PROTOTYPE DEVELOPMENT OF CAR BY IMPROVING AERODYNAMIC SHAPES & CALCULATION OF AERODYNAMIC FORCES

Prakash Shakti*[1], Parth Nikunjkumar Bhatt[2], Ravneetsingh Gulzarsingh Gill[3], Ajaysinh Bharatsinh Jadeja[4], Deval Jayeshbhai Parekh[5]
[1*]Asst. Professor, Automobile Department, KJIT, Vadodara, Gujarat, India
[2,3,4,5] UG Students, Automobile Department, KJIT, Vadodara, Gujarat, India

ABSTRACTL: The main purpose of work is to calculate and improve aerodynamic forces on a sedan car by using rear spoiler so that we can get a better fuel economy as well as better stability when vehicle is moving on a road and also to find out the wind noise on a car. For this work we have used a 3D modelling software and simulation software.

Keywords: Sedan, Aerodynamic, Turbulence, Air passage, Drag, Forces

I. INTRODUCTION

"Aerodynamics" is a division of fluid dynamics concerned with learning the flow of air, mainly when it cooperates with a moving body. Understanding the flow of air around a body allows the calculation of forces and moments performing on the object. Characteristic properties calculated for a flow area include velocity, pressure, density and temperature as a purpose of position and time. By defining a control volume around the flow field, equations for the conservation of mass, momentum, and energy can be defined and used to solve for the properties. The use of aerodynamics through mathematical analysis, empirical approximation and wind tunnel experimentation for the scientific basis. [1]

Fig 1. 3D Printed Sedan

The importance of aerodynamics to several type car bodies model needs a development of drag and lift estimation to know how much the car performance on the road against air resistance beside to improve the stability, reducing noise and fuel consumption.

Drag and lift will cause many problems on the performance of car model like instability, noise and fuel consumption. Thus, in this project the CAD models of sedan bodies was simulated and analyse of their aerodynamics especially on the drag and lift estimation. In addition, using CFD analysis as a possible procedure were develop the drag estimation and aerodynamics studies on the body.

In this section, the fundamental of aerodynamics is discussed to gain understanding in doing analysis of the project. The basics equation and terms in aerodynamics field or fundamental of fluid mechanics such as turbulence, pressure, velocity and drag coefficient, boundary layer, separation flow, and shape dependence are studied. [1]

Fig 2. Design of Sedan

So that aerodynamic means study of air flow about a solid bodies (In case of automobile car, bus, trucks etc.)

When a vehicle is moving on road, the air flow is dependent on the vehicle speed and the ambient wind. The atmospheric wind has non uniform velocity profile and fluctuating in both magnitude and direction. The study of aerodynamic aspect is essential for an automobile to reduce the resistance against the movement of vehicle and to save nearly 3% to 35% fuel cost.

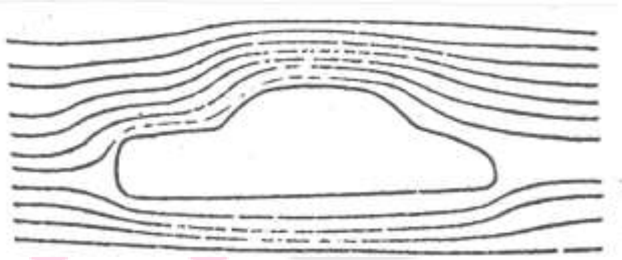


Fig 3. Streamline over vehicle body

1.1 IMPORTANCE OF AERODYNAMIC

i. To reduce the force and movements produced on the body against the forward movement of vehicle.
ii. To save the fuel cost by better streamlining of the body.
iii. To increase the stability and safety of vehicle by moving.
iv. To give good aerodynamic appearance by shaping of the body.
v. To provide better flow pattern of exhaust and wind.
vi. To provide better ventilation of internal body structure.
vii. To provide positive roll, pitch and yaw moments during dynamic condition.
viii. Aerodynamic noise will be reduce by better designed and streamlined body during high speed.

