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Study of Design and Aerodynamics of A Formula-1 Car

Ram Sai Seelam[1*], Palla Partha Sai Reddy[2]

[1,] *Dept. of Aero. Institute of Aeronautical Engineering, Hyderabad*

Abstract

One of the most dramatic examples of an aerodynamic device is a Formula 1 racing car. It wasn't so, in fact in pre- 1946 F1 cars made very little use of aerodynamics. Thinking at that time was to optimize cars for straight-line speed, i.e., minimize drag. The complicated design of the F1 car shows the overall passion and hard work done by many engineers in order to develop it into a masterpiece of aerodynamics and speed.Studied and presented different designs of an F1 car (from 1946 to 2019) and the evolution of aerodynamic design. By reviewing different reports, the overall aerodynamic structure and design of the car are recognized.

Keywords: Formula 1,Design,Aerodynamics.

1. Introduction

A Formula One car is an open wheel, open cockpit, racing car equipped with two wings (front and rear) which is one of the most dramatic examples of an aerodynamic device. A Formula-1 vehicle has many extra gadgets that go for lessening the lift and drag powers on the vehicle and there-by decreasing the lap times. Be that as it may, the lift and drag powers are conversely corresponding to one another.

A modern Formula One (F1) Car has almost as much in common with an aircraft as it does with an ordinary road car. Aerodynamics has become a key to success in the sport and teams spend millions of dollars on research anddevelopment in the field each year for improving performance.

The design of a Formula-1car is rather complex and aerodynamically fluent compared to the cars seen on the road. It is the cumulation of vast history of research and development done by different engineers throughout the period of 1946 -present (2021).In order to design a F-1 car one must keep in mind the important parameters such as drag, lift, streamline flow, downforce, traction, strength. It is due to these parameters that the F-1 is different to those of road cars.

2. Literature Review

Forces acting on a F-1 car

The forces acting on the car are;

Gravitational Force:it is the weight of the car, including all of its contents (i.e., fuel, driver, engine, etc.). We generally indicate it W.

Streamline flow:it is the characteristics that determine how the fluid of the stream will move in a stream channel.

Aerodynamic Force:it is the force generated by the air acting on the surface of the car. We generally denote it A.

Aerodynamic force is sub divided into

Lift:the lift, L, is the component of the aerodynamic force acting normal to the free stream direction.

Drag: the drag, D, is the component of the aerodynamic force acting in the freestream direction.

Down Force:the downward lift force created by aerodynamic characteristics of a vehicle.

Shubham Borole1 et.al,In our Project we are ad libbing on the structure of the front wing of a Formula 1 Vehicle. This aides in improving drag and down power which adds steadiness to the vehicle. Particularly on turns/corners at high speeds. Having done CFD on the front wing we see better plans as we become familiar with the stream examples and its impact our vehicle. In this way contrasting various plans helped us with accomplish higher productivity of front wing.

W. Kieffer et.al, A great deal of research has been ending one on the aerodynamic characteristics of race cars competing in major racing series throughout the world. Due to the aggressive idea of engine sport, this exploration is generally not distributed until after it is outdated. The teams operating at the minor league levels of the sport do not have the funding resources of the major series to perform aerodynamic research. In an effort to provide some information for teams competing in the minor league Formula Mazda race car class, this study was directed utilizing the Star-CD CFD code to play out a fierce reenactment (utilizing a k–ε model) of the airflow on the front and back wings of a Formula Mazda vehicle with various approaches and the impact of the ground on the front wing. Results are exhibited graphically, indicating weight and speed dispersions and lift (Cl) and drag coefficients (Cd) for the various cases. It was demonstrated that the ground impact markedly affects the Cl and that the approach has a significant impact on the lift and drag coefficients, and it was demonstrated that an edge of 12◦ underneath the level appears to show slowing down conditions. It is proposed that this data, alongside exploratory approval, can be significant for improving the ideal treatment of these Formula Mazda race vehicles.

