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AERODYNAMICS OF VEHICLES

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ABSTRACT

Automobile performance depends upon engine, tires, suspension, road but most significant impact is by aerodynamics, nobody was thinking about aerodynamics when horse was replaced by thermal engine over 100 years ago. The goal was to shield the driver and passengers from wind, rain and dust as before. After the tremendous advancement flight engineering, the idea of applying aerodynamics to road cars appeared much later. Smooth and streamlined shapes were developed for both airships and aircraft that significantly lowered the drag and allowed higher cruising speeds at any (limited) engine power. This article will discuss about all the small components of aerodynamics, its importance in vehicle design. Broadly vehicles are divided into two segments one is racing vehicles and other is general vehicles though both type of vehicles require aerodynamic properties but in different objectives. Importance of aerodynamics in motorsports and in road vehicles will be discussed as well as the need of other aerodynamic components used in these vehicles.

Key words: Aerodynamics, performance, flight, engineering, cruising speed, motorsports, road vehicles & streamlined.

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1. INTRODUCTION

Aerodynamics can be defined as the study of the interaction of fluids and body flowing under and through bodies. Initially aerodynamics came from aeronautical engineering while researching aircraft wing design for aircraft flying in the atmosphere of the earth. Aerodynamics are used in many things such that to design different buildings, bridges, motorsports vehicles etc. Few most vital components of aerodynamics are:

Drag: Aerodynamic drag is defined as the force opposing direction of the movement of the body. Front of the body experiences high pressure and rear of the vehicle experiences negative pressure left behind, these two are the main contributors of vehicle drag.

Lift: Force acting perpendicular towards the vehicle movement. In terms of aircraft positive lift always helps in lifting of aircraft from the ground, for motorsports negative lift is required in order to keep the vehicle on the ground and maintain high grip levels resulting fast cornering.

Downforce: Downforce is just opposite to lift as discussed earlier it is the force required to keep the vehicle on the ground and provide high grip levels and even improving cornering.[1]

2. LITERATURE SURVEY

2.1 How Downforce is created

From the old days the design of the race cars has been made in a streamlet shape specially when reducing air resistance at high speed was very important. Up to 1960's this was the trend, believing that aerodynamic car is esthetically appealing. In fast moving vehicles the pressure of wind is continuously exerted, the force exerted on the vehicle bodies pushes the vehicle in opposite direction this causes drag, if this drag is channelized in such a way that the additional grip required by the vehicle from the tyre is enhanced it can be used for a good cause. In vehicles initially racing cars used this concept to increase grip levels since these are fast moving vehicles G forces act on the body and dis balances the vehicle during fast corners. The concept of wing was introduced from aircraft engineering, were large wing is fitted on the rear of the vehicle such that when the air travels across the vehicles it hits and pushes the wing downwards it generates down force explained in the figure 1..

Figure 1

2.2 Importance of Aerodynamics in Motorsports

At the start of the twentieth century, when the first two cars pulled one next to the other, automotive racing must have started from there. Initially when that first moment on the sport grew steadily, not always following the automotive industry's evolutionary trends, contemporary race cars, for example, had features such as inverted wings and protruding angular plates that appear unpractical and are therefore unusable by the automotive industry. Many involved in the sport maintain that motor racing is a "pure sport" with its own set of rules that the general automotive industry does not need to gain. Those involved in the sport insist that racing is a "pure sporting event" with its unique set of rules that the general automotive industry does not need to benefit. These views paved the way for many forms of racing. The vehicles feature production sedans in some racing categories, and in others they look like fighter aircraft, not to mention the different tracks that range from gravel roads to dead straight, country side, or regular roads.[2]

Aerodynamics gradually emerged as a significant design aspect or component in all the mentioned form of racing, however, and by the end of the first century of automobiles, all racing car designs have some aerodynamic element level and gradually the engineering grew year after year onto the next level. Although the base of aerodynamics were defined over the past 2 centuries, not all concepts were initially utilized for racing car design. Naturally, the need for minimal drag was recognized first and Hucho described one of the 1st streamlined racing cars to break the 100 kilometer barrier. This particular car had a long cylindrical cigar like shaped structure to reduce aerodynamics. Onwards there was rapid change in aerodynamic designs which included droplet like shape then the design was dominated by airfoil shape. [3], [4]

