	0.41	-35.071	158.809	-0.221
7	0.53	-51.647	158.809	-0.325
8	0.59	-61.228	158.809	-0.386
9	0.67	-70.274	158.809	-0.443
10	0.73	-78.685	158.809	-0.495
11	0.83	-79.629	158.809	-0.501
12	0.88	-70.235	158.809	-0.442
13	0.02	-585.156	158.809	-3.685
14	0.12	-344.314	158.809	-2.168
15	0.25	-299.904	158.809	-1.888
16	0.37	-206.461	158.809	-1.3
17	0.49	145.088	158.809	0.914
18	0.62	-93.417	158.809	-0.588
19	0.71	-78.529	158.809	-0.494
20	0.86	-70.133	158.809	-0.442

e. At Angle of Attack (15^0):-

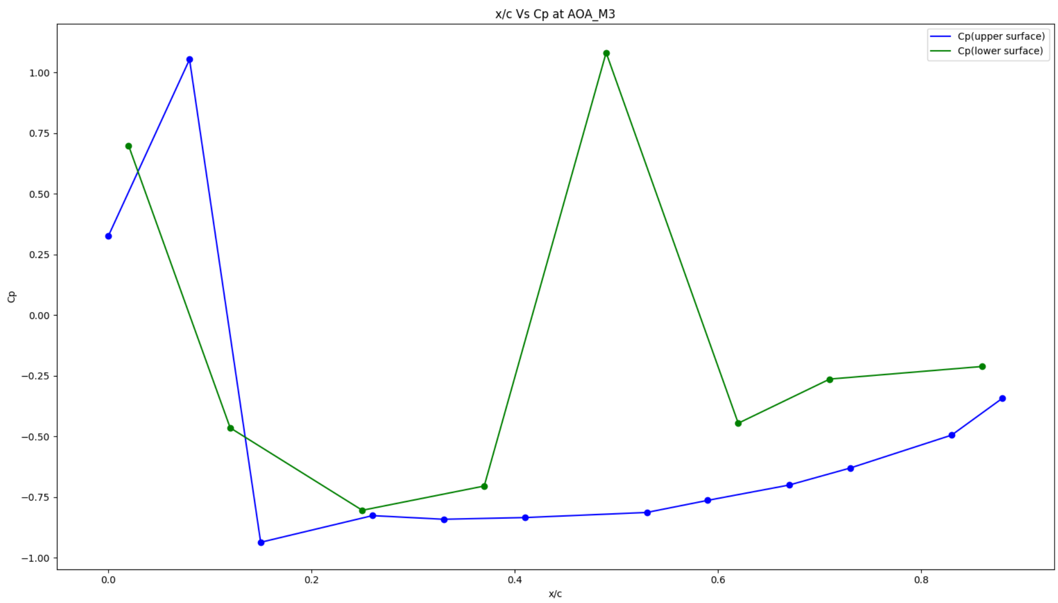
Sl.No.	x/c	P-P∞ (Pa)	P0-P∞ (Pa)	Cp
1	0	-322.1133845	159.392	-2.021
2	0.08	168.241772	159.392	1.056
3	0.15	54.023864	159.392	0.339
4	0.26	20.15530625	159.392	0.126
5	0.33	-11.17376025	159.392	-0.07
6	0.41	-34.50788975	159.392	-0.216
7	0.53	-57.48503475	159.392	-0.361
8	0.59	-78.74252325	159.392	-0.494
9	0.67	-91.005417	159.392	-0.571
10	0.73	-108.38793375	159.392	-0.68
11	0.83	-122.6036285	159.392	-0.769
12	0.88	-117.154291	159.392	-0.735
13	0.02	-521.8382875	159.392	-3.274
14	0.12	-281.07275775	159.392	-1.763
15	0.25	-207.87128075	159.392	-1.304
16	0.37	-188.695793	159.392	-1.184
17	0.49	149.04144675	159.392	0.935
18	0.62	-176.773777	159.392	-1.109
19	0.71	-167.800659	159.392	-1.053
20	0.86	-154.07875825	159.392	-0.967

