ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and CFD Analysis of Aerodynamic of a Car with Various Aerodynamic Devices

Udayagiri.Lingaiah
M.Tech Student,
Design for manufacturing,
SSESGI - Srisai Educational Society Group Of Institution.

B.Venkat Narayana
Professor & HoD of Mechanical Engineering
SSESGI - Srisai Educational Society Group Of Institution.

Ch. Ashok
Assistant professor,
Department of Mechanical Engineering
Anurag Engineering College.

ABSTRACT:

The usage of automobiles is in predictable in day to day life which is common among people for travelling in Indian economic condition. More Indian families prefer family cars like Tavera, Innova, Qualis, etc… for long drives. But, these family cars provide less mileage when compared to sedan class and small cars. In order to increase the mileage of car implemented aerodynamic device which is known as cut section of wing on ceiling of a car. When the car is in motion at the average speed of about 120km/hr the aerodynamic device generates sensible lift force which tries to pull the car from ground and the weight of car acts downwards which pushes the car towards ground. Each force cancels each other and the net force will be the subtraction of lift force generated by aerodynamic device and this would reduce Gross Vehicle Weight. By the known phenomena Miles per Gallon of a vehicle which can be improved by reducing the GVW.

INTRODUCTION

In a day to day life vehicle becomes a necessary thing for humans, due to large number of vehicle usage in the world especially in India there is a need for large gallons of fuel. Hence fuel usage increases day by day with a dramatic hike in fuel price for the past few years. So paper has decided to improve mileage of most commonly used automobiles in India.

To reduce fuel consumption here is implementing aerodynamic device on automobiles.As per Indian condition most Indian families would prefer family cars (MPV) for long drive. You may ask why paper chooses family cars instead of hatchback and sedan class cars because these cars have acceptable mileage on highways but when paper compared family cars with these types of cars they have very less mileage.

In this approach consider a family car like Toyota Innova (MPV) and NACA 632615, SELIG SERIES air foils, The intent being, design, analyze and study a car with aerodynamic device capable to produce the lift with ground effect (due to the attachment of aerodynamic device on ceiling of a car ground effect was considered). Imagine a car traveling at a speed of around 140 km/hr (38.888 m/s) on the NH road with AD attachment at angle of attack 10-18˚ with slotted flap deflected at 40˚; parameters which reflect actual driving condition.

Airfoil: An airfoil is the shape of a wing or blade or sail as seen in cross-section. An air foil-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 air foils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with asymmetric chamber. Foils of similar function designed with water as the working fluid are called hydrofoils.

The lift on an air foil is primarily the result of its angle of attack and shape. When oriented at a suitable angle, the air foil deflects the oncoming air, resulting in a force on the air foil in the direction opposite to the deflection. This force is known as aerodynamic force and can be resolved into two components: Lift and drag. Most foil shapes require a positive angle of

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

attack to generate lift, but cambered air foils can generate lift at zero angle of attack.

This"turning" of the air in the vicinity of the air foil creates curved streamlines which results in lower pressure on one side and higher pressure on the other. This pressure difference is accompanied by a velocity difference, via Bernoulli's principle, so the resulting flow field about the air foil has a higher average velocity on the upper surface than on the lower surface. The lift force can be related directly to the average top/bottom velocity difference without computing the pressure by using the concept of circulation and the Kutta-Joukowski theorem.

Spoiler:A spoiler is an automotive aerodynamic device whose intended design function is to 'spoil' unfavorable air movement across a body of a vehicle in motion, usually described as turbulence or drag. Spoilers on the front of a vehicle are often called air dams, because in addition to directing air flow they also reduce the amount of air flowing underneath the vehicle which generally reduces aerodynamic lift and drag.

Aerodynamic Effects of Installing Spoiler on Automobiles:

Aerodynamic characteristics of a racing car are of significant interest in reducing car-racing accidents due to wind loading and in reducing the fuel consumption. At the present, modified car racing becomes more popular around the world. Sports cars are most commonly seen with spoilers.

