*Priyabrata Adhikary Journal of Engineering Research and Application* *www.ijera.com*
*ISSN: 2248-9622 Vol. 8, Issue 12 (Part -II) Dec 2018, pp 66-70*

RESEARCH ARTICLE OPEN ACCESS

# C.F.D. Analysis of Modern Cars: A Comparative Study

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**ABSTRACT**
Aerodynamics is the science of how air flows around and inside objects. More generally, it can be labeled "Fluid Dynamics" because air is really just a very thin type of fluid. Above slow speeds, the air flow around and through a vehicle begins to have a more pronounced effect on the acceleration, top speed, fuel efficiency and handling. Therefore, to build the best possible car we need to understand and optimize how the air flows around and through the body, its openings and its aerodynamic devices.
***Keywords –*** CFD, Aerodynamics, Automobile, Car Design

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Date of Submission: 20-12-2018 Date of Acceptance: 04-01-2019

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## I. INTRODUCTION

As millions of air molecules approach the front of the moving car, they begin to compress, and in doing so raise the air pressure in front of the car. At the same time, the air molecules travelling along the sides of the car are at atmospheric pressure, a lower pressure compared to the molecules at the front of the car. Just like an air tank, if the valve to the lower pressure atmosphere outside the tank is opened, the air molecules will naturally flow to the lower pressure area, eventually equalizing the pressure inside and outside the tank. The same rules apply to any vehicle. The compressed molecules of air naturally seek a way out of the high-pressure zone in front of the vehicle, and they find it around the sides, top and bottom of the vehicle. Rear vacuum is caused by the "hole" left in the air as a vehicle passes through it. At speeds above a crawl, the space immediately behind the car's rear window and trunk is "empty" or like a vacuum. These empty areas are the result of the air molecules not being able to fill the hole as quickly as the car can make it. The air molecules attempt to fill in to this area, but the car is always one step ahead, and as a result, a continuous vacuum sucks in the opposite direction of the car [1-20].

This inability to fill the hole left by the car is technically called Flow detachment. Flow detachment applies only to the "rear vacuum" portion of the drag forces and has a greater and greater negative effect as vehicle speed increases. In fact, the drag increase with the square of the vehicle speed, so more and more horsepower are needed to push a vehicle through the air as its speed rises. Therefore, when a vehicle reaches high speeds it becomes important to design the car to limit areas of flow detachment. Ideally, we give the air molecules time to follow the contours of a car's bodywork, and to fill the hole left by the vehicle, its tires, its suspension and its protrusions. Extra bodywork allows the air molecules to converge back into the vacuum smoothly along the body into the hole left by the car's cockpit, and front area, instead of having to suddenly fill a large empty space. The force created by the rear vacuum exceeds that created by frontal pressure, so there is very good reason to minimize the scale of the vacuum created at the rear of the vehicle. When the flow detaches, the air flow becomes very turbulent and chaotic when compared to the smooth flow on the front of an object. The entire length of the car really needs to be optimized (within reason) to provide the least amount of turbulence at high speed [21-40].

## II. METHODOLOGY ADOPTED

To enable the comparison of the drag produced by one vehicle versus another, a dimensionless value called the Coefficient of Drag or Cd was created. Every vehicle has a Cd which can be measured using wind tunnel data. The Cd can be used in drag equations to determine the drag force at various speeds. The best Cd is achieved when a vehicle has these attributes:

- Has a small nose/grill, to minimize frontal pressure.
- Has minimal ground clearance below the grill, to minimize air flow under the car.
- Has a steeply raked windshield (if any) to avoid pressure build up in front.
- Has a "Fastback" style rear window/deck or sloped bodywork, to permit the air flow to stay attached.
- Has a converging "Tail" to keep the air flow attached, and to minimize the area against which flow detachment eventually occurs

Car body would be shaped like a tear drop, as even the best sports cars experience flow detachment. The best road cars today manage a Cd of about 0.28. Formula 1 cars (standard cars have value 0.36 – 0.45), with their wings and open wheels (a massive drag component) manage a minimum of about 0.75. If we consider that a flat plate has a Cd of about 1.0, an F1 car really seems inefficient, but what an F1 car lacks in aerodynamic drag efficiency, it makes up for in downforce and horsepower [41-60].

The governing equations of viscous flow are based on conservation of mass, momentum and energy which are Langrangian in nature. Commercial CFD packages contain modules for CAD drawing, meshing, flow simulations, solver and post-processing [61-75].