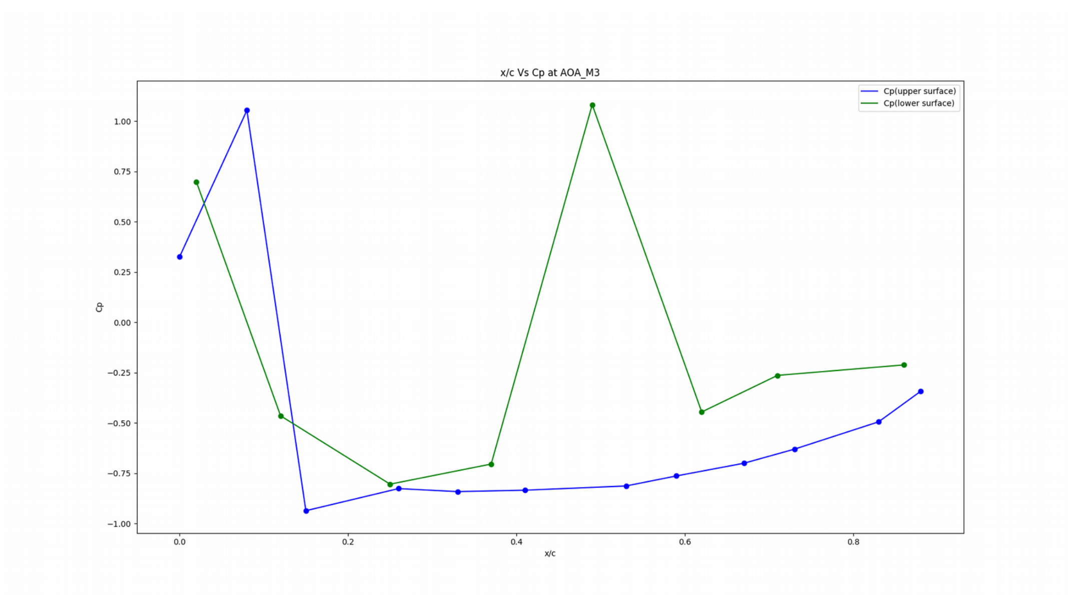
f. Angle of Attack and corresponding Coefficient of Lift :-