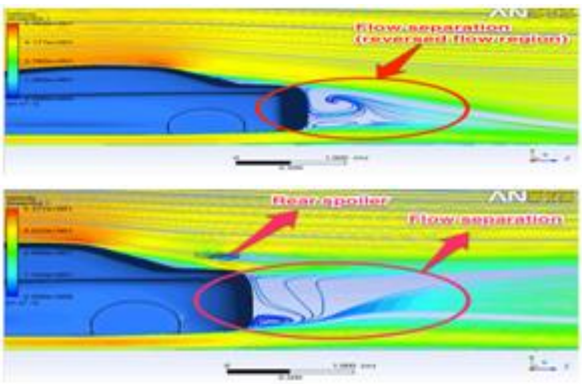


Fig 1: Aerodynamic effect of car with spoiler and without spoiler

AEROFOIL SELECTION AND LOAD CALCULATIONS

Design of Airfoils:

Span and Chord of AD should not exceed 1.7m, Co efficient of pressure point of AD should be designed equal or nearer to the center of gravity point of car, it should not spoil stylish design of car.

Automobile Specification:

Car chosen for testing: Toyota Innova diesel ZX 7 seater (MPV)

Length: 4585 mm, Width: 1765 mm, Height: 1760 mm, Ground clearance: 176 mm, Max, kerb weight: 1680 kg, Gross weight: 2300 kg, Max output: 75 kn@3600 rpm 1102 ps@3600 rpm, Rear spoiler: No, Engine: 2.5 Litre D-4D, Common Rail Diesel Engine.

Airfoil Specification:

Chord: 1.7 m, Span: 1.7 m.

Weight Estimation of Payload:

Vehicle loading capacity (VLC) = Gross weight – kerb weight. VLC = 2300-1700, VLC = 600 kg, from books 1kg = 9.80665 N. 600 kg= 5883.99 N Self weight of device = 50 kg, so =600+50= 650kg = 6375 N.

Hence **6375 N** of payload weight has been targeted for elimination to improve fuel economy.

Co-Efficient Of Lift Estimation for Airfoil Selection:

$$\mathbf{L = ½\, \rho v^2 s C_l}$$

For steady level flight L= W, W =weight= 6375 N

ρ = density=1.225 kg/m^3

v =velocity= 38.888 m/s

$$W = ½\, \rho v^2 s C_l$$

$$C_l = \frac{2\,w}{\rho s v^2} \rightarrow C_l = \frac{2 \times 6375}{1.225 \times 1.7 \times 1.7 \times 38.88^2} = 2.38$$

$\boldsymbol{C_l}$ Required to produce 6375 N of lift will be around 2.38.

Selected Airfoil From Naca Reports:

100 km/hr: 3.12*10^6 for chord = 1.7
120 km/hr: 3.74*10^6K.V= 1.511E-6
140 km/hr: 4.37*10^6 20 deg
100 km/hr: 3.02*10^6 for chord = 1.7
120 km/hr: 3.60*10^6 K.V= 1.560E-6
140 km/hr: 4.20*10^6 25 deg

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Reynolds no > 3 000 000 for 20 & 25 Degree, Mach no: 0.117 for 140 km/hr (38.888 m/s), Mach no < 0.75, from report NACA 824, NACA 632615 Air foil is selected for analysis.

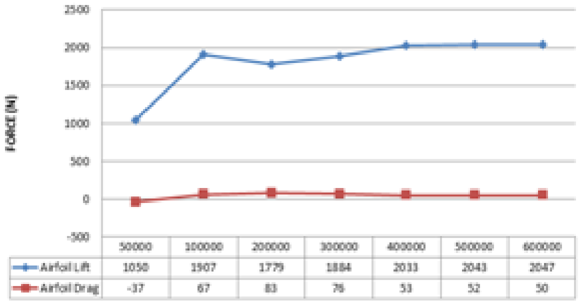
ANALYSIS OF CFD

Analysis was done using ANSYS CFX 14.5 Software.
From NACA 824 report cl value at 0 degree angle of attack for NACA 632615 is stated below.
Cl = 0.44 and CD = 0.007 @ 0 degree AOA for 30 Lakhs Reynolds number
From ANSYS CFX analysis using structured mesh
Wing model specification:
Span: 1.7m, Chord: 1m. Result from ANSYS CFX: Lift: 691 N, Drag: 12.21 N

Cross checking calculation:

From, where L=Lift weight
L = ½ $\rho v^2 s C_l$; Cl = 0.44 from NACA 824 report. L=692 N, W = ½ $\rho v^2 s C_l$; Cd = 0.007 from NACA 824 report. W= 11.023 N
NACA report and ANSYS CFX result value of lift and drag are matching with 0.27% of error.

