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Role of Aerodynamics in Sport Formula F1 car

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Abstract

A Formula One team is allowed to spend a maximum of $135 million (€128m) on materials and activities related to car performance each year, and about 15-20 million dollars alone on the sports car. The engine of this car is expected to last only for 7 races. The most important component of making a Formula One (F 1) car is aerodynamics i.e., the study of forces and the motion of the objects through the air. Now, the study allows us to measure forces that are lift, drag, thrust and downforce. Many technologies used in F1 cars are the same that are used by NASA or SpaceX, would use to design their rockets. Also, it is used in a way that the car goes around the racetrack. Now an F1 car requires two things, make super quick turns and go extremely fast in a straight line. The challenge is that what makes a car good at one makes it harder for the other one, so the car has to do both of the things all together to make it a winning car. In this article we will know the fundamental requirements of the car, covering the aerodynamical part of the manufacturing.

Keywords: Formula 1 car, Aerodynamics, Sports car, Forces

INTRODUCTION

Formula 1 got its name due to the 'FORMULA' which is the rules of the sport established by FIA (Federation Internationale de L'Automobile – International Automobile Federation). The first ever race recorded under the FIA was in the year 1950, marking the beginning of the sport [1]. A Formula One team is allowed to spend a maximum of $135 million (€128m) on materials and activities related to car performance each year, and about 15-20 million dollars alone on the sports car. The engine of this car is expected to last only for 7 races. The sport not only focuses on the driver or the car as an individual respectively but as a whole, both of the factors are important apart from the pit crew also playing a significant role in the race as well [2]. The sport might seem useless and money consuming to many people but despite a lower margin of profit to the teams participating in the race, many huge manufacturers we forced to withdraw themselves from the sport due to the high cost cut off, such as Honda withdrew itself in 2010 [1]. The main concept for a formula car is aerodynamics which helps to attain the speed and stability of the car. Aerodynamics consists of two words aero which means air and dynamics which means force acting on a moving body, so altogether it means forces acting on the forces acting on a body with its motion in the air [3]. The race car consists of many components, and each component has its significance, through the years of evolution many innovations and changes have occurred in the car, as aerodynamic studies got advanced the cars could go up to a higher speed with the same engine compared to the initial days of the sport [1]. The main aim of aerodynamics in this sport is to reduce the drag, and noise emission and also prevent the unnecessary lift acting on the car. The most complicated and interesting part of this subject is that 'the downforce and drag are both inversely proportional' causing the car to slow down one way or the other, that is what aerodynamics helps the most. Since every part of the car is important for the aerodynamics to work engineers spend a lot of time testing each component of the car as well for the testing of the car, it is kept in wind tunnels which creates the exact inverse conditions to produce the adequate amount of minimum drag but at the same time the maximum amount of the downforce [3]. Apart from the car, it is also the driver skill as well as the pit crew efficiency that leads to a win [2]. Since the G forces of the car are high during the city races even the manholes need to be welded down because the downforce affects them and leads to them shooting up in the air if not welded into place. This also makes us concerned about the driver as the downforce is so huge that it causes the driver to lose about 4 kg of mass in just one single race of the sport [1]. The environmental factors play a significant role in the driver i.e., temperature, toxicant exposure, humidity. Some main effects on the driver are the g forces, and the heat (which is inevitable as it is the bioproduct of all the forces acting on the car the temperature is normally from 50°C to 65°C and can also reach up to 82°C depending upon the surroundings and the current temperature of the race track). Now, since a Formula 1 car is an open wheel racing car and the engine is behind the driver. This also leads to the exposure of noise and carbon monoxide side in contrast with heat to the racers. Now the sport also does not allow the teams to refuse their tanks during the race which reduces the health threats to the driver as well as the pit crew in comparison to other racing sports, such as IndyCar and NASCAR. During the sport, the air quality is also decreased due to the exhaust fuse from the race cars and the electric generators used in the garage and put areas,

but the exposure to carbon monoxide also depends upon some general factors that as the raised duration number of cars on the track, what is the proximity between the cars. The control of the car is designed for a driver to know the precise control and get feedback on how the car handles. The main goal of the control system is also to ensure that the steering system as well as the suspension geometry are working together smoothly and giving the driver clear, physical sensations and feedback. A survey of 40 professional drivers also revealed that the upper body and the arm strength that is required to control and steer the car are the major physical demands during the race. The fatigue of the hand and arm can cause neuropathies i.e., when the nurses that are located outside of the brain and spinal code are damaged, this causes weakness, numbness, and pain to the driver. Due to all the circumstances, a driver has to face during a race. Therefore, they are already during the training are assessed to be habitual of the atmospheric temperatures and also how to use their eyes during the race, but apart from the physical problems, a driver is also mentally challenged so their mind also needs to be trained so that they can achieve their best performance, spatial awareness is also important [2]. The sport Formula One also led to a significant innovation that is commonly used in sports cars nowadays, which is the invention of carbon fibre. Now carbon fibre is produced with three different types of material that is viscose, polyacrylonitrile and pitch. Innovations like these contribute to the reason why huge manufacturing car companies such as Mercedes, Ferrari, et cetera, despite a very low margin of profit in the sport, take part in the races [4].