II. WIND TUNNEL TESTING

Wind tunnel testing was applied to automobiles, not so much to determine aerodynamic forces but more to determine ways to reduce the power required to move the vehicle on roadways at a given speed. In these studies, the interaction between the road and the vehicle plays a significant role, and this contact must be taken into consideration when interpreting the test results. In an actual situation the roadway is moving relative to the vehicle but the air is stationary relative to the roadway, but in the wind tunnel the air is moving relative to the roadway, while the roadway is stationary relative to the test vehicle.

It is the most useful tool to study the aerodynamic aspects of the vehicle. The various forces and moments can be evaluated by using scale models. The instrument used to measure the forces and moments is called a component balance.

For e.g. three component balance for three force, six component balance to measure all the forces and moments (3force, 3moment). In addition flow visualization studies can also be done by using wind tunnel.

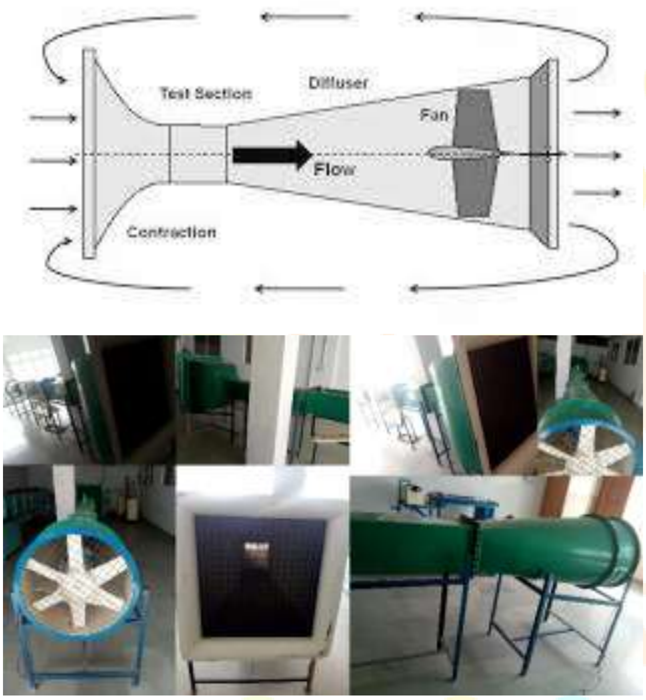


Fig 4. Wind tunnel Diagram

The air flow pattern around the vehicle and inside the vehicle is basically responsible for all aerodynamic characteristics of a vehicle. Hence, if one want to evolve a new aerodynamic design he must understand the air flow pattern around and inside the vehicle. To fulfil this objective, the flow visualization study on a modal of the vehicle is a fundamental one.

2.1 ADVANTAGES OF TUNNEL

i. Wind velocity and wind angle can be measured.
ii. Flow pattern study can also be studied.
iii. Forces and moments can be measured

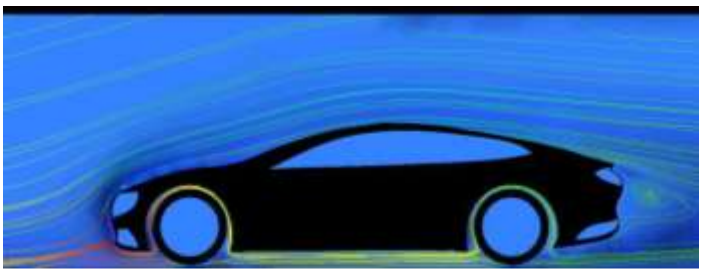


Fig 5. Wind Tunnel Test

2.2 MECANISM OF AIRFLOW

The gross flow over the body of a vehicle is governed by the relationship between velocity and pressure expressed in Bernoulli's Equation.

$$P_{static} + P_{dynamic} = P_{total}$$
$$P_S + ½\ p\ V^2 = P_t$$

Where,

p = Density of air
V = Velocity of air

This correlation is derived by applying Newton's Second Law to an incremental body of fluid flowing in a well behaved way. In originating the equation, the sum of the force brings in the pressure effect acting on the incremental area of the body of fluid. Equating this to the time rate of change of momentum brings in the velocity term.

