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Aerodynamic Study of F1 car

PrasadGaware[1], Anwar Maniyar[2],Vinod Sonawane[3],Nishigandh Gorade[4]
Department of Mechanical Engineering [1,2,3,4],Sharadchandra Pawar College of Engineering,Otur[1,2,3,4]
Email: prasadgaware1@gmail.com[1] ,maniyaranwar1993@gmail.com[2]

Abstract-Aerodynamics is a branch of dynamics which relates with studying the motion of air, particularly when it interacts with the solid object. Aerodynamic is a combination of fluid dynamics and gas dynamics, with much theory sharedbetween them. In this paper different forces acting on a formula 1 car (drag force, lift force).Measurement of forces is done by computational fluid dynamics CFD and wind tunnel testing WTT. On the basis of forces and measurement the comparison has been done over the F1 car. The Formula One cars design has constantly evolved throughout the sport's history, as teams attempt to both out-smart their competitors and keep up with ever changing regulations. Since aerodynamic performance is one of the most important factors in a car's design, teams fluid dynamics is the mathematical study of moving liquids and gases, to model the flow of air past the car as it races to the finish line. Fundamental to this study are the Navier-Stokes equations, which are so complex that they cannot be solved directly. The mathematicians turn to powerful computers to provide approximate but accurate solutions.

Index Terms-CFD, WTT.

1. INTRODUCTION

Automotive aerodynamics is the study of the aerodynamics of road vehicles. The main goals of which are reducing drag and wind noise, minimizing noise emission and preventing undesired lift forces and other causes of aerodynamic instability at high speeds. For so classes of racing vehicles, it may also be important to produce down force to improve traction and thus cornering abilities. Aerodynamics is most important factor in today's motorsport. The teams and the manufactures spend countless hours in the wind tunnels to make their car produce the minimum amount of drag but at the same time getting the most down force that they can. The aerodynamics is the last frontier where improvements can be made and getting the right settings for the right track, could spell win or lose.

A Formula-1 car has many aerodynamic devices that used for reducing the lift and drag forces on the car and there-by reducing the lap times. But, the lift and drag forces are inversely proportional to each other. Often one tends to ignore the fact that the combination of the right configuration of all the add-on devices is what contributes to the reduced lap times and not just the design of the individual aerodynamic add-on devices. For example, the lift reduction achieved by an aerodynamic device, say the front wing, comes at the cost of higher area being exposed the air leading to an increase in the drag force, but, the additional down force is essential for F1 cars as the high speed requires huge amount of traction to improve its stability, especially at corners to allow high cornering speed. In race cars, especially the open wheel types like the ones used in Formula-1, the add-on devices play a major role in the lap timings and ultimately is the difference between the best and the rest.

1.2 Types of forces acting on cars:

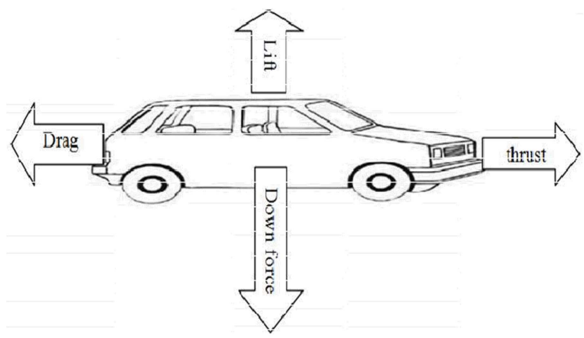

Fig 1. Forces acting on car

Weight: Weight is a force dependent on object's mass. The mass of the object is multiplied by the magnitude of gravitational acceleration gives weight. This weight has a significant effect on the acceleration of the object.

Lift: Lift is due to movement of the air around an object. It is the sum of all fluid dynamic forces on a body normal to the direction of external flow around the body.

Drag: Like wind friction causes drag in an automobile, aerodynamic friction and displacement of air during creates aerodynamic DRAG. Drag occurs any time that air is displaced from its normal condition.

Downforce: Downforce is simply the force acting down towards the ground. On our car we have a force which acts down on the ground to keep the car fixed to the track as it is going around corners.

Thrust: When a body is in motion a drag force is created which opposes the motion of the object so thrust is the force produce in opposite direction to drag that is higher than that of drag so that the body can move through the fluid.

