Streamlining and Aerodynamic Performance Add-on Devices of Sports Cars

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ABSTRACT

Automobile aerodynamics is the method of improving performance of vehicle to pass through air with least effort, with better handling on road. This paper describes various devices used in sports model cars to improve aerodynamic performance. Sports model cars are using lot of aerodynamic devices to get good road grip even during cornering with optimal drag force. Different manufacturers use different devices for better aerodynamic performance. Some devices were used to decrease drag force and some devices were used for improving down force while straight running or during cornering. In this paper effect of number of such devices were discussed. Spoilers, Air dams, Air Diffusers, Scoops etc., are some of the devices generally used in sports cars.

Keywords: Automobile aerodynamics, Streamlining, Drag coefficient, Lift coefficient, Spoilers, Baby spoilers, Air dams, Air diffusers.

1. INTRODUCTION

Aerodynamics is the performance of objects to move through the air. The objects may be an aeroplane, automobile, rocket, even kite that pass through air. The rules of aerodynamics explain how an object while moving through air, is affected by motion of air. Aerodynamics applied in wide field designing many different things including building design, bridge design, towers, aeroplanes, rockets and motorsports/automotive vehicle design and many more. Movement of object in the stable air can be treated as movement of air over a stable object. Hence, the automobile can also be affected by air. “Aerodynamics” is a branch of fluid dynamics concerned with studying the motion of air.

1.1 Need of Aerodynamics

To control global warming, controlling of greenhouse gasses is very important. The majority of pollutants are emitting from IC engines of automobiles. By improving the aerodynamic performance the drag force can be reduced drastically from 40kmph and hence fuel can be saved. The saving of fuel in turn decreases emission of pollutants harming environment.

1.2 Objectives of the Project

The objectives of this project are

- To discuss air flow around the car while running at faster speed (at least more than 40 kmph)
- To reduce drag force and lift force on the car using streamlining
- To improve vehicle handling by using devices such as wings, splitters, spoilers, dams, diffusers etc.
1.3 Literature Review

Lombardi et al. [1] optimized the values of the design parameters, to minimizing a given objective function. They claimed that their approach is very flexible, meets multi-disciplinary requirements also to search for solutions without getting adverse effect on car style or performance providing better safety and efficiency.

Devanshu et al. [2] worked on solar car for reducing running resistance by reducing Coefficient of drag. There by optimized the performance of the solar car. They introduced aerodynamic consideration in designing solar car body which is to be participated in World Solar Challenge.

Rafael et al. [3] studied aerodynamic performances longitudinally, on the prototype of their Baja vehicle Bajarara Team Hermínio Ometto University, Araras, to develop the Baja project.

Pravin et al. [4] analyzed aerodynamic performance using Computational Fluid Dynamic (CFD) techniques, Morphing technique, statistical methods, Meshing and Morphing tools in ANSA to develop CFD mesh model.

Siva et al. [5] modeled Toyota fortuner car model in solid works and analysed using ANSYS Fluent. They determined the aerodynamic characteristics such as drag, pressure and down force.

Yuan et al. [6] investigated the aerodynamic characteristics of an automobile using numerical simulation and wind tunnel experiments. They investigated the sensibility of aerodynamic characteristics at the underbody, and summarized the influence of aerodynamic attachments on the vehicle drag.

2. PRINCIPLES

The forces acting on automobile and the condition of flow of fluids around the car while running are discussed in this chapter.

2.1 Forces on Automobile

The various forces acting on automobile while passing through air are shown in figure 1

- Drag force
- Lift force
- Down force

![Figure 1. Forces on Automobile while in motion](image-url)
2.1.1 Drag force

Aerodynamic drag is the force opposing the vehicle motion. The vehicle drag is due to high pressure acting on the front of the vehicle, surface friction and the vacuum left behind the vehicle.