Visualizing the Vehicle as stationary and the air moving, the air streams along lines, appropriately called "streamline."
At a distance from the vehicle the static pressure is simply the ambient, or barometric, pressure (P_{atm}). The dynamic pressure is produced by the relative velocity, which is constant for all streamlines approaching the vehicle. Thus the total pressure, P_t is the same for all streamline and is equal to $P_S + ½\ p\ V^2$.

III. RESULT & DISCUSSION

In our work we have design a sedan car and done a CFD analysis. The main changes in our design is removing of side mirror because Side mirrors both increase the frontal area of the vehicle and increase the coefficient of drag meanwhile they swell from the side of the vehicle. In demand to decrease the influence that side mirrors have on the drag of the vehicle the side mirrors can be replaced with smaller mirrors or mirrors with a different shape.

We were providing frontal air passage so that the air can directly flow over the bonnet to the roof of the car and rear spoiler.

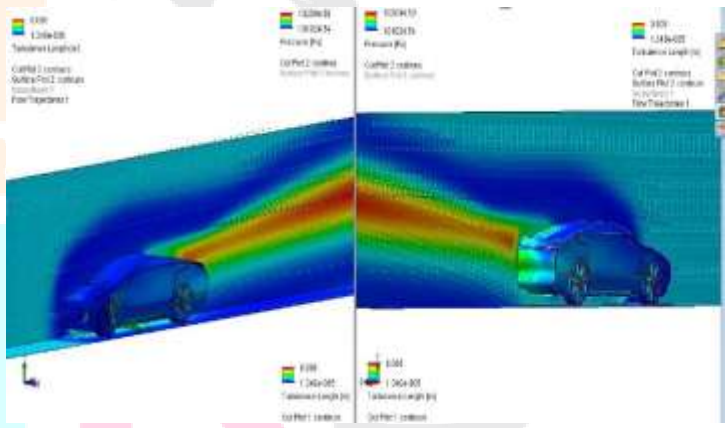


Fig 6. Turbulence plot on plane

The detail calculation of work and design of car is given here. The aerodynamic is calculated at 92 kmph flow of air over the sedan.

Fig 6 show the turbulence and fig 7 showing the velocity, turbulence viscosity and temperature.

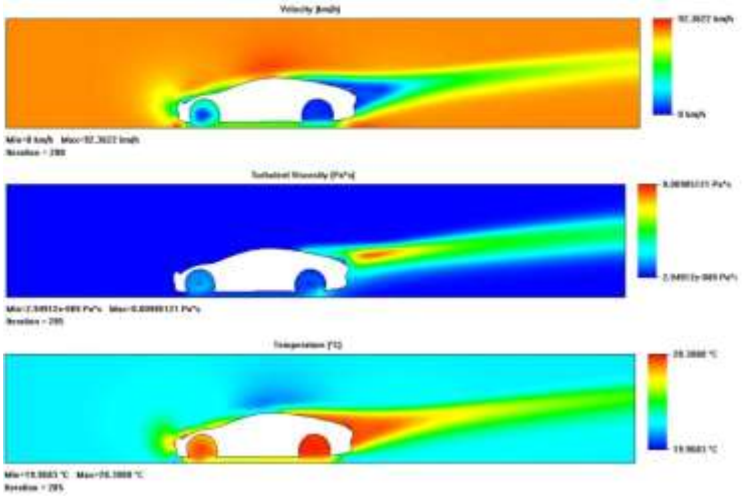


Fig 7. Velocity, Turbulence, Temperature

3.1 AMBIENT CONDITIONS

Table 1 is the input data for the analysis. In this the thermodynamic parameters such as static pressure and temperature is taken for the atmospheric condition.

The velocity of wind is selected as 80 kmph which describe the velocity of car.