CFD Mesh Independent Study:



RESULTS

Air is in the form of ideal gas, Total temperature is 300 k, Outlet pressure is 101325 N/m^2, Car and ad are attached by beams as welded joints, Tires are not designed in car, instead ground clearance between wall and car bottom is given while designing domain, because of negligible amount of area cover by tires on car body. Beams connecting AD and car are not designed for analysis because it will only create very small change in flow pattern.

Generic Car Models:

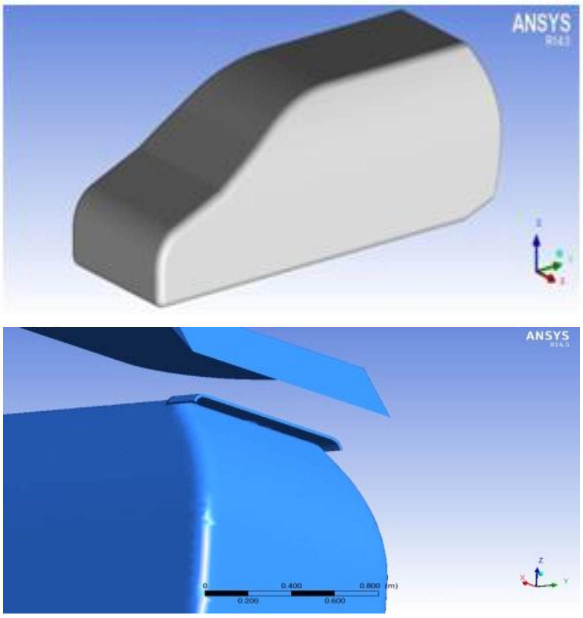


Fig 2: Generic car Model view in ANSYS

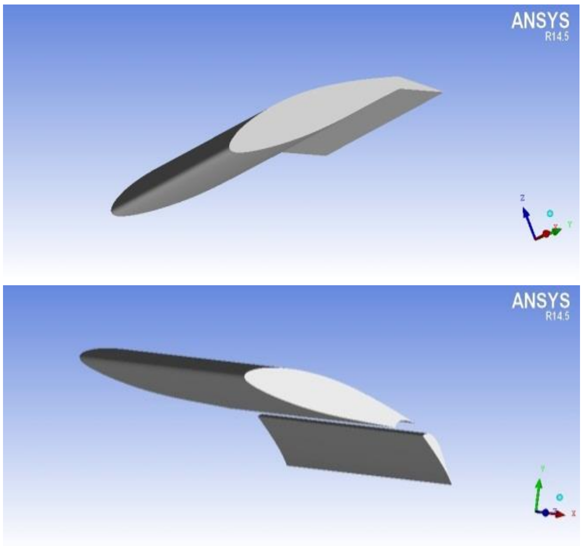
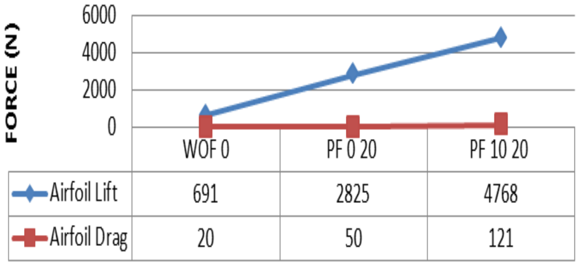


Fig 3: Aerodynamic Device Models (without flap, Plain flap, Split Flap)

CFD Analysis and Results:



Graph 1: Lift and Drag Curve

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

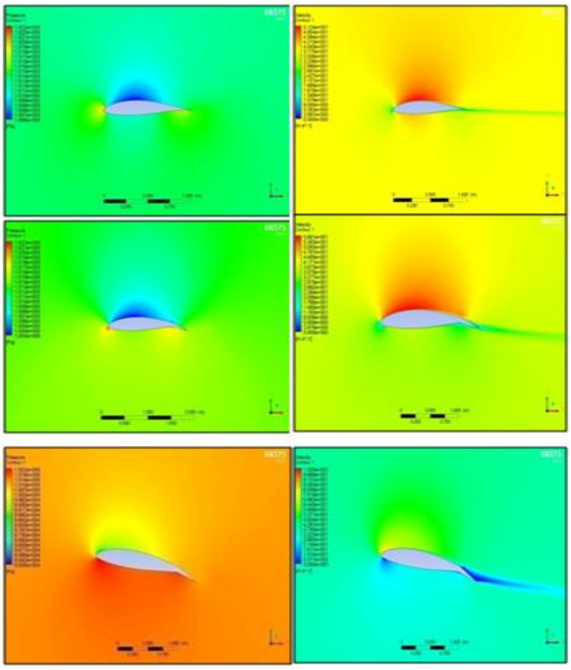
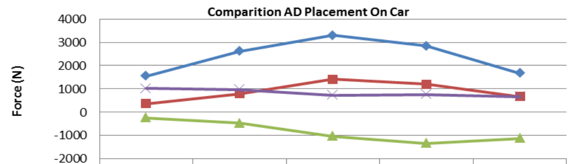