Triya Nanalal Vadgama et.al, In this task, a Formula One race vehicle will be structured utilizing the CAD programming CATIA V5R20. Every one of the measurements depend on the norms set somewhere around the FIA (Fédération International de l ‘Automobile). The vehicle configuration will be improved to streamline the stream over the vehicle. Different parts that will be structured incorporate the wheels, front and back airfoils, front and back wings, vehicle body case, among different subassemblies. A driver will likewise be set in a run of the mill driving situation inside the vehicle.

Simon Durrer et.al, In this undertaking, different highlights of the vehicle will be improved to make the entire vehicle all the more fundamentally effective by examining the comparing structure and powers utilizing Ansys Workbench (Static Structural) programming. Fundamentally

proficiency will be accomplished by considering the Downforce and Force Reaction, created at a specific speed, weight, material, quality, and other execution parameters to accomplish the above expressed essential concerns.

Description:

History:

A wheeled motor vehicle used for transportation is a car. The year 1886 is considered as the birth year of the modern car. It is observed that the modern-day cars are actually the results of countless engineers developing them throughout their lives. At the start it was treated as means of transport for luxury and status. Later on, they were mass produced as they were helpful in many ways, in order to make them available for everyone. There after people started a sport using these Cars for their entertainment. As the sport showed more profit and entertainment, they focused on improving the cars in order to attain greater speeds. While doing so they made the sport global and had different designers and companies join together for competing against each other. In the year 1936 formula cars were made specifically for the entertaining sport called racing.

The thought then was to make cars such that they had very little drag as possible in order to attain speed that the normal cars couldn't attain. As years passed the sport gained a lot of popularity and the teams customized their designs by considering different design parameters. These design parameters had a great influence on the overall design and look of the car.

Design Overview:

Streamlined Shape:

The chassis of the car was designed such that it could move faster on the ground without creating much drag. The shape was designed particularly by seeing the aircrafts as they had greater speed and efficiency. The chassis were modified to resemble the shape of monocoque of the aircraft. By doing so they found a greater increase in the speed and stability of the car.

Front Wing:

The introduction of front wing showed major impact on the aerodynamic fluency of the car and its stability. It improved the downforce produced by the car and help maintain the stream line flow over the car for a longer period. The shape of the wing was that of an airfoil but was inverted so as to reduce the lift production and increase downforce.

Rear Wing:

The introduction of the rear wing further stabilized the car and increase the aerodynamic efficiency. The air flow front wing travelled along the chassis and would move away from the car's rear there by creating a lot of down force on the car and reduced drag.

Complex chassis design:

The chassis were fitted with dome shaped structures so as to increase the air flow to the engine. As these domes were introduced the stability was disturbed, so the chassis were designed along with the domes so that they had refined aerodynamic characteristics.

Study:

Different designs starting from 1936 to present (2019) are studied in detail to understand the overall growth of the car design and aerodynamic efficiency. Several changes were made to the

car in order to make it aerodynamically stable and attain greater speeds (375 kmph/233mph (at present)).

The design parameters such as lift, drag, downforce, streamline flow, etc. were studied for each generation and were compared in order to understand what flaws were rectified and improvements done on the successor cars to their predecessor's ones.

3. Results and Discussion

Comparison of details/designs of f1 cars

Design change during (1936-39):

The year 1936 marked the birth year for the formula racing. The cars produced during this period didn't particularly use any aerodynamic implementation. The thought was to reduce the drag force produced by the car just by making the body/chassis light weight and curved. The car had wider wheels and the ground clearance was high. The engine was placed at front of the car so that the car would have forward weight such that it would not fly at speeds of 175kmph.

Design change during (1940-1944):

The car had a sleeker body compared to the previous one. The ground clearance was reduced in order to stabilize the car. The design was refined and used a monocoque honeycomb like structure to withstand the GeForce acting on the body. The car was produced by rectifying the flaws of its predecessor.

Design change during (1945-1949):

The engine was placed at the back, in order to sustain the produced Ge force. The major defect by placing the engine at rear was that the car had no front weight, so as speed increased the stability of the car decreased and there were cases when the car would lift off from the track as the front portion was light weight. The driver had to use their own weight in order to withstand the Ge force and to keep the car on track, which took a lot of toll on the driver.

