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Spoiler Analysis and Wind Tunnel Experiment

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Abstract
As in today's world the use of petroleum products is increasing, it leads to more pollution and degradation of our environment. This work will investigate the result of an experimental study carried out to determine the performance of a car spoiler (inverted aerofoil) and study the pressure difference produced by it and also prove the transit theory of pressure difference over an aerofoil. It is used widely in formula racing cars. The various angles of attack and there effects on pressure differences will be measured. The performance parameters are to be investigated and observed.

Index Terms**:** Wind tunnel experiment, spoiler, airfoil, transit theory, computational fluid dynamics, ansys

I. INTRODUCTION:

As in today's world the use of petroleum products is increasing, it leads to more pollution and degradation of our environment. This work will investigate the result of an experimental study carried out to determine the performance of a car spoiler (inverted aerofoil) and study the pressure difference produced by it and also prove the transit theory of pressure difference over an aerofoil. It is used widely in formula racing cars. The various angles of attack and there effects on pressure differences will be measured. The performance parameters are to be investigated and observed.

CROSS SECTION OF A SPOILER (INVERTED AIR FOIL)

II. METHODOLOGY AND EXPERIMENT:

Wind tunnel experiment was carried out under subsonic conditions with an air velocity of 16 kmph. The following shows the experimental setup and the use of anemometer.

The next figure shows the experimental setup. We used 11 different pressure points on the aerofoil (inverted spoiler). Each of them connected to piezometer for the measurement of positive and negative pressure.

To start, we set the aerofoil at 0°. Further, we found out the pressures at different pressure points by acknowledging the height differences in manometer. We also carried out experiment using a smoke generator to see the exact streamlines of air around the aerofoil.
From the pressure we could derive the forces and pressure graph. We repeated the same procedure for 5°, 10° and 15°.

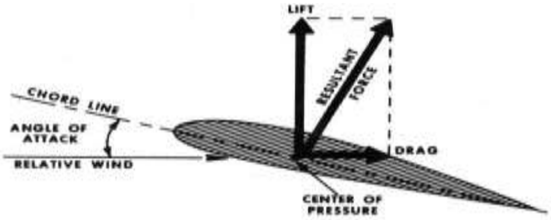
III. CALCULATIONS:

- Gauge Pressure Calculation = $\rho*g*\Delta h$ N/m²

- Absolute pressure Calculation = Atmospheric pressure + gauge pressure
  = 101325 N/m² + $\rho*g*\Delta h$ N/m²

- Force ($F_{1,2,3}$…) = Absolute pressure N/m² * Area($A_{1,2,3}$…) N

- Net Force F_N = Resultant of forces $F_{1,2,3}$…….N.



(***Resultant force –direction***)

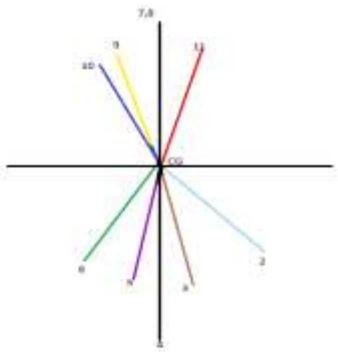
• Drag force (Fh) = $F_1\cos\theta_1 - F_2\cos\theta_2 - F_3\cos\theta_3 + F_4\cos\theta_4 + F_5\cos\theta_5 + F_6\cos\theta_6 + F_7\cos\theta_7 + F_8\cos\theta_8 - F_9\cos\theta_9 - F_{10}\cos\theta_{10} + F_{11}\cos\theta_{11}$

• Lift force (Fv) = $-F_1\sin\theta_1 + F_2\sin\theta_2 + F_3\sin\theta_3 + F_4\sin\theta_4 + F_5\sin\theta_5 + F_6\sin\theta_6 + F_7\sin\theta_7 + F_8\sin\theta_8 + F_9\sin\theta_9 + F_{10}\sin\theta_{10} + F_{11}\sin\theta_{11}$

Resultant force (F_R)(N) = sqrt(Fh² + Fv²)