Table 1. Basic details for calculation

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 20.05 °C
Velocity parameters	Velocity vector Velocity in X direction: 80.000 km/h
Turbulence parameters	Turbulence intensity and length Intensity: 0.10 % Length: 0.001 m
Material	Air (Fluid)

3.2 GOALS RESULT

Table 2. Calculated Result

Name	Unit	Value	Progress	Delta	Criteria
Av Static Pressure 1	Pa	101326.90	44	0.2112808	0.0925492756
Av Total Pressure 1	Pa	101595.38	21	3.19750106	0.676345418
Av Dynamic Pressure 1	Pa	268.20	20	2.96401303	0.603761653
Av Temperature (Fluid) 1	°C	20.08	19	0.00288759962	0.000548955853
GG Av Turbulent Viscosity 1	Pa*s	0.0003	7	7.76151855e-005	5.5510481e-006
Av Turbulence Length 1	m	9.790e-004	11	6.33480762e-005	7.22050393e-006
Av Turbulence Intensity 1	%	2.50	35	0.128024628	0.0447971189
Turbulent Energy 1	J/kg	0.331	9	0.0498420653	0.00464600318
Av Turbulent Dissipation 1	W/kg	44.84	10	5.10868407	0.529714451
Normal Force 1	N	1.269	100	0.0171574969	0.187985793
Normal Force (X) 1	N	1.235	100	0.0130021283	0.178648994
Normal Force (Y) 1	N	0.292	49	0.124037735	0.0611616855
Normal Force (Z) 1	N	6.580e-004	100	0.00046106359	0.00426931976
Force 1	N	1.344	100	0.0173042308	0.190720787
Force (X) 1	N	1.311	100	0.0126071456	0.181090761
Force (Y) 1	N	0.297	49	0.12413736	0.060561164
Force (Z) 1	N	0.001	100	0.000460072906	0.00427775133
Friction Force 1	N	0.076	100	0.00128282859	0.00312339488
Friction Force (X) 1	N	0.075	100	0.00130087186	0.00310963995
Friction Force (Y) 1	N	0.005	100	0.000247011429	0.0006837041
Friction Force (Z) 1	N	4.859e-004	67	3.14070129e-005	2.11016366e-005
Torque (X) 1	N*m	-1.789e-004	32	0.000433069784	0.000138097709
Torque (Y) 1	N*m	0.001	100	9.41586895e-005	0.000338189678
Torque (Z) 1	N*m	-0.038	66	0.00848844828	0.00557535349

Table 3. Min/Max Table

Name	Minimum	Maximum
Pressure [Pa]	101024.54	102094.50
Temperature [°C]	19.97	20.31
Density [kg/m^3]	1.20	1.21

Velocity [km/h]	0	94.563
Velocity (X) [km/h]	-41.370	86.387
Velocity (Y) [km/h]	-62.350	48.598
Velocity (Z) [km/h]	-49.765	51.527
Temperature (Fluid) [°C]	19.97	20.31
Mach Number	0	0.08
Vorticity [1/s]	0.003	4336.203
Shear Stress [Pa]	0	6.86
Relative Pressure [Pa]	-300.46	769.50
Turbulent Viscosity [Pa*s]	2.9491e-009	0.0099
Turbulent Time [s]	6.944e-004	0.256
Turbulence Length [m]	1.348e-005	0.005
Turbulence Intensity [%]	0.10	1000.00
Turbulent Energy [J/kg]	6.695e-005	28.329
Turbulent Dissipation [W/kg]	2.67e-003	21025.22

Graphs Details

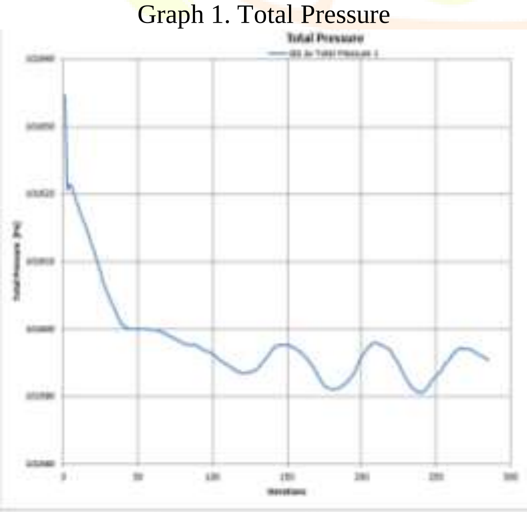
From Graph 1 describe the total pressure of static, dynamic and gravitational pressure (p & q). It is the measure of the overall energy of the airflow & is equal to static plus velocity pressure as shown in Fig 9.