The formula used to calculate aerodynamic drag force is

\[
F_D = C_D \frac{1}{2} \rho v^2 A \quad \text{... (1)}
\]

Where,

- \( F_D \) – Aerodynamic drag force
- \( C_D \) – Coefficient of Drag
- \( \rho \) – Density of air
- \( v \) – Velocity of the vehicle
- \( A \) – Frontal area

2.1.2 Lift force

Lift is force acting perpendicular direction to the path of the vehicle. It is essential for aircrafts to create positive lift to fly, but is dangerous in motorsports. In motorsports negative lift is preferred, which helps to increase vehicle grip on road and leads to faster cornering speed. The formula used to calculate the aerodynamic lift is similar to the drag formula but \( C_D \) is replaced with \( C_L \) (Lift coefficient) and is as follows.

\[
F_L = C_L \frac{1}{2} \rho v^2 A \quad \text{... (2)}
\]

Where,

- \( F_L \) – Aerodynamic Lift force
- \( C_L \) – Coefficient of Lift
- \( \rho \) – Density of air
- \( v \) – Velocity of the vehicle
- \( A \) – Frontal area

2.1.3 Down force

Down force is the force on automobile due to gravity or air passing over the surface of automobile. It can be treated as negative lift. This force helps the vehicle to have better grip on the ground and helps to enable greater cornering speeds.

### Table (1): Coefficient of drag of various body shapes.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Shape</th>
<th>Diagram</th>
<th>( C_D )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rain Drop (or Tear Drop)</td>
<td><img src="image1" alt="Diagram" /></td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td>Hemi Rain Drop</td>
<td><img src="image2" alt="Diagram" /></td>
<td>0.09</td>
</tr>
<tr>
<td>3</td>
<td>Wedge</td>
<td><img src="image3" alt="Diagram" /></td>
<td>0.42</td>
</tr>
<tr>
<td>4</td>
<td>Hemi Sphere</td>
<td>![Hemi Sphere Diagram]</td>
<td>0.42</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td>5</td>
<td>Sphere</td>
<td>![Sphere Diagram]</td>
<td>0.47</td>
</tr>
<tr>
<td>6</td>
<td>Square block</td>
<td>![Square Block Diagram]</td>
<td>0.80</td>
</tr>
<tr>
<td>7</td>
<td>Square block</td>
<td>![Square Block Diagram]</td>
<td>1.05</td>
</tr>
<tr>
<td>8</td>
<td>Cylinder</td>
<td>![Cylinder Diagram]</td>
<td>1.15</td>
</tr>
</tbody>
</table>

### 2.2 Types of Fluid Flows

The flow of fluids is mainly of two types.

- Laminar
- Turbulent

#### 2.2.1 Laminar flow

The particles of fluid of a flow system are always parallel to each other, then they are said to be laminar flow.

#### 2.2.2 Turbulent flow

If the path of fluid particles are not definite then the flow is said to be turbulent.

![Laminar and Turbulent Flows](image2)

**Figure 2. Laminar and Turbulent Flows**

![Laminar and Turbulent Flows past over sphere](image3)

**Figure 3. Laminar and Turbulent Flows past over sphere**
The flow of fluid over the car is laminar, but the flow becomes turbulent at rear end as shown in figure 4. This is due to formation of vacuum at the rear end. This vacuum has to be collapsed, otherwise it increases drag force on the vehicle which increases fuel consumption.

3. STREAMLINING

Streamlining is generally aimed at reducing air resistance as the vehicle moves through the air. Reducing air resistance improves fuel efficiency potential speed and various other things. It must be considered in the design of a various automobiles according to their engines rpm and torque of the vehicle such as payload, appearance comfort, size, cost, cooling, performance etc.

Streamlining is the process of enhancing the capability of an automobile to pass through air with least effort. From the drag force formula it can be observed that the drag force increases exponentially with vehicle speed. Up to 1930 the vehicles are made open top or flexible. Those vehicles could not reach speed more than 40 kmph. At that time Tatra, a Check company made their model T77 as shown in figure 6 with taper back claimed a $C_D$ value 0.22. From that the automobile manufacturers started modeling of vehicles in streamlined shapes.
Rain drop (Tear drop) shape gives least $C_D$ value from table (1). Generally solar cars as shown in figure 7 are made in such shapes to save the fuel and to get maximum range.

![Figure 7. Streamlined Body](image)

4. ADD ON DEVICES

Several devices are used to decrease the drag and lift coefficients of automobiles such as Spoiler, Wing, Air Dam, Air Diffusers etc.

3.1 Spoiler

A spoiler as in figure 8 is an automotive aerodynamic device which is used to spoil the vaccum created behind the car while motion and there by decreases the drag.

