Fluid Dynamics Simulation Of a Car Spoiler

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Fluid Dynamics Simulation of a Car Spoiler

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ABSTRACT

This paper contains the simulation analysis of car with and without spoiler by using the ANSYS Fluent software. For designing of spoiler we have used NACA 4 digit airfoils. We have done analysis of different 4 digit NACA series airfoils at different angle of attack and from that we took most efficient airfoil for design of spoiler. Then we took the different heights of spoiler and did the analysis and chose the best height for spoiler, Lastly we have compared the simulation data of car with and without spoiler.

Keywords : Spoiler, Ansys(Filuent), Airfoils, Simulation

1.INTRODUCTION

A spoiler is an automotive aerodynamic device whose intended design function is to "spoil" unfavourable air movement across a body of a vehicle in motion, usually described as drag. Spoilers on the front of a vehicle are often called air dams, because in addition to directing airflow they also reduce the amount of air flowing underneath the vehicle, which generally reduces aerodynamic lift and drag. The goal of many spoilers used in passenger vehicles is to reduce drag and increase fuel efficiency.

1.1TYPES OF SPOILERS

Front Spoiler:-

Car front spoilers, also known as air dams, create downward force by decreasing the air flow beneath the vehicle. This, in turn, allows the car to more easily slice through the air and increases the overall handling of the vehicle.

Rear Spoiler:-

Car rear spoilers work on the concept of creating drag, and thus provide better rear vehicle control. They do this by catching the air as it flows over the vehicle and hits the spoiler. The taller the spoiler and the steeper the spoiler angle, the more drag created.

Side Skirts:-

Car side skirts have an effect on the overall aerodynamics of a vehicle. While not considered a spoiler, car side skirts do affect the overall handling of a car, and thus deserve consideration as part of the entire spoiler package or as part of a car spoiler body kit. They work by continuing the diversion of the air started by the front spoiler around the sides of the car and keeping the air from getting underneath the vehicle chassis. This creates more downward force and increases handling.

2.Validating Result

As we don't have the actual reading of the model which we are going to analyse on the **Ansys software** so we are going to simulate on a different model which we already have in laboratory so that we can cross check the result.
So we have taken model of Santro car which is available in the fluid laboratory. And we have done the analysis on the wind tunnel.

Fig 1.Santro car

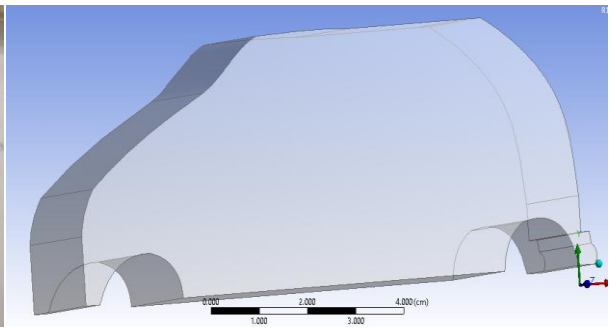


Fig 2.Santro car Cad model

Force Report:-
The Equation use for obtaining the velocity

Pressure of water = Pressure of air

$$\rho_w \, g \, H_w = \rho_a \, g \, H_a$$

H_a will be find by above equation.

Velocity equation = $\sqrt{(2gH_a)}$

The velocity obtained from this eqn. was used to obtain the simulation in anysis

Reading obtained by Practical Analysis:-

Pressure Diff.of Water (cm)	Air Velocity (m/s)	RPM	Drag Force (kg)
3	21.92	1377	0.23
4	25.31	1598	0.26
5	28.29	1815	0.27

TABLE 1

Reading obtained by CFD Stimulation:-

Forces – Direction Vector (1 0 0) was taken to analysis on the CFD software.

Drag Forces (N) at 28.29m/s velocity			
Zone	Pressure	Viscous	Total
wall-solid	0	2.0587379	2.0587379
Car	0.63140858	0.022880751	0.65428933
Net	0.63140858	2.0816186	2.7130272

TABLE 2

Now, it's validated for experimental and simulation result at 28.29 m/s and we can do analysis for car model in Ansys.

3.CAR MODEL WITH AND WITHOUT SPOILER:-

In this analysis we have taken Ford Mustang model, 3D model of car is made by using a Soildworks software.