Design change during (1950-1954):

The engine was again placed at the rear as drivers suffered severely from the previous design. The chassis were designed keeping in mind the aerodynamic forces acting and gain advantage by utilizing the concept of streamline flow. The strain on the driver reduced as weight was uniformly distributed along the car body.

Design change during (1955-1959):

The car was designed by rectifying the flaws of the previous one. The air flow to the engine was increased by letting the air flow through the chassis directly into the engine. Due to this the power produced increased tremendously there by increasing the speed of the car. The refined aerodynamic design of the maintained the stability.

Design change during (1960-1964):

The engine was again placed at the rear in order to make the driver comfortable in the cockpit and gain greater weight at the back. The front region of chassis was designed such that no lifting force was produced. The speed of the car increased drastically correlated to the previous ones.

Design change during (1965-1969):

Different types of tires were introduced such as wet, compound, medium tires with 10-inch radius and thick-walled tubes in order to increase traction and friction between the car and the ground. Due to this the speed increased even more and the stability of the car improved a lot.

Design change during (1970-1974):

After detailed study of the aerodynamic characteristics of an aircraft, engineers thought of ways to introduce the same wings to F-1 car so that the car would be aerodynamically stable and the speed of the car increase much more than it was then. Due to the introduction of front and rear wings the down force on the car improved and speed increased along with stability.

Design change during (1975-1979):

After the introduction of front and rear wings the power of the engine was diminished as the fuel air mixture was insufficient for the combustion engine. So, the side domes were introduced such that the air mass would enter directly into the carburetor so that the power produced would increase there by increasing the speed of the car.

Design change during (1980-1984):

The flaws of the previous car were rectified and the chassis design was modified to fit the new parameters. The tires were resized to increase the traction. Due to the introduction of the modified wing the stability and the speed of the car enhanced.

Design change during (1985-1989):

Small changes were made to the designs of the front and rear wings which resulted in a slight increase in the down force and reduction of drag. The chassis were also customized so as to make it aerodynamically stable.

Design change during (1990-1994):

The length of the chassis was slightly increased so as to compensate a large rear wing in order to increase the down force produced and to reduce the drag. Due to this the stream line flow of the car improved.

Design change during (2000-2004):

The side domes of the chassis were customized such that the stream would directly enter the carburetor and increase the fuel-air ratio which would result in the increase in the power production. The wings are also slightly changed to compensate for the smooth flow of the air across the body.

Design change during (2000-2004):

The front wing is altered so as to increase the stream line flow over the chassis and to increase the downforce acting on the car there by increasing the stability. The side domes are improved to suck a lot of air mass in order to increase power produced by the car.

Design change during (2005-2009):

The front wing is modified such that it contains smaller winglets like structures in order to direct the wind in a streamlined flow over the chassis and produce greater negative lift on the frontal area. The tires were modified to have 13/14/16-inch radius fat tires in order to increase the traction between the car and the ground.

Design change during (2010-2014):

The front wing was elevated in order to increase the negative lift acting on the front region. The length and width of the chassis was also altered to maintain effective streamline flow over the body.

Design change during (2015-2018):

The front wing was lowered as the efficiency of the car was better compared to when the wing was high. The chassis had a little tune up in order to gain good suction of air into the carburetor of the engine.

Design change during (2019):

Halo an important safety feature was introduced so as to protect the drivers from getting severely injured during a crash. It didn't affect the aerodynamic efficiency of the or the vision of the driver. Slight improvements were done to both the front and rear wings of the car to make is aerodynamically fluent.

Design Change:

1946-1957:

Ferrari's first vehicle, the "Ferrari 500" which conveyed Alberto Ascari to the marque's first Formula 1 drivers' title in 1952, and which become the key vehicle in Ferrari's voyage to turning into the best constructor in F1 big showdown history, taking the first of the group's joined aggregate of 31 drivers and constructors titles, was of this sort of development. There was nothing especially enormous or sharp about the Ferrari 500. It was essentially an adjusted rendition of the Scuderia's past F2 vehicle: a stepping stool case with transverse leaf jumps up front and a De Dion pivot at the back, presently situated by trailing arms, yet with a less complex and significantly more successful V12 motor, and this engineering would stay a pillar of the Ferrari go for a considerable length of time to come, yet in two-litre structure it had been all around beaten in F2. Ferrari 500 won each big showdown fantastic prix from May 1952, until Maserati racer Juan Manuel Fangio broke its run at Monza on September 13 1953. Official "500" was contending from in 18 races, with 14 wins (77, 78%).