$\tan\theta = Fv / Fh$

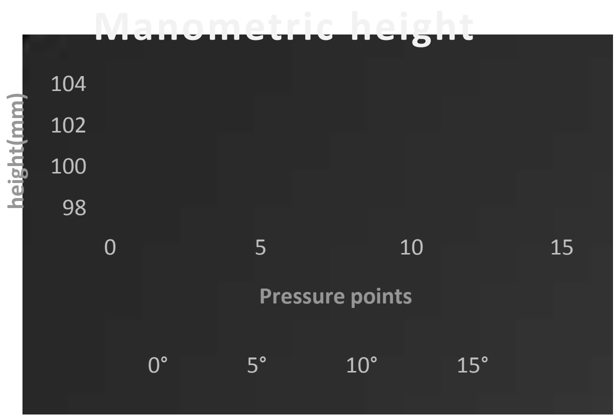
Pressure points	1	2	3	4	5	6	7	8	9	10	11
Angles(point forces)°	0	60	84	90	83	66	90	90	83	78	86



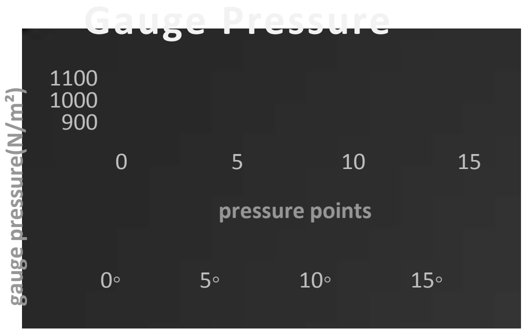
Pressure points wrt. Center of gravity

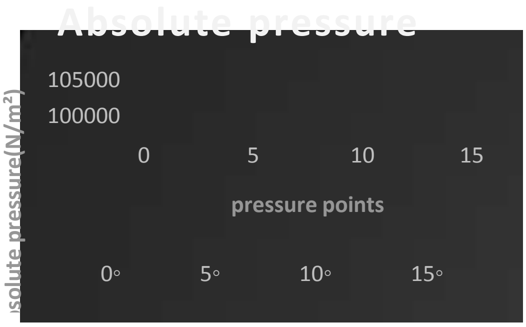
IV. ANALYTICAL RESULTS:

Pressure points	Manometric heights(mm)			
	0°	5°	10°	15°
1	101	101.5	102	102.5
2	102.1	102.3	102.5	102.5
3	102.2	102.4	102.7	102.7
4	102	102.1	102.5	102.5
5	103.5	103.4	103	103
6	102	102	102	102.3
7	98.5	98.7	99.5	99.6
8	99.5	99.5	99.8	99.8
9	100	98.8	100	99.9
10	100	98.8	100	99.9
11	99.5	99.4	99.5	99.9



Pressure points	Manometric pressure (ρgΔh)(N/m²)			
	0°	5°	10°	15°
1	-989.8	-994.7	-999.6	-1004.5
2	-1000.58	-1002.54	-1004.5	-1004.5
3	-1001.56	-1003.52	-1006.46	-1006.46
4	-999.6	-1000.58	-1004.5	-1004.5
5	-1014.3	-1013.32	-1009.4	-1009.4
6	-999.6	-999.6	-999.6	-1002.54
7	965.3	967.26	975.1	976.08
8	975.1	975.1	978.04	978.04
9	980	968.24	980	979.02
10	980	968.24	980	979.02
11	975.1	974.12	975.1	979.02





V. FINAL FORCE RESULT TABLE:

Angle of attach α	Drag force (F_H)(N)	Lift force (F_V)(N)	Resultant force (F_R)(N)	Resultant angle (θ)
0°	380.169	4539.16	4555.05	85.21
5°	773.835	4487.64	4553.879	80.216
10°	1155.97	4404.06	4553.24	75.29
15°	1535.36	4286.48	4553.163	70.29

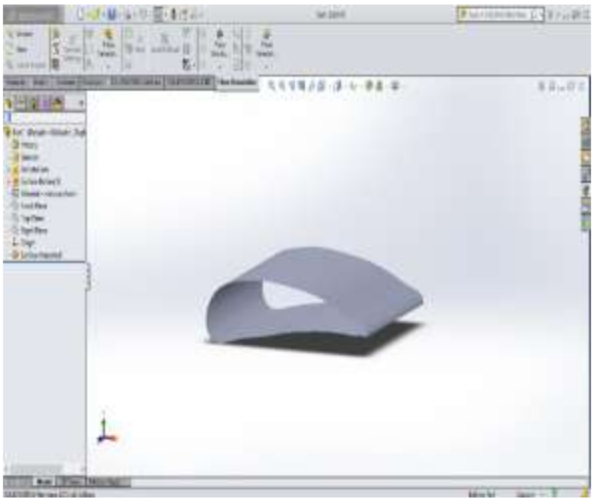
VI. COMPUTATIONAL RESULTS:

As the airfoil we used was of unknown dimensions, we had to reproduce the airfoil in solid works to carry out the computational fluid analysis. For achieving this, we had to plot the X-Y points on the graph by extrapolating the coordinate points and using these same points for producing the exact profile on Solidworks.