## III. THEORY AND CALCULATION

The FloEFD commercial CFD tool solves the Navier Stokes and conservation equations. The equations that we used are not closed, so we need to use Turbulence Modelling [ k-Ɛ (k-Epsilon) ]to close the equation set and then iterate towards a solution. The most commonly used models are the RANS models due to their low cost in terms of compute power and run times. [50-75].

## IV. RESULT AND DISCUSION

The advanced CFD model used in this research solves the Navier-Stokes equations, which are formulations of mass, momentum and energy conservation laws for fluid flows. This CFD model is able of predicting both laminar and turbulent flows.

Most of the fluid flows in engineering practice are turbulent, so this model uses the RANS equations, where time-averaged effects of the flow turbulence on the flow parameters are considered. Through this procedure, extra terms known as the Reynolds stresses appear in the equations for which additional information must be provided. To close this system of equations, it employs transport equations for the turbulent kinetic energy and its dissipation rate (k-ε model).

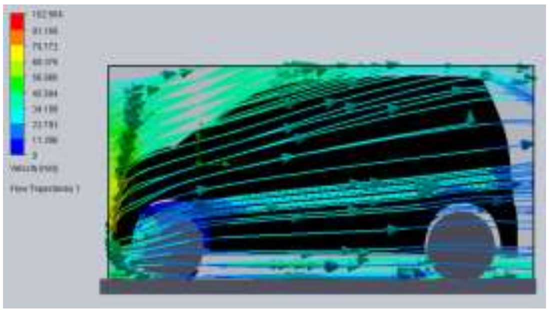

Fig.-1 Non-Aerodynamic Designed Car (Velocity)

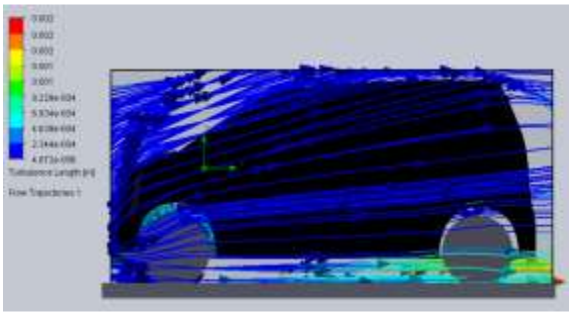

**Fig.-2** Non-Aerodynamic Designed Car (Turbulent Length)

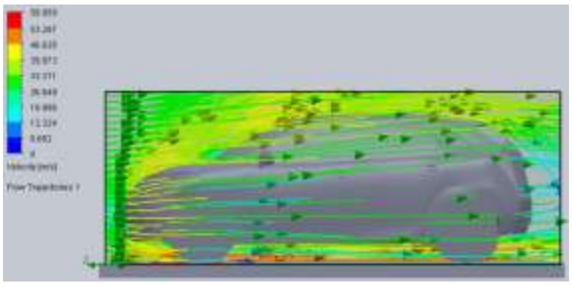

**Fig.-3** Aerodynamic Designed Car (Velocity)

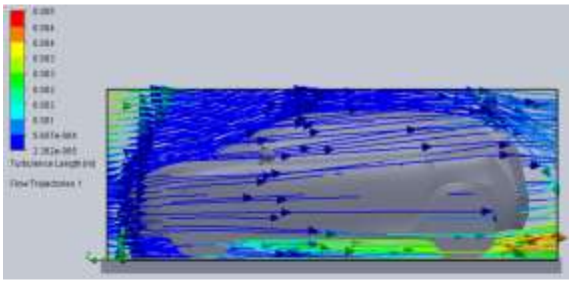

**Fig.-4** Aerodynamic Designed Car (Turbulent Length)

This research shows the utility of the CFD numerical simulations (FloEFD) as a tool for design and optimization of car performance and flow behavior through modern cars at minimum time-cost-effort.

**Comparison between above numerical results and car manufacturer's data (not shown here for company privacy policy) reveals a good agreement.**

## V. CONCLUSION

The advanced CFD model used in this research solves the Navier-Stokes equations, which are formulations of mass, momentum and energy conservation laws for fluid flows. To close this system of equations, it employs transport equations for the turbulent kinetic energy and its dissipation rate (k-ε model). This research shows the utility of the CFD numerical simulations as a tool for design and optimization of modern car performance and flow behavior at minimum time-cost-effort. The best road cars today manage a Cd of about 0.28. Formula

1 cars (standard cars have value 0.36 – 0.45), with their wings and open wheels (a massive drag component) manage a minimum of about 0.75. If we consider that a flat plate has a Cd of about 1.0, an F1 car really seems inefficient, but what an F1 car lacks in aerodynamic drag efficiency, it makes up for in downforce and horsepower.

## ACKNOWLEDGEMENTS

Authors declare, there is no conflict of interest.

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