2. AERODYNAMICS IN F1 CAR

2.1 Front Wing

Fig 2.Front wing

- Main Plane(1) is nearly the whole width of the car suspended from nose(4).
- Two aerofoil flaps (2) are fitted on each side of main plane.
- End plates (3) are mounted on each side of main plane.

The front wing on the car causes about 1⁄3 of the car's downforce and it has experienced more modifications than rear wing. It is the first part of the car to meet the air mass. Therefore, besides creating downforce, it's main function is to efficiently guide the air towards the body and rear of the car, as the turbulent flow impacts the efficiency of the rear wing.

2.2 Rear Wing

The rear wing consists of two sets of airfoils connected to each other by the wing endplates. The most downforce is provided by the upper airfoil.Modern rear wings produce approximately 30-35 % of the total downforce of the car.

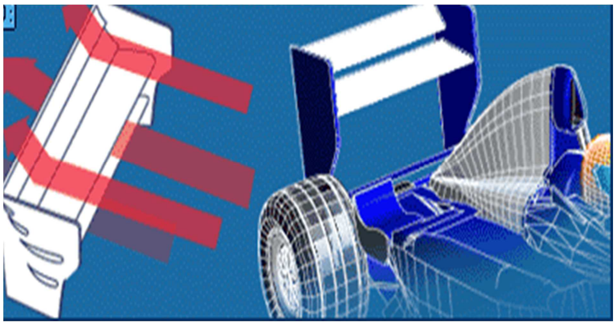

Fig 3.Rear wing.

2.3 Barge Boards

Barge boards smooth out and separate the air that has been disrupted by the front wheels.

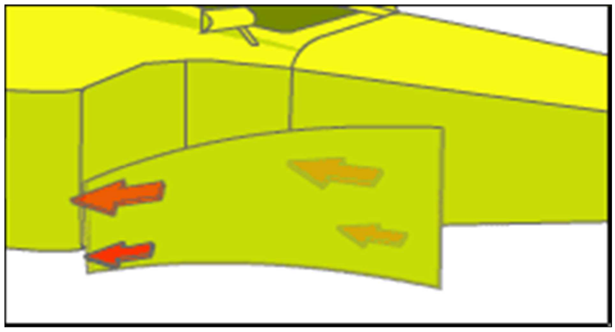

Fig 4. Barge board

They separate the flow into two parts:

1. First directed into the side pods to cool the engine.
2. Other is diverted outside to reduce drag.

2.4 Ground Effect

The flow volume between the vehicle and the ground is strongly dependent on the car's attitude relative to the ground. The gap between the bottom of the sidepods and the ground was sealed with so-called sidepods. Very small ground clearance results in positive lift, since there is almost no airflow between the underbody and the ground.

2.5 Rear Fans

This is new way of creating downforce independent of speed. It is done by using two rear fans to suck in air from under the car, thus creating low pressure under the car.

2.6 Wheels

Open-wheeled race car have a verycomplicated aerodynamics due to the large exposedwheels. The flow behind wheels is completelyseparatedThe frontalarea of the fourwheels may be asmuch as 65% of the total vehicle frontalarea.

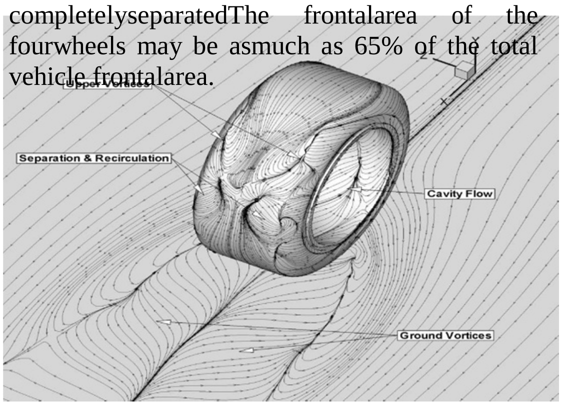

Fig 5. Surface flow pattern on wheels

2.7 Diffuser

- Mounted at the underside of the car behind the rear axle line.
- It consist of many tunnels and splitters to control airflow.
- It increases suction thus increasing downforce.