Fig 3: Pressure and Velocity Contour for Aerodynamic Devices



	PF 0 20 C-1	PF 10 20 C-1	PF 12 40 C-1	PF 10 40 C-2	SF 10 40 C-2
Airfoil Lift	1550	2613	3306	2851	1678
Airfoil Drag	368	800	1428	1199	653
Car Lift	-245	-471	-1037	-1329	-1125
Car drag	1026	981	734	758	661

Graph 2: Lift and drag curve

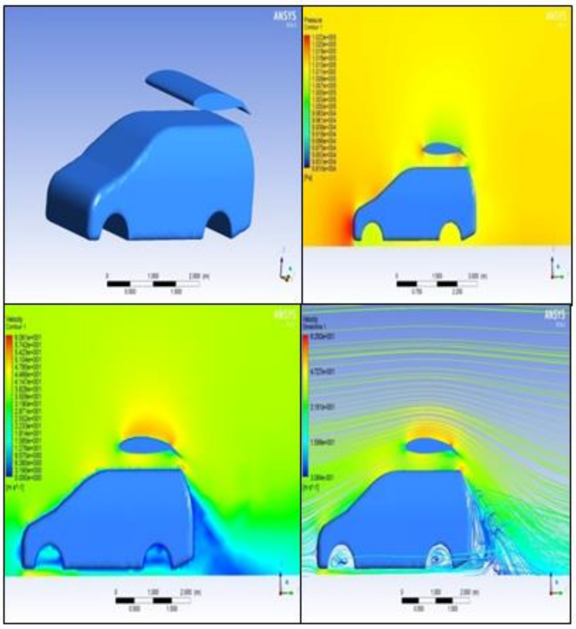


Fig 4: Aerodynamic effect when spoiler is in different angle

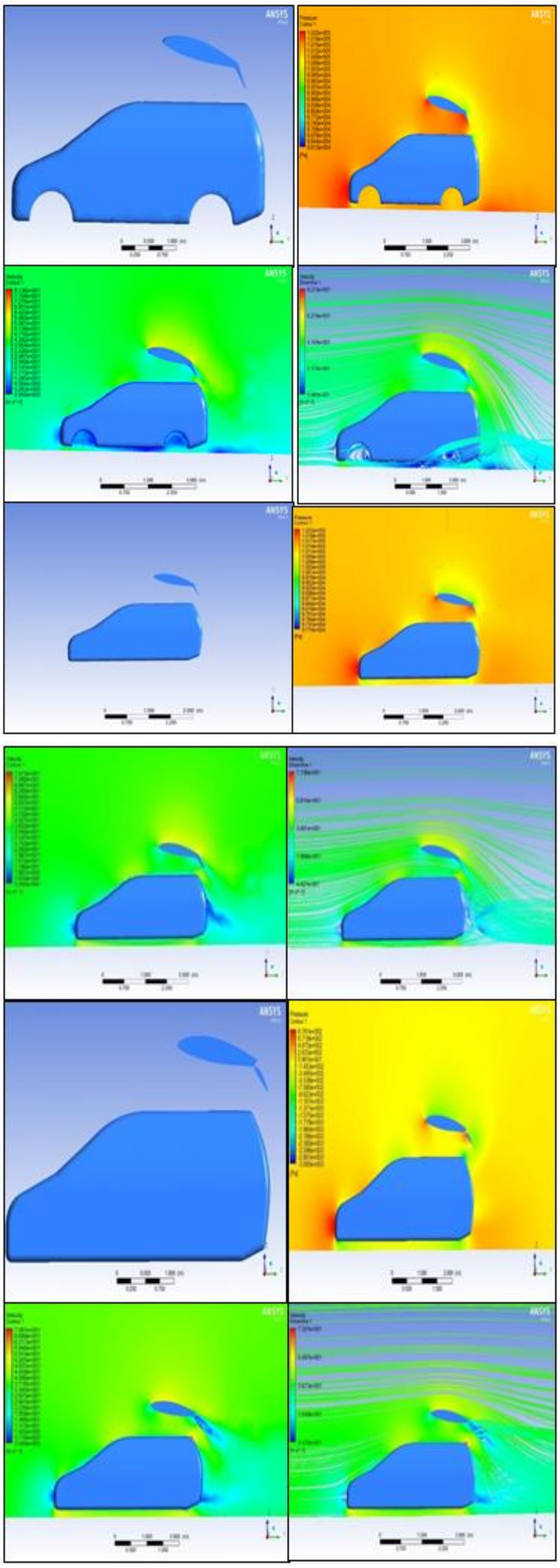
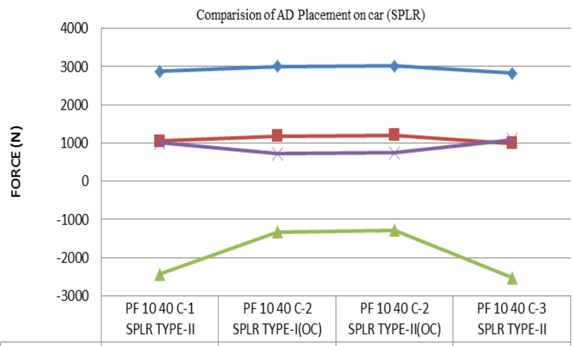