Graph 2 describe the temperature changes i.e. atmospheric air temperature changes when the air velocity is collide with the car body.

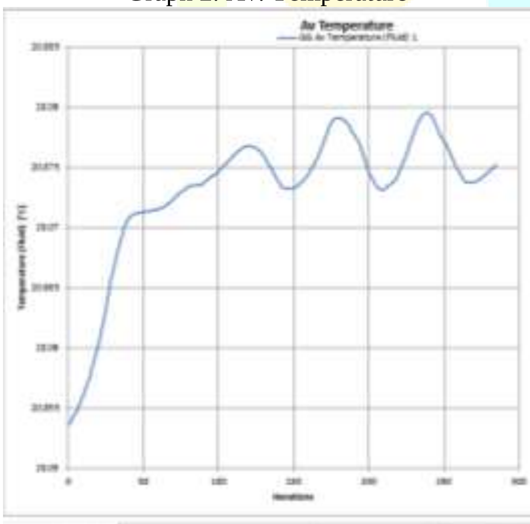
Graph 3 & 4 describe the excessive kinetic energy in parts of fluid flow, which overcomes the damping effect of the fluid's viscosity.

Graph 5 & 6 Describe the forces acting on the car body when wind was flowing.

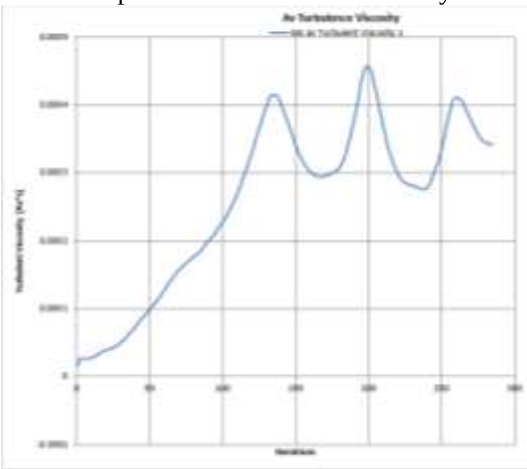
Graph 1. Total Pressure



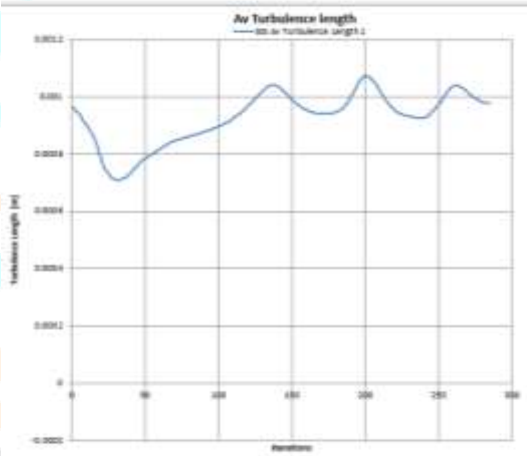
Graph 2. Av. Temperature



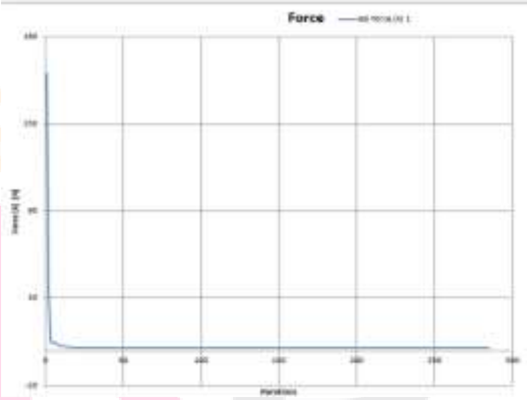
Graph 3. Av. Turbulence Viscosity



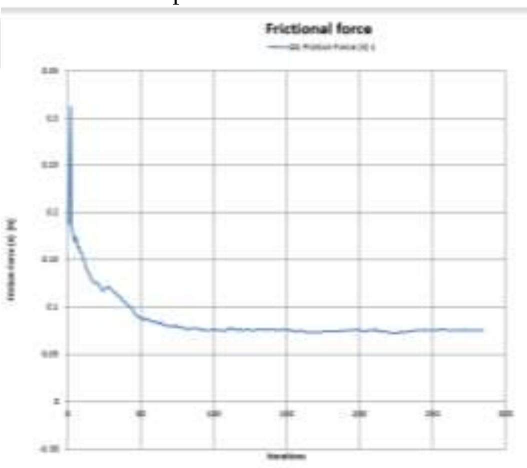
Graph 4. Av. Turbulence length



Graph 5. Force



Graph 6. Frictional force



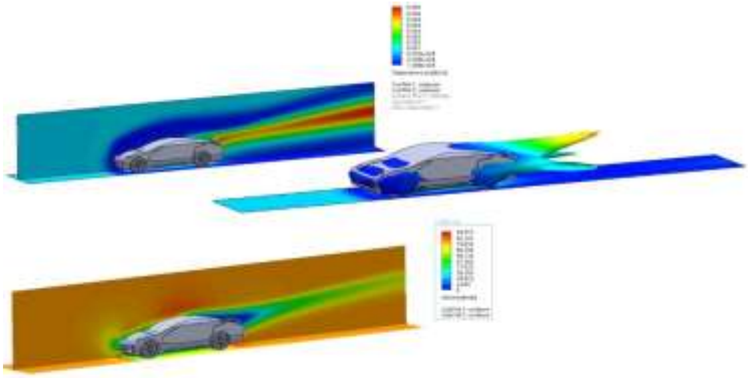


Fig 8. Velocity & Turbulence