To create a model in solidworks we have taken Lr ratio as 13.5

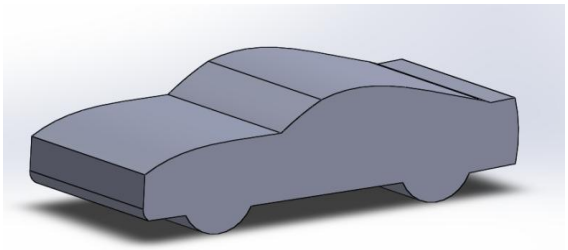


Fig 3.Car without spoiler

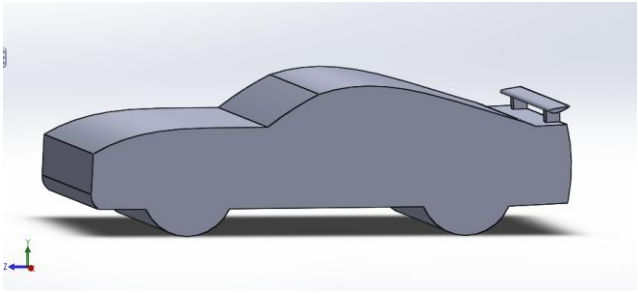


Fig.4Car with spoiler

Design of spoiler:-

In this simulation we have used a NACA 4 digit airfoils to designing spoiler.

NACA 4 digit series consist of mainly three digits. First digit indicates the maximum camber, second digit shows the maximum chamber position from the leading edge and last two digits depict the thickness of airfoil. Therefore, many combinations are possible for 4 digit series and due to this we have taken combinations according to as digit. For doing any analysis in Ansys software (Fluent) , some steps should be followed.

4.Analysis of an airfoil:-

CASE 1:

Firstly we fixed the second digit 4,last two digit 21 and changed the first digit as 1,2,4,6,9 and did the analysis in Ansys software at 0 degree angle of attack.

The lift force and drag forces for different airfoils shown in below table.

Airfoil	Drag force(N)	Lift Force(N)
1421	2.4845	0.117
2421	2.507	0.0544
4421	2.5173	-0.152
6421	2.4	-0.3477
9421	2.544	-1.01986

TABLE 3

CASE 2:

Secondly, we have kept first two digits fixed as 2 and 4 for first and second digit respectively, and changing the last two digits as 08, 10, 18 and 21.

Airfoil	Drag Force(N)	Lift Force(N)
2408	2.4715	-0.00642
2410	2.4739	-0.0432
2418	2.3757	0.01544
2421	2.507	0.0544

TABLE 4

From the above data we see that as thickness of airfoil increases drag force also increases.

CASE 3:

At last we have changed second digit of an airfoil and kept the first and last digit fixed as 2 for first digit and 10 for last digit.

Airfoil	Drag Force(N)	Lift Force(N)
2410	2.4739	-0.0432
2510	2.4756	0.2086
2610	2.2985	0.0335

TABLE 5

From the above tabular data it can be seen that drag force increases as maximum chamber thickness position changes from 0.4 to 0.5 of chord length, likewise positive lift.

In summary, as in case 1 as changes the maximum camber negative lift is increasing and in case 2 as thickness increases lift is also raises.

Therefore, as per all combinations result we can say that mainly three airfoils NACA 4421,6421 and 9421 have maximum negative lift force**.**

5.Analysis of an airfoil at angle of attack :-

If we put the Airfoils at different angle of attack then it might give more negative lift and less resistant by air. So, Next step is to put an airfoil to different angles of attack.

Angle of attack: In fluid dynamics, angle of attack is the angle between a reference line on a body (often the chord line of an airfoil) and the vector representing the relative motion between the body and the fluid through which it is moving. Angle of attack is the angle between the body's reference line and the oncoming flow.