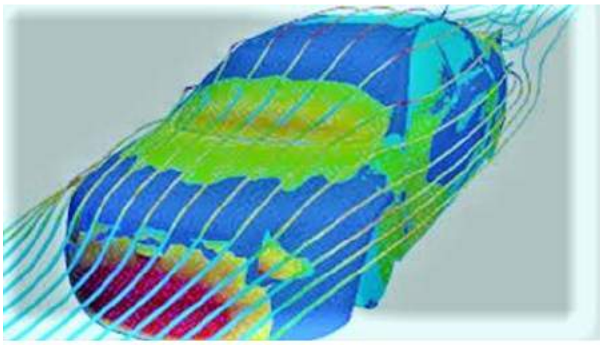

Figure 2: Aerodynamics flow on car

After few more years an Opel designed race car was seen equipped with wings, these were positioned in the side in such a way that they created a much needed down force to keep the fast moving car on the ground and to provide maximum grip to the road. After whole 40 years it was seen that fixed wings will only work one dimensionally and finally adaptive wings were created which could change their angle according to the speed of the car for example to give maximum down force the wing will be at an angle of 90 degree and to provide least air drag it will adjust itself at around 0 or 180 degrees. The flow of air around a fast moving racing car in one or the other form affects all of its components.[5][6]–[9]

In maximum forms of racing it is ideal to build fastest vehicle in a particular segment. In an orthodox manner in terms of drag, stability and lift, the result of existing aerodynamics are summarized. Initially the side force acting on the vehicle was not taken into observation because racing cars go much faster than the prevailing winds and making powerful downforce instead of lifting became new problem. The three components of aerodynamics came to light as engineers discovered if they can manage downforce on tires then vehicle stability can increase drastically. When car is travelling at high speed from view of driver lateral instability can be very uncomfortable. This was seen in high speed record vehicles which used enormous stabilizers. When high speed car having weight of 1000kg taking a corner, the force on the tire will be less than 1000kg even if it uses high performance tires this will decrease the stability at the corner and even the grip, the only solution to it can be high amount of downforce generated by wings.

2.3 Importance of Aerodynamics in road vehicles

In the field of fluid mechanics, general vehicles are close to a bluff body. Their structure is extremely complex in nature. Cavities present at inner and outer side of the body, rotating wheels with different shapes and sizes constitute to more complexity into the design. Vehicles possess complete 3 dimensional stream, flow separation is very common and follow by reattachment. Huge turbulent wakes forms at the rear end of the body and in most of the cases contain longitudinal trailing vertices. As a typical bluff body design "drag" which not the only issue is the most common issue which is called pressure drag, which is different from drag experienced by aircraft and ships which is called frictional drag. The avoidance of the mentioned drag or if not practical its control in correct direction is the main goal of vehicle aerodynamics.

With regard to their usage road vehicles comprises of wide range of variety in terms of shape and sizes for example passenger car including hatchbacks, sedans, SUV's and other type of vehicles such as busses, truck, getaway etc. It is interesting to know that truck and even race cars have more than one body comparing with general vehicles having single body.

As race car design being an exception the design of the road vehicles is not determined by the need of aerodynamic effects. An airplane is designed keeping in mind to extract more and more lift and ion the contrary passenger or general vehicles are designed for functional, economical as well as most importantly aesthetic concept. The approach in designing of these two type of vehicles is totally different. Depending upon the need and purpose of each type of vehicle the objectives of aerodynamics for each and every vehicle differ widely. While designers look to pull out a design having least drag other aerodynamic property are also very significant. Negative lift is boon for cornering aspects of race cars but it is not relevant for trucks. Wind noise is the critical aspect in road vehicles and busses but significant with race cars. For general vehicles exterior design is most important because as they say “what looks good sells good” in the car market worldwide.

Consequently, while vehicle aerodynamics is evolving and improving, it is not advancing towards a single ultimate design, as in the case of subsonic transport aircraft, for example. On the opposite, it has to come up again and again with new shapes. However, it cannot be denied that aerodynamics does influence design. The high trunk typical of hatchback cars with low drag is the most striking example. Although it tends to look "bulky," due to its beneficial impact on drag— and the extra luggage space it offers, designers had to embrace it. Today's cars are more streamlined than ever, and its own styling element has become an "aero-look."

2.4 Active Aerodynamics

The Convention specifies that there will be some drag associated with any component that produces downforce. So how do we get the Aero’s Holy Grail, get downforce at the corners and low or no drag in a stretched road? Active aero comes into play here. Active aero is an aerodynamic control surface providing best of the both world. A wing can either retract into the bodywork for straight-line speed reducing drag or extend itself in the corners to give downforce. A good example of this is the active rear wing of the McLaren P1 a super car from a British brand. The wing tugs itself and lies flat within the rear bodywork when minimal drag is necessary and at low speeds; and at higher speeds, it is lifted by two hydraulic struts, resulting in downforce. The wing hits its highest position and most powerful angle of attack in race mode, as with the new Ford GT, driving the P1 into the ground for intense lateral grip. The wing also rapidly folds forward under heavy braking to provide an impact on the airbrake.[10][11]