![Figure 8. Spoiler](image)

A Baby spoiler as in figure 9 is just like a spoiler but in smaller size. Generally the baby spoilers are made integral with luggage boot such as Maruti swift Dezire.

![Figure 9. Baby Spoiler](image)

The wing/Air foil as in figure 10 is similar to spoiler but it splits the stream line and some part passes over the wing which creates down-force and some part of air passes below it and collapses the vaccum to decrease drag force.

![Figure 10. Wing/Air foil](image)
3.2 Front Splitter

The front bumper consists of a parallel extension at the bottom which is called front splitter as shown in figure 11. The area above splitter creates down-force at front side and increases road grip on front wheels.

![Front Splitter and Air Dam](image)

**Figure 11. Front Splitter and Air Dam (Front Spoiler)**

3.3 Air Dam/Front Spoiler

Air dams, also called as air dampers which is different from splitter/scoops. Air dam is crucial for engine cooling and high speed stability for the vehicle. Intercoolers and oil coolers need air dams to give better cooling.

A well-designed front air dam will keep the nose steady and pointed at the pavement in high speed driving. This would give the driver more confidence and control over the steering and vehicle in sustained high speed driving environments. When the spoiler is fitted at the front of the vehicle, it is known as an Air Dam. The Air Dam is fitted at the bottom of a car’s nose or front bumper. It directs the flow of air around the car instead of under it.

3.4 Side Skirts

Side skirts as shown in figure 12 are used to minimise the ground clearance at the side of the vehicle. They help to create aerodynamic downforce by reducing the amount of high pressure from around the vehicle being drawn to the low pressure area under the vehicle. The effectiveness of the side skirts depend on the clearance from the ground, 2 cm or less.

![Side Skirts](image)

**Figure 12. Side Skirts**

3.5 Ducts

Different ducts are shown in figure 13 which provides supply of coming air to cool the brakes, engine, inter coolers etc. and at the same time provides downward force. The air passing through the channel creates down-force.

![Ducts](image)

**Figure 13. S-Duct, Side air intake, Side Ducts**
3.6 Diffusers

Aerodynamics is not only enough on upper side or four sides of the vehicle. The bottom surface also has to be aerodynamically modeled, because the air flowing below the car is slower than upper side flowing air. Slow speed means high pressure which creates upward force and lifts the car. Figure 14 shows such air borne accidents.

![Figure 14. Air borne accidents due to flying of cars during races](image)

Diffusers are as shown in figure 15 comes under body aerodynamics. They accelerates the flow of air under the car, and creates low pressure, and thus increasing down force. The diffusers are like fins decreases ground clearance, thereby decreases amount of air passes under the car.

![Figure 15. Air Diffusers](image)

3.7 Active Aerodynamics

The angle of Spoilers/Wings or Air diffusers gives optimum performance at a particular speed or limited range of speeds since their angle is fixed. Some vehicles are equipped with active aerodynamics i.e., they are intelligently operated with speed. The embedded system varies the angle of spoiler or diffusers according to speed. Bugatti veron, Lamborgini, Ferrari, Porsche etc., are some of the vehicles equipped with active aerodynamics.

![Figure 16. Active Spoiler](image)
5. CONCLUSIONS

With this paper the following conclusions were made.

- Automobile aerodynamics is must in sports cars which are used to improve performance of vehicle, with better handling on road.

- Along with Streamlining add on aerodynamic devices are needed to get good road grip even during cornering with optimal drag force.

- Different manufacturers use different devices for better aerodynamic performance. Some devices are used to decrease drag force and some devices are used for improving down-force while straight running and/or cornering.

- Spoilers are used to increase down force at back side of the car, so as to get good road grip. Air foil/Wing increases the down-force as well as collapses the vacuum pressure at the back side of the car.

- Air dams are used to collapse the front air pressure and sends air to cool engine/radiator.

- Air splitter is the bottom most part of the front bumper, which is used to create down force at front end.

- Diffusers are under body aerodynamics, used to accelerate air flowing under the car and there by decreases the pressure at bottom side of the car, which in turn decreases upward force and stops flying of car.

- Active aerodynamic devices are smart aerodynamic add-on devices, which of their inclinations or active work position changes with speed.

REFERENCES