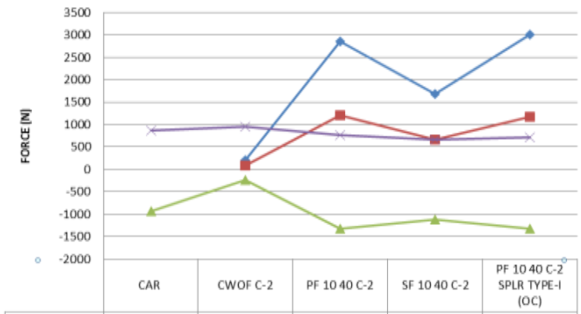
Fig 5: Car model, velocity, pressure, streamline contour

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



	PF 10 40 C-1 SPLR TYPE-II	PF 10 40 C-2 SPLR TYPE-I(OC)	PF 10 40 C-2 SPLR TYPE-II(OC)	PF 10 40 C-3 SPLR TYPE-II
Airfoil Lift	2870	3002	3014	2828
Airfoil Drag	1050	1177	1200	990
Car Lift	-2426	-1332	-1282	-2529
Car Drag	1007	717	741	1089

Graph 3: Comparison of AD placement car (SPLR)



	CAR	CWOF C-2	PF 10 40 C-2	SF 10 40 C-2	PF 10 40 C-2 SPLR TYPE-I (OC)
Airfoil Lift		194	2851	1678	3002
Airfoil Drag		85	1199	653	1177
Car Lift	-940	-238	-1329	-1125	-1332
Car Drag	862	952	758	661	717