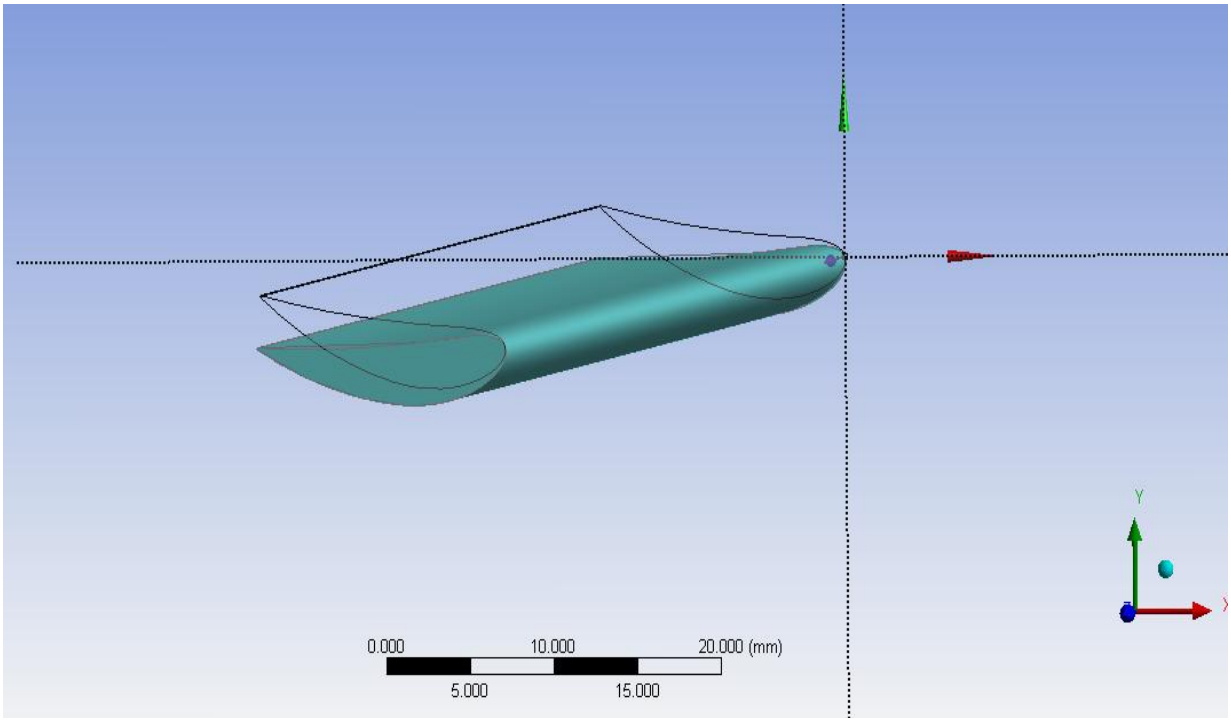


Fig 5.Aerfoil at Angle of Attack

Different Airfoil at Different Angle:-

Airfoil	Angle of Attack(degree)	Drag Force (N)	Lift force (N)
4421	5	2.5298	-0.991
	10	2.5369	-1.091
	15	2.6017	-1.4548
	20	2.7192	-2.0818
6421	5	2.427	-1.2265
	10	2.4776	-1.6357
	15	2.5694	-2.0832
	20	2.6175	-2.2093
9421	5	2.547	-1.0219
	10	2.591	-1.4638
	15	2.6308	-1.8235
	20	2.7184	-2.1764

TABLE 6

As function of spoiler to generate more downward force and from numerical simulation data shown in Table 6 , more negative lift we get at 20° angle of attack, as well as at same angle we get high amount of drag force.But,20° becomes critical angle so we took 10° angle of attack for design purpose.

However, the drag force is merely higher in airfoil 9421 as compared to 4421 airfoil. But, to get a more negative lift as Spoiler function we have taken two airfoils 6421 and 9421 to design a spoiler.

We have done analysis of two spoiler NACA airfoil 6421 and 9421 with different heights and result of this analysis are mentioned in Table 7.

Car with spoiler	Height (mm)	Drag force (N)	Lift Force (N)
9421	5	4.0543	-2.279
	10	4.4127	-2.4261
	15	4.432	-2.4548
	23	4.5174	-2.694
6421	5	4.1661	-2.1561
	10	4.2485	-2.4727
	15	4.2721	-2.5238
	23	4.81	-2.8115

TABLE 7

Simulation data of car without and with spoiler:

Car without spoiler	Drag force (N)	Lift force (N)
Velocity (25 m/s)	4.0733	-0.70604
Car with Spoiler		
Velocity (25 m/s)	4.0543	-2.279