1957-1961:

The chassis were reinforced and the design was slightly made into a curved shape such that the drag produced is reduced and the speed of the car is increased compared to the previous ones. The engine is placed at the front of the chassis rather than at the back to increase the down force produced.

During the late 1950s and mid-1960s, three key changes changed the game. In the first place, the Cooper group began winning races and afterward titles with vehicles whose motors were mounted behind the driver, giving a superior taking care of parity.

Producers constructed case from steel and aluminium until 1981, when McLaren stunned the F1 world with the MP4, which highlighted a carbon-fibre undercarriage. Carbon fibre immediately turned into the skeleton material of decision, and remains so right up till the present time.

1962-1966:

The chassis are made sleeker and the flaws of the previous car were rectified so as to reduce the lift and drag forces acting of the body. The Engine is placed at the back of the body in order to compensate for the down force acting on the body. The suspensions are made large so as to support the large wheels.

1968-1976:

The flaws of the previous ones are rectified and a better model is designed such that the shape is of monocoque structure and the body itself is of the streamlined shape such that the drag is reduced and the aerodynamic efficiency of the car is increased.

1977-1982:

The design of the chassis is modified in order to introduce the front and rear wings. The refined design along with the wings made the car to be aerodynamically stable compared to its predecessor and the stream line flow along the car is drastically increased.

An advanced F1 vehicle is worked around a focal carbon-fibre structure called a "tub," which incorporates the cockpit. These tubs need to pass a progression of static load and crash tests, including a recreated rollover. The cockpit divider, for instance, must withstand an effect equal to 250 tons.

The scope of suspension solidness has fluctuated significantly throughout the years. Essential case plans each have their very own qualities and shortcomings. Each body is a trade-off between weight, part size, unpredictability, vehicle purpose, and at last, the expense. What's more, even inside an essential plan strategy, quality and firmness can shift fundamentally, contingent upon the subtleties.

1983-1988:

The suspensions were reinforced and the chassis are made of carbon fibre in order to sustain vigorous strain caused by the rotating wheel. The stream lined design of the chassis is refined in order to increase the speed of the car.

1989-1994:

The length of the car is increased to contain the 8-valve engine and the modified wing designs. Side domes are introduced in order to let the air to fuel mixture be rich with high mass ratio. The chassis is designed to compensate the aerodynamic characteristics of the car.

1994-1999:

The flaws of the previous generation cars were rectified and the design of the chassis was made sleeker in order to make it aerodynamically stable and the stream lined flow of the fluid over the car was improved due to which the speed and stability improved.

2005-2008:

The length of the chassis increased in order to make it aerodynamically fluent and the ground clearance is reduced for more traction and ground force. The side domes of the chassis were modified so that the intake of the air would increase.

The chassis were not changed that much as there was no loss observed in the aerodynamic characteristics of the body. The length was slightly increased to support the modified front and rear wings.

2014-2019:

The chassis were slightly modified as Halo was introduced in order for the safety of the drivers. This didn't change the aerodynamic efficiency of the chassis. The chassis were made up of carbon fibre and other composite materials which were light weight and strong.

4. Conclusion

From the analysis we can interpret that there is room for improvement of the design parameters thereby enhancing the cars performance. As there are improvements made to these design parameters there might be some chances of flaws which are further rectified in the future. Correlated different designs and came to a conclusion that each car was improved by rectifying the flaws of the previous ones. Pressure, Velocity, streamline impacts mainly on the front and rear wings which produce down force and maintain vehicle stability and eliminates lift. By this survey on the formula 1 cars from its first (1946) generation to present generation there are many changes in the structure to minimize drag and increase streamlined flow with the ground force. It is observed that the present generation (2019) F-1 car uses the most advanced aerodynamic designs and testing in order to make it a master piece. There are chances to further minimize the drag and increase more aerodynamically efficiency just by slightly changing the design parameters.

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