Graph 4: Comparison of successful configurations

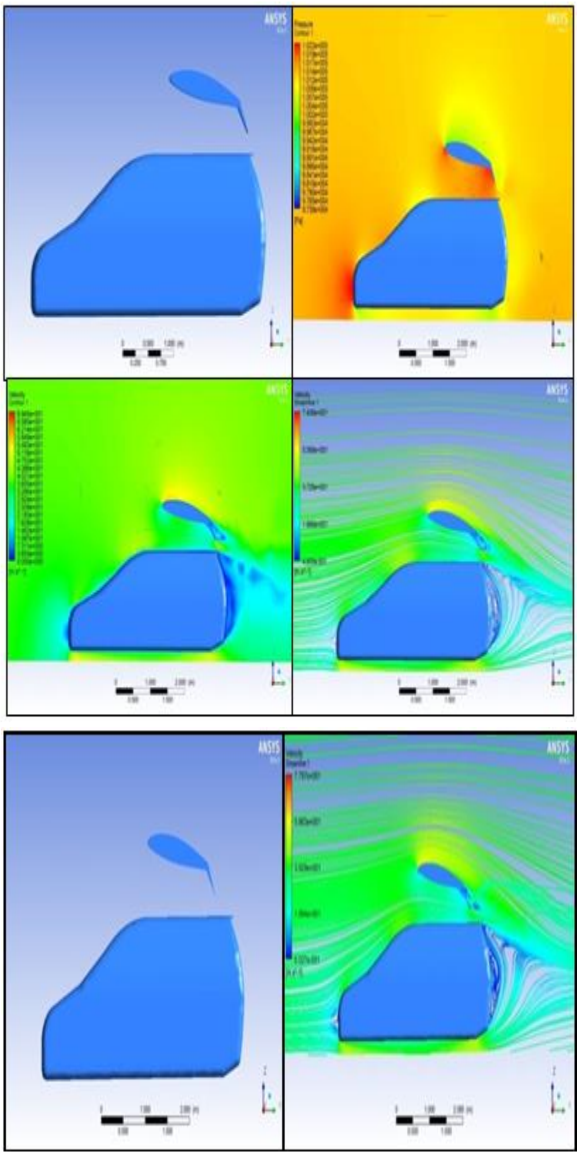


Fig 6: Aerodynamic effect acting on a car with spoiler

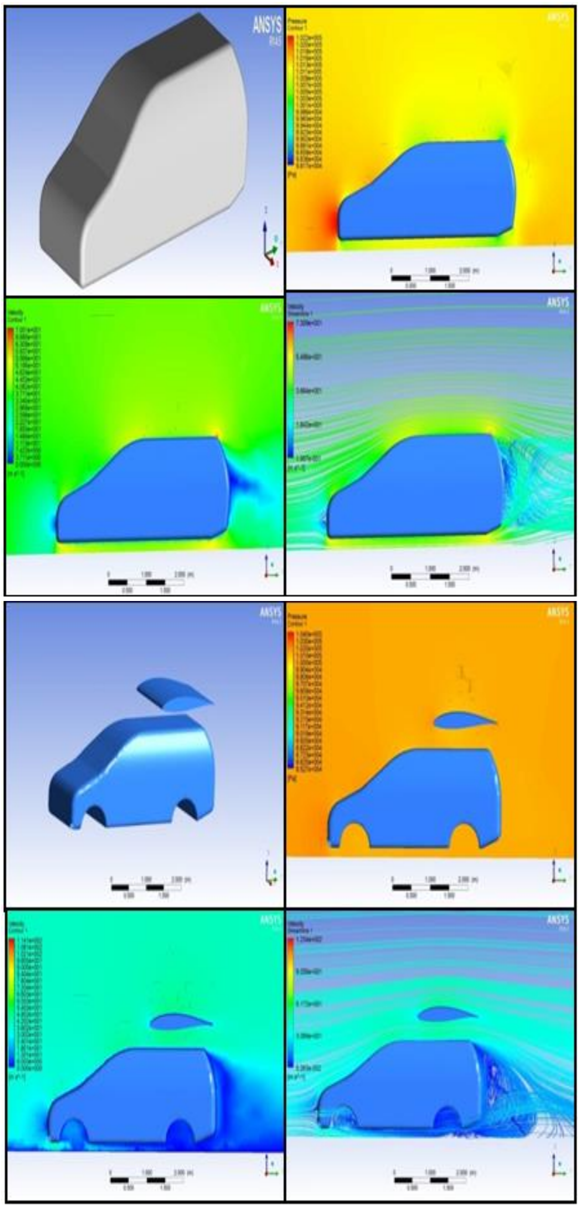


Fig 7: Aerodynamic effect when spoiler is in different angle

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

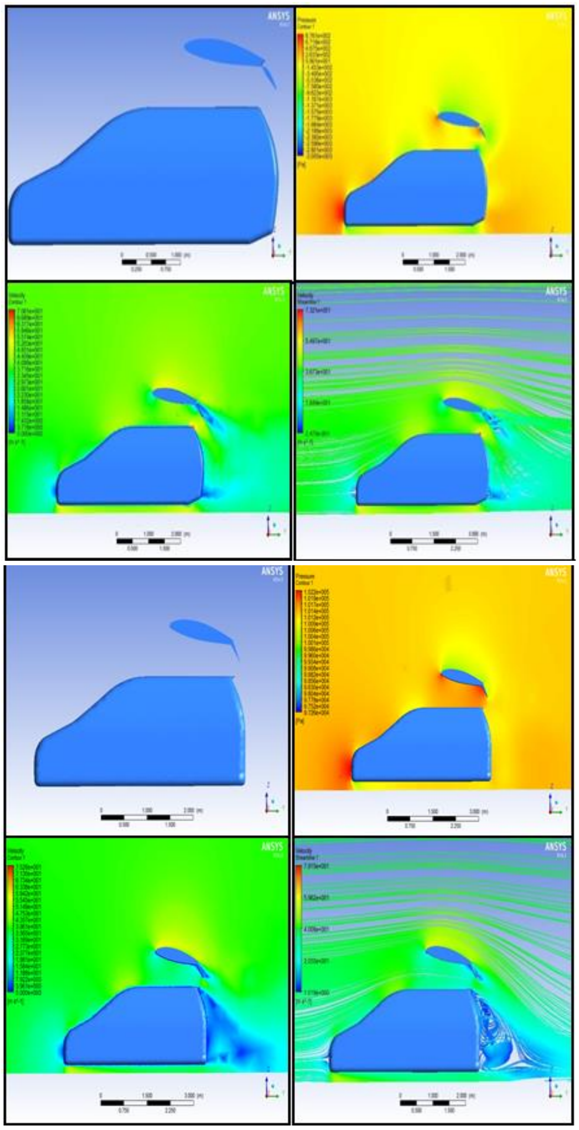


Fig 8: Aerodynamic forces effecting when spoiler is in different angle

Analysis Result:

After studying results of analyses following data's are found:

I tcan't be used because of increased pressure force acting on surface of car body leads to structural failure.It increases the disturbed flow pattern on CAR configuration.It performs best then other configurations. But cannot be used on real life because of its rugged look and needs higher car ceiling clearance for best performance.It creates streamlined flow on car but falls in producing desired lift requirement, Otherwise drag on all bodies are less than other configurations.

Result Evaluation:

From above comparison paper found that this configuration is capable to produce designed lift without stalling at higher angle of attack at varying airspeed.Almost 5500 N of lift force can be obtained from AD which is useful to eliminate the payload