3. TOOLS FOR AERODYNAMIC STUDY:

1. Computational Fluid Dynamic (CFD)
2. WindTunnel Testing

3.1 Computational Fluid Dynamic (CFD)

Computational Fluid Dynamics (CFD) is a computer-base technology that studies the dynamics of all things that flow. In Formula One racing, CFD involves building a 3D model of a race car and then applying the laws of physics to the virtual prototype to predict what the down-force or drag may be on various components of the car or how the car will respond in various wind conditions, changing environmental conditions or on different road surfaces.

3. Steps in solving CFD problem

- Define the modeling goals.
- Create the model geometry and mesh.
- Set up the solver and physical models.
- Compute and monitor the solution.
- Compute and monitor the solution.

Three models are created using PRO-E and these are analyzed using FEA these results are shown as below.

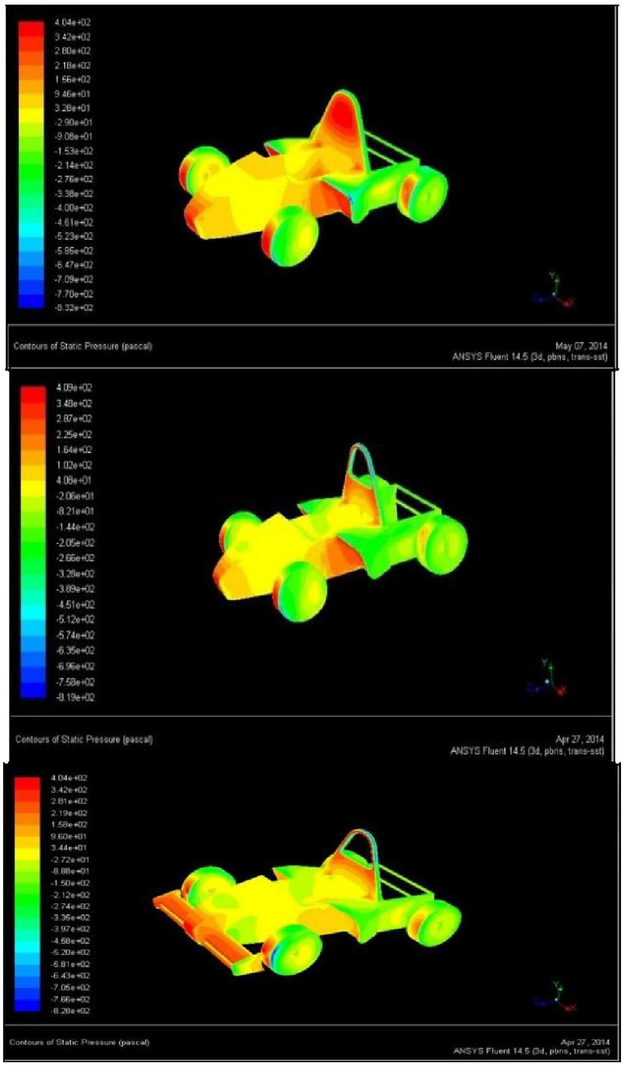

Fig 5. CFD Comparison of model 1, model 2, model 3.

3.2 WindTunnel

Wind tunnel is the mainexperimentaldevelopmentfacilityMeasurement. The wind tunnel are based onthe reciprocity effect of the wind speed andvehiclespeed (vehicle is steady, air ismoving). The largest test section would be desirabletoreduce blockage and better simulaterealcondition. But the disadvantage is operational cost of a fullscale tunnel ishuge.

Fig 6. Wind tunnel

A typical design of an windtunnel:

1. Model scale40-60%
2. Contraction ratio5-7:1
3. Wind speed: 40-60m/s
4. Rollingroad
5. Boundary layersuction
6. Temperaturecontrol

Many wind tunnels use scaledmodels. The aerodynamic similitude is respectedifcoefficients are the same for scaled andreal model.

CONCLUSION

After detailed study of aerodynamics in F1 car, we can say that F1 car is most aerodynamic of all the vehicles. The design is made such that it cuts through the air with minimum air friction and channelize the air flowing over up to the rear wings. It gives highly reduced drag and lift force acting on the car body. It generates more amount of down word force making the car stable at very high speeds. It is the pinnacle of racing sport technology.

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