TABLE 8

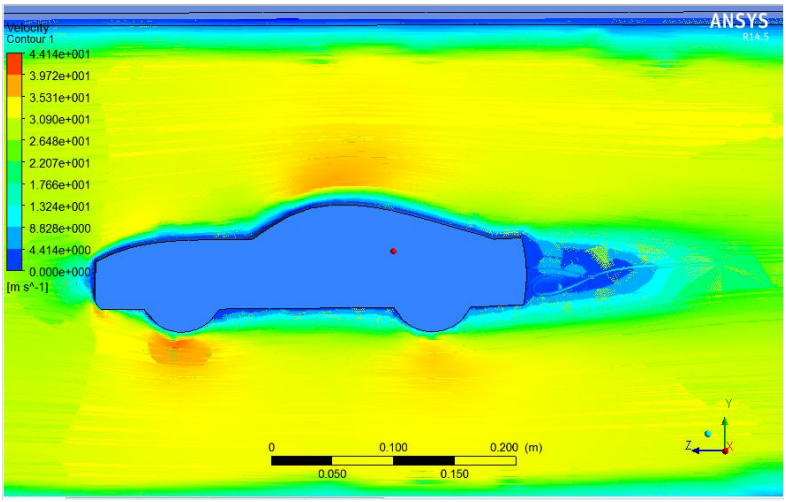
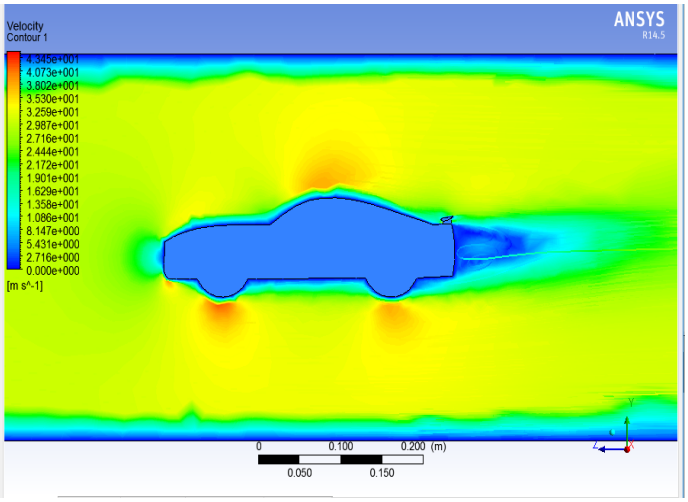


Fig.6(a)VELOCITY CONTOUR(Car Without Spoiler)



(b)VELOCITY CONTOUR(Car With Spoiler)

6.Testing of car model in wind tunnel:-

The wooden car model is made and we did testing of that model in wind tunnel. In our laboratory open circuit wind tunnel is available. Which has air flow velocity capacity up to 30 m/s.

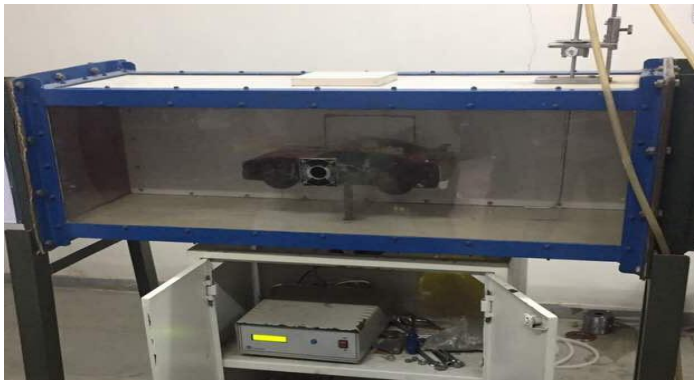


Fig 7. (a)

Fig 7.(b)

Fig.7 (a&b) Testing of Car model with spoiler(NACA 9421) in Wind tunnel

The results obtained from the wind tunnel are(without spoiler):-

Car Velocity (m/s)	Drag Force (N)	Lift Force (N)
15.62	7.2	10.4
19.14	5.7	9.9
21.7	5.9	9.8

TABLE 9

The results obtained from the wind tunnel are(with spoiler):-

Car Velocity (m/s)	Drag-Force (N)	Lift Force(N)
15.62	17	-42.8
19.14	16.3	-40.7
21.7	15.9	-41.1

TABLE 10

We performed the practical and the experimental results are shown in table 9 and 10.As we observed form the tabular data that for the same speed car with spoiler has higher value of downward force than car without spoiler.