in order to reduce GVW of vehicle. At the same time AD producing around 2500 N of drag force which is to be reduced by implementing drag reducing techniques on AD in future for successful completion of our project.

Fuel Economy Estimation:

Conditions:

All fuel economy values are just comparisons with the report Impact of Vehicle Weight Reduction on Fuel Economy for Various Vehicle Architectures by Richard alumni only. Actual fuel economy for implementing AD on Automobiles can be obtained only by performing real time test with various velocities and GVW.

Automobile Weight Reduction Technique:

AD as a Spoiler:

Main motive of spoiler is to reduce drag on car. Hence by implementing AD on car it can act as a spoiler reduces the car drag and makes the recirculation flow smoothly join with the streamline flow of atmosphere.

Work done by AD on Car:

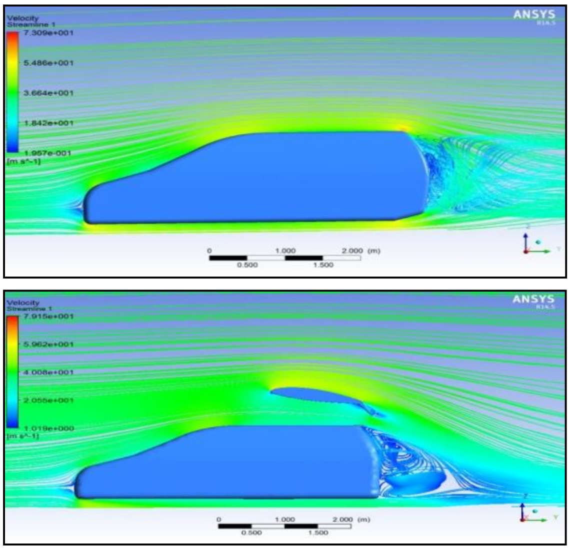


Fig 9: Aerodynamic effect of a car with and without spoiler

By reducing recirculation flow behind the car decreases drag acting on car leads to gain fuel economy. CAR taken for this project is a type of Small SUV/MPV, paper can compare innova with Saturn Vue because both cars have same 2.5 Litre diesel engines, dimensions and almost same weight.