AOA	CL
-3	-0.3242
0	0.0191
5	0.5214
10	0.6466
15	0.6003

6. Plots and Figures :-

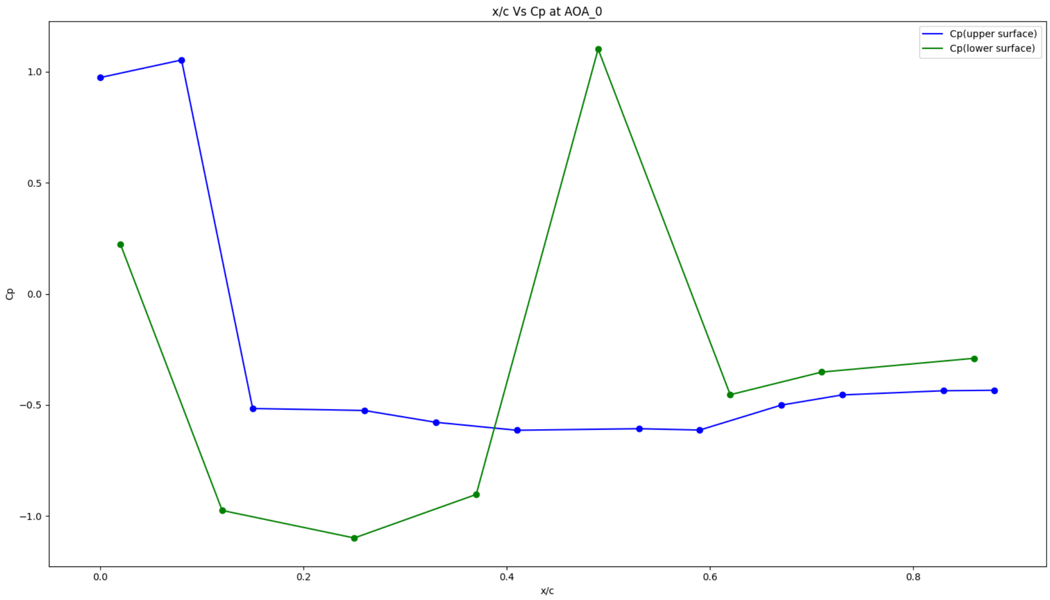
Profile Section



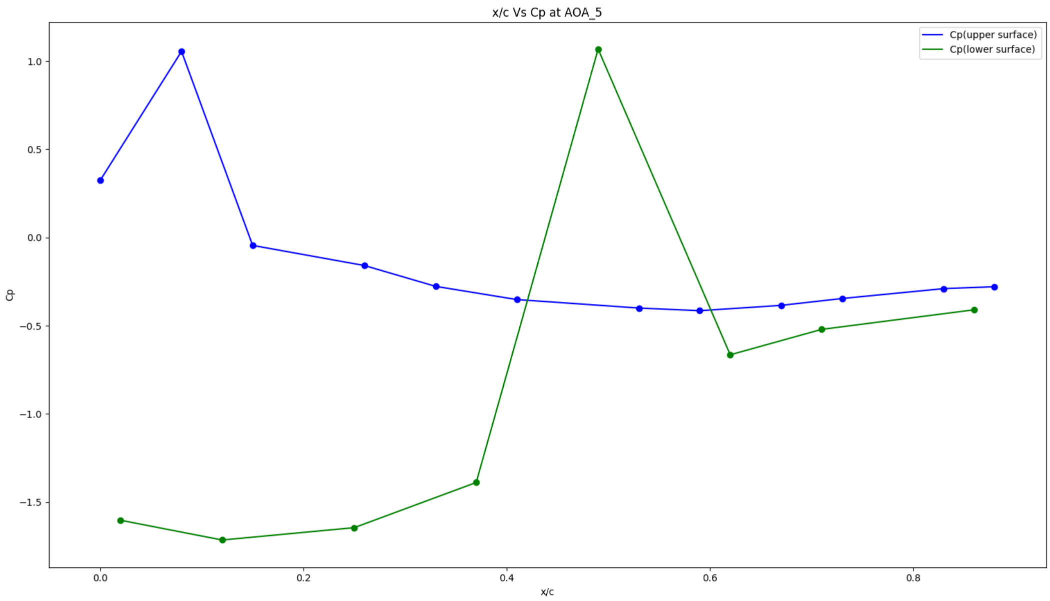


x/c Vs C_p at Angle of Attack at -3^0

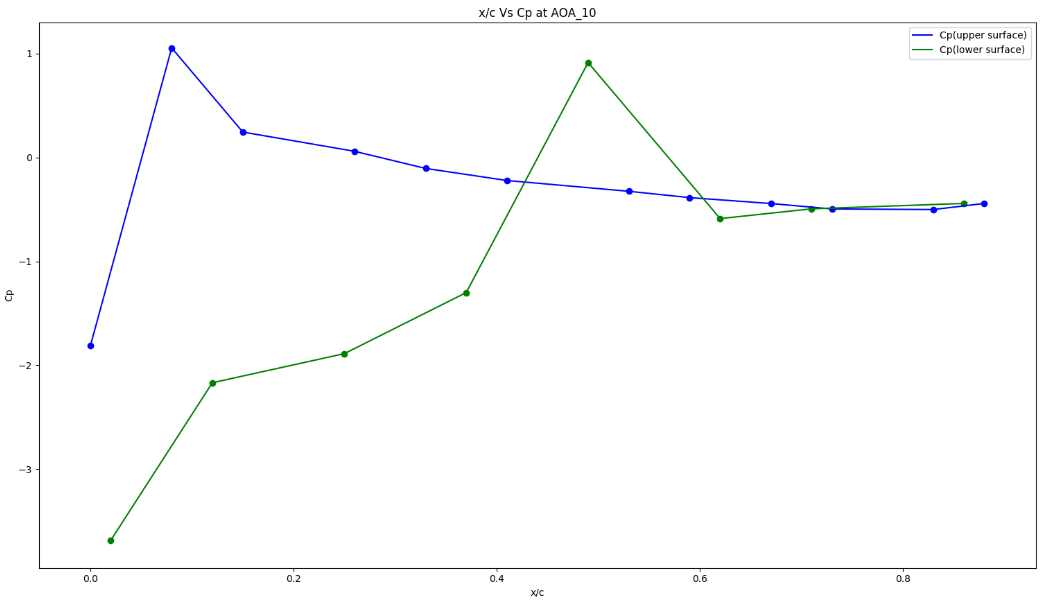
x/c Vs C_p at Angle of Attack at 0^0



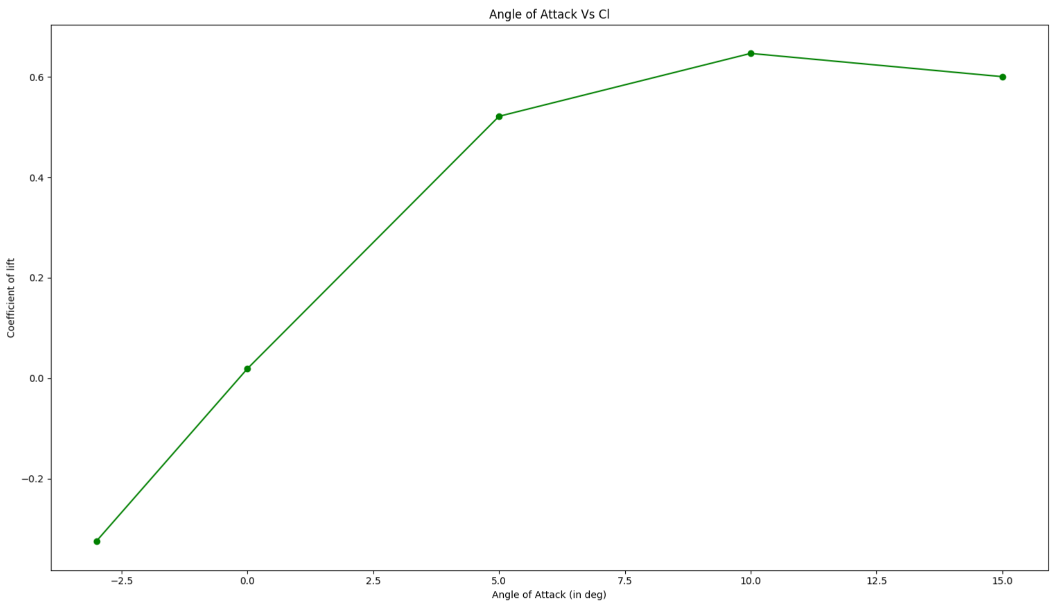
x/c Vs C_p at Angle of Attack at 5^0



x/c Vs C_p at Angle of Attack at 10^0



x/c Vs C_p at Angle of Attack at 15^0



7. Discussions:-

a. **Wind Tunnel :-**

An open circuit suction type wind tunnel is used in the experiment. It incorporates an air-inlet, a square cross section settling chamber fitted with a honeycomb meshes, a contraction section, followed by the test section and the diffuser. An axial fan is located at the end of the diffuser. The maximum speed achievable in the test section is 35 m/s.

b. **Working of DSA 3217:-**

DSA 3217 incorporates 16 temperature compensated piezoresistive pressure sensors with pneumatic calibration valve, microprocessor, RAM and 16 bit A/D converter. The amount of resistance of these piezoresistive elements to stress or load at any time indicates the pressure acting on the sensor. However the resistance exhibited by these elements and its sensitivity to stress or load depends on the temperature which is compensated by the inbuilt microprocessor. These microprocessors also control the actuation of internal calibration valve to perform online zero or multi point calibration. In addition to the microprocessor does the engineering unit conversion where the pressure data output is interfaced via Ethernet using TCP/IP protocol.

c. **Aerodynamic Properties of E340:-**

Eppler E340 flying wing airfoil has a maximum thickness of 13.7% at 28.8% chord. The max camber is 2.6% at 19.7% chord.

d. **Variation of C_p with α :-**

From the observations made through plots, we can say that as angle of attack increases, the coefficeints of both upper and lower surfaces of the airfoil increase near the leading edge. Other observations include :

i) No stagnation point : For negative and zero angle of attack

ii) Stagnation point appears on the upper surface near the leading edge as Angle of Attack becomes positive.($C_p = 1$).

iii) As angle of attack goes to 15^0, the stagnation point moves to lower surface.

iv) For α=150 , Cp of the upper surface maintains a nearly constant value for x/c>.374, indicating that for x/c>.374,the flow is separating from the air-foil surface and a wake region is being formed(in the wake region the pressure remains nearly constant).