Effect of fluid dynamics over the external structure of the vehicles

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Abstract:-

In the paper below we are going to review the various fluidic forces acting on the external body of the high speed bodies ,mostly sports car and motorcycles . The acting of the various fluid mechanism like surface drag and downforce can be best analyzed by the study of the aerodynamics and illustrating principle of its applications.High velocity vehicles such as motogp bikes and formula 1 car are so designed to limits the force of drag on them which effects its performance and fuel economy despites the downforce is also maintained to effect the better cornering capabilities for such.modern day automotive industry uses various methods like wind tunnel, CFD method to study the flow of the air mass on and around their external body shape and how to overcome the necessary turbulence being produced on the curves end.

Key Words: Aerodynamics, Drag measurement, CFD Analysis, SAE Formula, High velocity vehicles

1. INTRODUCTION:-

Improved engine efficiency and reducing drag was the method to increase the fuel comsumption of the vehicles and right from the starting of the automotive revolution engineers and designers had tried to streamline the body shape of the vehicles to reduce the drag over them [1]. Hence it is very important to formulate basic principles of vehicle body optimization, and definition of drag lower limit. For a perfect car body configuration the lowest possible aerodynamic drag coefficient should be ~0.16. [9]Great attention has being paid to the aerodynamics of racing cars as the race car is always at a high-speed condition compared with ordinary cars. The motive of the aerodynamic research and development of race car is to provide maximum downforce, minimum aerodynamic drag and good directional stability at high speeds.

Also, considerable attention must be given to the unsteady aerodynamic effects on vehicles. In some of the typical cases in which the understanding of unsteady aerodynamics is essential are as follows: the effects of atmospheric turbulence on the aerodynamic drag, running stability under breezy crosswind conditions, and driving stability at a high-speed condition. In all cases, the problem that we face is strongly related to the correlation between the ideal steady measurement in a wind tunnel and the real unsteady condition on the road [2].

2. Aerodynamics characteristics:-

Some of the basic forces of the fluid properties influencing the motion of the speeding vehicle are lift ,drag, thrust, weight.Out of this the down force and the lift is the fundamental to be working in and around the body of the vehicles.It is genially produced due to the difference in the air pressure created due to the flow of air over and under the vehicle.This difference led to the generation of the force in the downward direction assisting in the cornering ability of the vehicle.

2.1 Aerodynamic drag (Cd):

Drag is the resist that the flow of the air produce when it flow over the surface of the moving body. Aerodynamic drag is the combination of pressure drag and viscous drag. The pressure drag is the most dominant one of the both. The pressure drag is causes due the shear forces acting between the two layers of fluid.

Aerodynamic drag, Cd = Drag force/$0.5\rho * v^2 * A$

Where,

ρ is the air density in kg/m3

A is the effective frontal area in m2 v is the velocity in m/s

Aerodynamic drag can only be decrease by analyzing its source. As mentioned formely, aerodynamic drag opposes the forward thrust of the vehicle hence it is an unwanted form of the motion in the endurance of the vehicle or any moving body.

Drag is a function of the frontal area, air density, the coefficient of drag of the vehicle, and the vehicle speed squared [5]. The speed of the vehicle is proportional in the power of cube to the opposing drag force so a small increment in the drag force produce by the speed of the vehicle on the body requires a large change in the power output generated by the engine . The air density and the velocity of vehicle are unable to be changed by the design of the vehicle but the frontal area but coefficient (Cd) of drag could be. Reducing dimensions of the car can reduce the frontal area, but there is a limit to how small this area can be since people must be able to sit comfortably inside the vehicle. Therefore, the easiest method of reducing drag is to lower the coefficient of drag of the car [3].

The drag coefficient of the vehicles depend prodimentaly on the shape and geometry of the car so designers gave priorty to the exterior appearance of the vehicle.

The main difference between the aerodynamics of a racing vehicle and the aerodynamics of a passenger vehicle is that racing vehicles aim to increase downforce, while passenger vehicle aim to decrease drag [6].

Where less advancement has taken place in the modernization of the drag reduction around the wheel of the vehicles as it could be complicated as compared to the top and bottom surface of the vehicle.

2.1.2 Aerodynamic Downforce

Downforce is the force of the air acting downward on the car and helping the wheels stick when you want to corner, and stick when you want to accelerate down the straight.[9]

Downforce generates negative lift or down lift by the flowing air over the body. The shape of the aircraft is designed so that they produce less downforce to lift it above the ground [7]where as on contrary the inverse is done with the ground moving vehicle by making more air to be pushed and shift all over the top surface of the body making it stick to the ground .The direction of the air is done by the front section of the vehicle. The frontal end fascial features a very reducted angled nose and flared, wide from fenders.