Fuel Economy Improvement from Steady State Conditions of Vehicle:

Case i:

When Saturn car travels 45 MPH if 5 %(115 kg) of GVW reduced then fuel economy will increase by 0.9%. If innova travels at 45 MPH gets AD deflected at 14 AOA and 40 degree Flap angle. Lift force generated on AD for above condition is 1244 N. AD can reduce 127 kg on GVW of car. So, paper can improve 0.274 MPG (0.9%) of fuel.

Casei (i):

When Saturn car travels 60 MPH if 10 %(230 kg) of GVW reduced then fuel economy will increase by 1.5%.If our innova travels at 60 MPH gets AD deflected at 18 AOA and 40 degree Flap angle. Lift force generated on AD for above condition is 2187 N. AD can reduce 222 kg on GVW of car.So, paper can improve 0.457 MPG (1.5%) of fuel.

Casei(ii):

When Saturn car travels 75 MPH if 20 %(460 kg) of GVW reduced then fuel economy will increase by 1.9%.If our innova travels at 60 MPH gets AD deflected at 18 AOA and 40 degree Flap angle.Lift force generated on AD for above condition is 3156 N. AD can reduce 321 kg on GVW of car.
So, paper can improve 0.5185 MPG (1.7%) of fuel.

Fuel economy improvement per 100lb weight reduction on vehicle:

NOTE:

Average fuel economy of innova is 30.5 MPG (fuel economy improvement was calculated from average fuel economy).

Case i:

When Saturn car travels 60 MPH if 100 lb (45 kg) of GVW reduced then fuel economy will increase by 0.4%. If our innova travels at 60 MPH gets AD deflected at 18 AOA and 40 degree Flap angle. Lift force generated on AD for above condition is 2187 N. AD can reduce 222 kg (489.4 lb) on GVW of car. So paper can improve 0.61 MPG (2%) of fuel.

Case ii:

When Saturn car travels 70 MPH if 100 lb (45 kg) of GVW reduced then fuel economy will increase by 0.2%. If our innova travels at 70 MPH gets AD deflected at 18 AOA and 40 degree Flap angle. Lift force generated on AD for above condition is 3156 N. AD can reduce 317 kg (700 lb) on GVW of car. So, paper can improve 0.427 MPG (1.4%) of fuel.

CONCLUSION

The analysis results from ANSYS CFX software confirm the above statement and reflect that our AD is capable to reduce GVW and recirculation zones behind the car. At the same time fuel economy gained on car by this device will be affected by drag force generated on AD. From the analysis reports we found that drag produced by AD is in the form of induced drag which can be eliminated by drag reducing techniques (especially we can eliminate induced drag by designing AD with Winglets). If drag on AD is reduced we can surely get even better fuel economy on automobiles in the history. We hope that our project will become a grand success and implemented on all automobiles in the future.

Future scope:

To reduce drag on AD winglets have to be attached and analyzed to estimate the amount of drag reduced.

To stabilize unwanted lift and drag force produced on AD, automatic angle of attack changing mechanism can be implemented by using hydraulics for attaching AD and CAR instead of rigid beams.

REFERENCES

1. Impact of vehicle weight reduction on fuel economy for various vehicle architectures report conducted by ricardoinc. for the aluminum association.

2. Effects of payload on the fuel consumption of trucks- research for the department for transport

(dft) funded through the department for environment food and rural affairs (defra) aggregates levy sustainability fund (alsf).

3. CFD study on aerodynamic effects of a rear wing/spoiler on a passenger vehicle by must afacakir, santraclara university.

4. CFD analysis over a car body by kunalkumartirkry, sureshkumar. s, mcadcentre, msrsas, bangalore.

5. naca report 824 by ira h. abbott, albert e. von doenhoff, abd louis s. stivers, jr.

6. naca report 427 by fred e. weick and joseph a. shortal.

7. naca report 677 by carl j. wenzinger and thomas a. harris.

8. naca report tn 705 by isidore g. recant, langley memorial aeronautical laboretory.

9. nasa report tn d-7428 c.1(r), robert j. mcghee, langley research center, hampton, verginia.

10. naca wartime report cb no. l4g10 by felicien f. fullmer, jr.

11. Theory of wing sections including a summary of airfoil data by ira h. abbott, director of aeronautical and space research, national aeronautics and space administration.

12. Summary of low-speed airfoil data - volume 1, 2, 3.