X axis (cm)	Y axis (cm)	Z axis (cm)	X axis (cm)	Y axis (cm)	Z axis (cm)
0.8	10	10	10.5	8.85	10
0.75	9.5	10	11	8.9	10
0.7	9.2	10	11.5	9	10
1	8.5	10	12	9.05	10
1.2	8.25	10	12.5	9.1	10
1.4	8.1	10	18	9.4	10
1.6	7.9	10	20	9.4	10
1.9	7.8	10	23	9.3	10
2.25	7.7	10	23.3	9.2	10
2.75	7.7	10	23.3	9.4	10
3.5	7.8	10	21.1	10.7	10
4	7.9	10	20	11.1	10
4.5	8	10	17	12.1	10
5	8.1	10	14.6	12.6	10
5.5	8.2	10	11.5	13	10
6	8.25	10	9	13.2	10
6.5	8.3	10	6.7	13.1	10
7	8.4	10	5	12.9	10
7.5	8.45	10	4	12.75	10
8	8.5	10	2.5	12.2	10
8.5	8.6	10	1.5	11.35	10
9	8.7	10	1.2	10.9	10
9.5	8.75	10	0.9	10.5	10
10	8.8	10	0.8	10	10

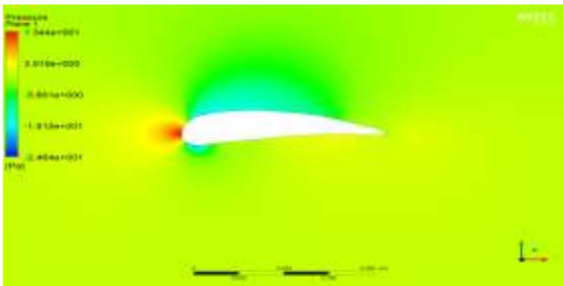
Following are the basic condition for our aerofoil analysis:

- The conditions at boundary of the designed airfoil is NO-SLIP.
- Reference pressure is taken as 0 bar
- Conditions for sidewalls for airfoil is FREE-SLIP.
- Meshing is compiled using mesh sweep method. The mesh type is hexahedral and total no. of nodes per element is 8.
- The inlet velocity acting in the positive x direction is 18 kmph
- Total number of nodes = 1097693
- Total number of elements = 1053400

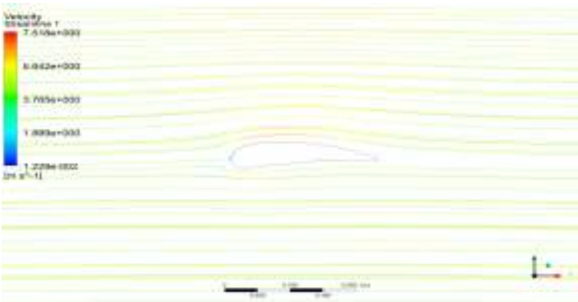


Profile generation in solid works

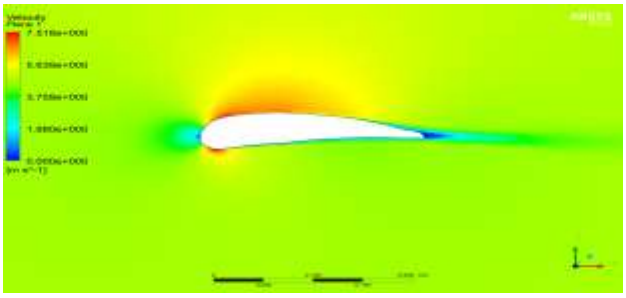
The above shown is the hexahedral meshing of the computational domain around the airfoil using sweep method



Pressure graph around the aerofoil



Streamline around the aerofoil



Velocity graph around the aerofoil

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