Result of Car at different speed in Ansys Software:-

The results obtained from the Ansys are(without spoiler):-

Car Velocity (m/s)	Drag Force (N)	Lift Force (N)
25	7.77	-0.7
30	11.85	-1.445
40	19.17	-2.234

TABLE 11

The results obtained from the Ansys are(with spoiler):-

Car Velocity (m/s)	Drag-Force (N)	Lift Force(N)
25	7.76	-2.275
30	10.99	-3.176
40	18.86	-5.692

TABLE 12

We have checked the spoiler working at different speed of car and those results are mentioned in Table 9 and Table 10.As velocity increases from 25 m/s to 40m/s, car with spoiler has less value of drag force than car without spoiler. Furthermore, car with spoiler has tremendous higher value of negative lift than car without spoiler as changes the velocity. Therefore, we can say that in racing car it is worth to put rear spoiler and at speed of car increases spoiler gives the optimistic function.

Additionally, we have changed the Position of columns, width of Spoiler and reduce the width of supporters of Spoiler and done the analysis. The effects on Drag and lift Force listed in below table.

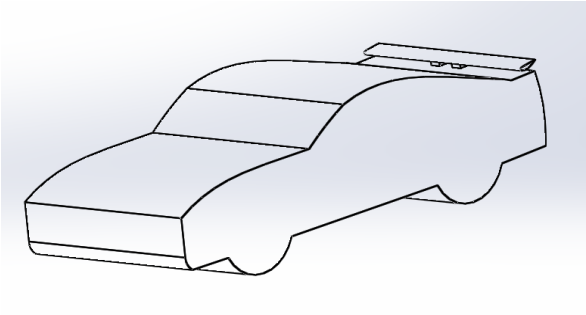


Fig 8.Supporters at middle of Spoiler

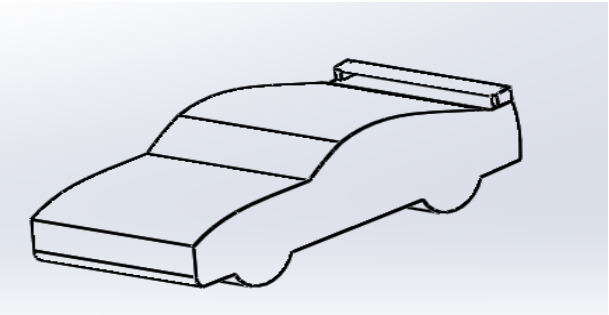


Fig 9. Supporters has thin width

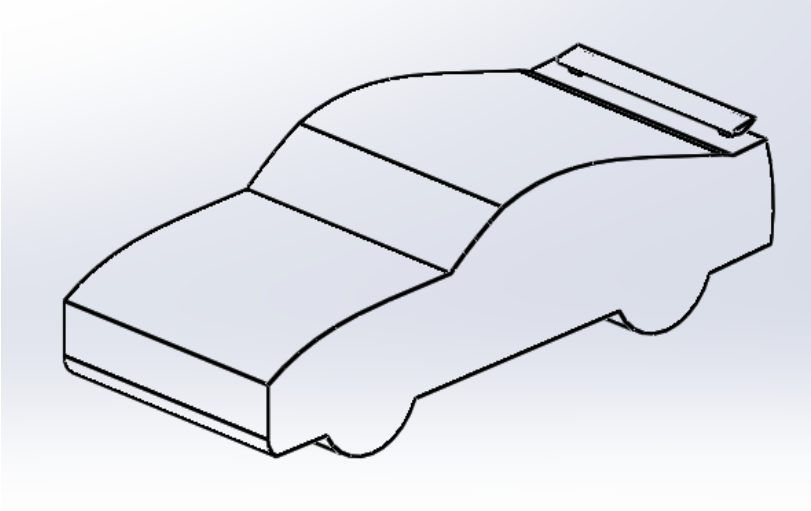


Fig 10.Short Spoiler

Car with Spoiler at 25m/s Speed	Drag Force(N)	Lift Force(N)
Spoiler width 130mm	4.2799	-1.9424
Spoiler with thin Supporter	4.1060	-1.6301
Spoiler has middle Supporter	4.1867	-1.8974

TABLE 13

7.Conclusion:-

In conclusion, we can say that **NACA 9421** Airfoil at **10°**Angle of attack, with **5 mm Height** of Spoiler at rear side of Ford Mustang car's trunk will definitely become **effective** for **increasing Negative lift force and reducing drag force**. **In general**, if the sedan car with around 4800 mm Length, approximately 2050 mm Width and 1385 mm Height then ideally NACA 9421 Spoiler will be become more efficient regarding car performance.

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