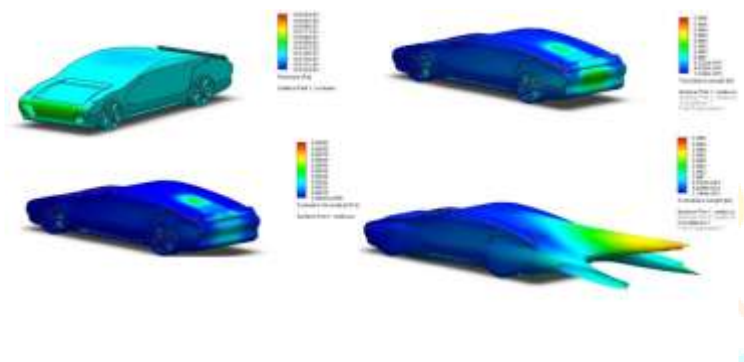


Fig 9. Pressure & turbulence

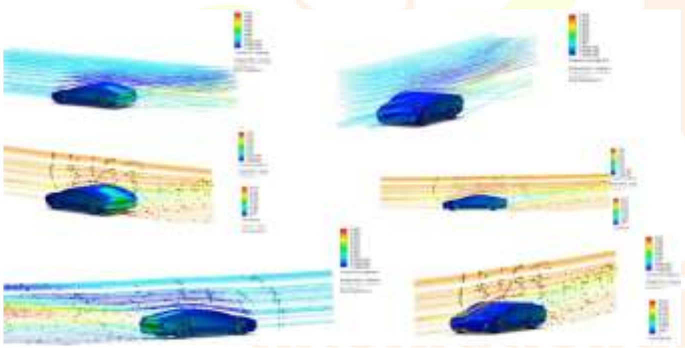


Fig 10. Streamline on plane

IV. CONCLUSION

By changing the design of car we have find that there is less aerodynamic drag, low wind noise and we can improve 2.5 % fuel efficiency of the car.

From the table 2 & 3 we have calculated drag force 'cd=0.29' and also reduces the drag force which is created by the side mirror and also the wind noise.

The frontal pressure is 102094.50 Pa, Mach number is 0.8 and also the turbulence length in meter is 0.005.

By improving the drag forces we can improve the vehicle mileage, better stability when car is running, improved road holding. Fig 1 & Fig 2. Show the 3D printed and modelling car.

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