The importance of downforce starts with motorsport. When the need is to go as fast as possible, one goal is to maximize straight line speed. The other solution is to increase speed on corners so that cars arrive on the straights going faster already and that increases speed overall, in every part of the track. The challenge with cornering a car harder is centrifugal force. Which essentially spends all its time trying to push anything going in a circular path, radially to the outside, pushing harder and harder as speeds rise. Engineers will add stickier tires, stiffer suspension and increase the width of the car to raise the speed at which centrifugal force overcomes grip but like the hunt for great straight line speeds, costs, technology and often rules will limit what is possible.

Enter wings, aero foils, splitters etc., are help the vehicle to increase the grip of the car by aerodynamic means by using downforce with respect to speed. And the faster you go, the more downforce gets created and hence, more grip you will have. It is stupendous amounts of downforce that allow F1 cars to corner as fast as they can. Ironically, it is also downforce that often prevents drivers from chasing each other closely into corners.

The motive of further increase in the tire grip led the major revolution in racing car design, by the use of negative lift or 'downforce'. Since the tires lateral adhesion is roughly proportional to the force acting downwards on it, or the friction between tire and road, adding aerodynamic downforce or negative lift to the weight component enhance the adhesion. The more downforce also allows the tires to transmit a greater thrust force without spin of wheels, and enhances the maximum possible acceleration. Without aerodynamic downforce to increase grip, modern racing cars have so much power that they would be able to spin the wheels even at speeds of more than 160 km/h.

Downforce, or negative lift, which pushes the car onto the track and makes the vehicle stable at high speed. It is said that at maximum speed, an F1 car produces 5 *g's* of downforce that is 5 times its weight pressing it down onto the track.

Downforce has to be balanced on the all part of the body of the vehicle.The left and right downforce is generally balanced by simply achieving the symmetrical shape of the body

3. Usually every part of the body of a vehicle produce downforce and it is divided into three main parts viz front end, rear end, bottom.

3.1 On rear

Spoilers,air difuuser and wigns are the main component to be used at the rear end of the vehicle mostly cars to increase the downforce.

Spoiler

A Spoiler is a flat or curved surface used at the end of the vehicle which disturb or break the air flowing in the streamline flow over the body of the car , producing a manageable segregation in flow in a desired place. This is necessary as the smooth air flow over the top surface of the vehicle produce positive air lift hence it becomes necessary to interrupt or totally remove it to produce the required downforce needed to keep the vehicle attached to the ground.

Diffuser is the most widely implicated idea working on the principle of the Bernoulli equation as same in the venture device producing downforce in the rear section of the vehicle.[9]

3.2 On Front

Main source of downforce are front spoilers (called spoilers, dam or splitters), canards (called also dive plates), vortex generators, front diffuser.

Splitter

Splitter is the extruded surface at the front end of the vehicle attached to increase the pressure over the vehicle rather than the underneath the vehicle by reducing the gap between the surface and the bottom of the vehicle. It is a parallel surface to the ground producing more amount of downforce on the vehicle acceleration.

In addition to this aeronautical industry has also contributed in the design aspect as specially in the design of the motogp bikes fairing. It led to the introduction of the winglet design to the front section of the fairing which work in the same as the spoiler or diffuser in the rear of the car,producing downforce which help in better cornering abilities of the bike and also making the wheelie act in affective in the mid torque power cycle as the downforce produce increases with the increase speed of the bike

3.3 On bottom

Althought nothing much has to done in the bottom of the vehicle but the air trapped and moving under the vehicle can be reduced by obstructing the path of the air .This is done by making air duct and air vent which form air vortex and air capturing in the bottom part resulting in reducing upward force due to the positive downforce.

4. Aerodynamic Flow of Fluid Simulation Methods

1. Closed Tunnel Test
2. Computational Fluid Dynamics (CFD)
3. Track test

4.1 Closed Tunnel Test

Closed tunnel test is the primary experimental development . Measurement here are done by the relative difference produced between in the steady vehicle and the flowing wind (in a streamline flow) over it and around it.

4.2 Computational Fluid Dynamics[9]

Computational Fluid Dynamic (CFD) is the branch of fluid dynamics providing a cost-effective mean of simulating real flows by the numerical solution of the governing equation.[8]

The governing equations for Newtonian fluid dynamics, namely the Navier-Stoke equation. The differential equation governing the system is converted to a set of algebraic equation at discrete points, and then solved using digital computer. For such a complex interaction, CFD analysis is probably the only efficient tool in order to assess specific design parameterization of a generic car shape.

Aerodynamic evaluation of air flow over an object can be performed using analytical method or CFD approach. On one hand the analytical method of solving air flow over an object can be done only for simple flows over simple geometries like laminar flow over a flat plate. If air flow gets complex as in flows over a bluff body, the flow becomes turbulent and it is impossible to solve Navier- Stokes and continuity equations analytically, in that case CFD is useful.

3. CONCLUSIONS

In the details given above by the paper we had gone through the various attachment or addition to the body geometry of the high velocity moving vehicle to reduce the drag produce or increase the downforce to give a better effect on its handling and cornering abilities.

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