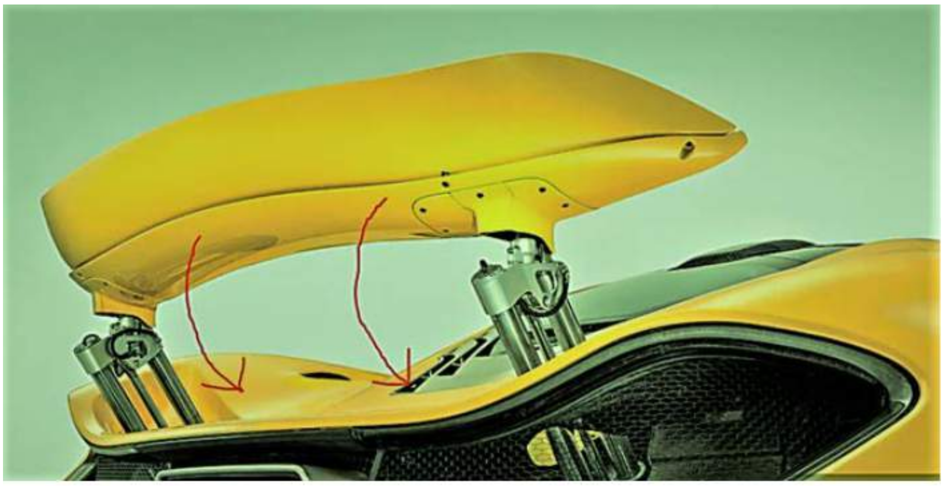

Figure 3 Rear Spoiler

2.5 Aerodynamic components used in cars

2.5.1 Front Splitter:

It is essentially an aerodynamic component that balances out the front and the rear distribution of downforce generated in high speeding car. It is generally found on the front end of a car just fitted under the front bumper. It consists of parallel flaps at the bottom, it creates a high pressure area above the splitter and low pressure below it, and hence this high pressure is drawn to low pressure pushing the front end of the car towards the ground.

2.5.2 Side skirts:

Side skirts do not reduce high pressure air on the side of the car however it splits the bottom of the car into two parts one the under body and other the side of the car. Underbody region has low pressure and high air velocity and side of the car has relatively higher pressure. Without the side skirts in place the air from side of the car will rush into the underbody due to pressure diffuser difference reducing downforce. With the presence of side skirts, it acts like a blockage. The performance of the side skirts is based on the clearance from the surface, below 2cm or less is best practice over this greater ground clearance drastically decreases.

2.5.3 Diffusers:

These are used to increase volume at the rear section of the car under the body, this increased volume creates a void which had to be filled and therefore increases velocity of air travelling at rear end of the car, and as the resultant of this low pressure will be created to increase downforce.[12]

3. RESULTS AND DISCUSSIONS

The study of automotive aerodynamics started as a step-by-step for similar research in the field of aviation, using wind tunnels and technologies developed for aircraft from the 1920s. In the first place the pioneers of low-drag cars demonstrated models which were both industry's ability to build and public's readiness to buy well ahead of the first time. The 1930s introduced a novel approach to automotive aerodynamics, focusing basic automotive engineering and achieving the first, serious production applications.

Drastic changes to automobile design occurred in the 1950s, due to aerodynamic concerns. After World War II in the 1950s, most of the aerodynamic research was aimed at prototype designs and race cars as well as production vehicles were almost entirely influenced by appearances. In the next decade, new wind tunnels were opened in a more promising way, for both climate and aerodynamic research. Car stability around the corners at high speed became an important part.

The manufacturers, who took this topic seriously, built their own internal tunnel facilities at the end of the 1960's, which has seen a record number of automotive aerospace applications. In the initial 50 years' aerodynamics of automotive came closer to wind tunnels with the help of universities and industries. These methods challenged researchers to find new test programs and manufacturers make more aerodynamic product with high efficiency, quicker and even silent model.

4. CONCLUSION

The importance of aerodynamics in vehicle and car is equated with aerodynamics in the aircraft and is not limited solely to drag reduction. Downforce generation and its effects on lateral stability have important impacts on race car performance, especially in high-speed turns. All aerospace-type design techniques are used to prototype and refine current race car types. Due to effects like stream separation, vortex flow or boundary layer change, it is not always possible to predict flow across most types of race vehicles.

Due to its competitive nature and the short development period, engineers have to use hyb rid track, wind tunnel and CFD tests to assess technology decisions. With the above study it is evident that aerodynamics is all about reducing drag, wind noise and prevent undesired and dangerous lift forces acting on vehicles at high speeds. So modern aerodynamics is a very important science, it is used to save fuel in terms of general vehicles, it is used to make such vehicles stable and finally makes our street safe around large skyscrapers.

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