A Formula 1 car is a single seated car since the beginning of the sport [5]. The car has an open cockpit chassis unit, the wheels are also uncovered. Some components help in cooling the air to engine water, and brakes [6]. The car also mainly works on aerodynamics as mentioned before in the introduction.

AERODYNAMICS OF AN F1 CAR

In this review article, we understand the role of aerodynamics, i.e., the study of forces on a body that is acting upon a body in motion through air (a fluid), in our case the object in the Formula 1 car, we understand the role of aerodynamics at a basic level for everyone to understand. There are Broadly for forces acting on the body concerned by aerodynamics that is lift, drag, downforce and thrust [3]. If we define these forces in basic, it is

1. **Lift:** It is an upward force that acts perpendicular to the direction of motion of the object that moves through a fluid (liquid or gas). This force acts in an upward direction to counter the gravitational force that acts downwards. If this force is surrounded by air as a fluid, it is called aerodynamic force in water or any other liquid. It is called a hydrodynamic force.
   An object doesn't need to be in motion. Therefore, if the object is stationary, the force still acts on the body. This course is mostly associated with wings or fixed wings aircraft but is also used in steam bodies and racing car wings. In a Formula 1 car, this force acts upon the car wings. These forces act on both the car wings present at the front as well as the back.

2. **Drag:** apart from the developed engine, drag of the car. Drag is a dynamic resistance or force that works against the direction of the vehicle. the more the area of a car in the air, the more the resistance or drag against the car as it goes in motion. The less, the drag, the more, the car would attain speed. the manufacturers of the car put a great effort to minimise the drag as much as possible. In modern F1 cars, the rear and the front wings are responsible for about 50 to 60% drag generation. There is a movable flap on the car rear wing that is designed to help reduce the aerodynamic drag that increases the speed of the car moving in a straight line.

3. **Downforce:** This force is perpendicular to an object, this force is also a counterforce to lift. It is very essential in Formula 1 as it stabilises the car and also helps in maintaining contact with the ground around 3 to 4 times down force acts upon the car, compared to its weight. To give an idea of if a car moves around 150 km/h. The downforce at acts on the body is almost equal to 795 KG at maximum speed. This force is around five times this value. Downforce is very important as it helps the car to maintain its speed during the corners of a race track. The aerodynamical design of the car pays attention to increasing the down. Force may need the three components of the car, the floor, front wing and the rear wing is pay specific attention to. The main concern is how to control and manipulate the downforce that acts on the car it is achieved by the help of rear and front wings by changing the size and angle of the wing elements. In conclusion, it helps in improving the grip and traction. Through the corners.

4. **Thrust**: It is a counter force to drag this force, helps the object to move, this force is produced by the engine of the car as it forces, the car to move forward

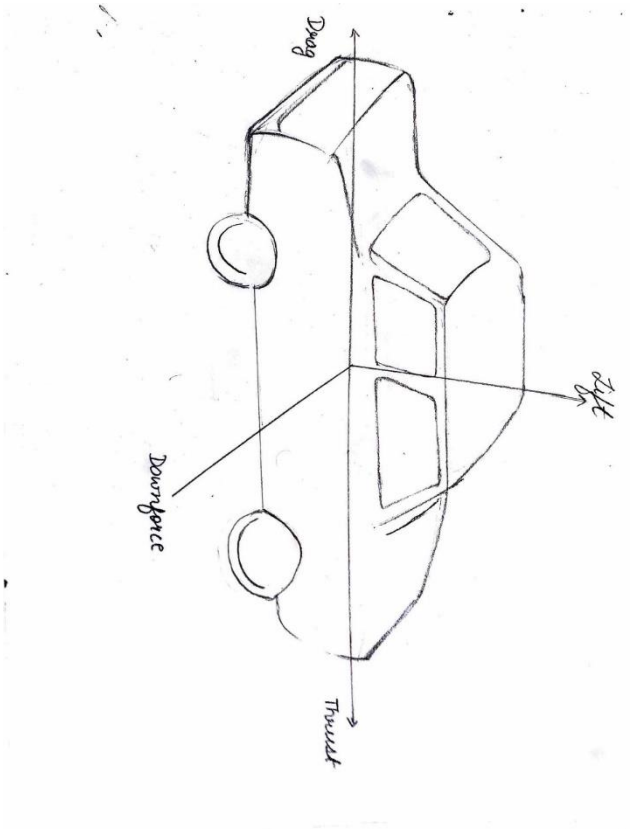

Figure 1 depicts the forces that are acting on the body as it moves through the air.

The fundamental aim of aerodynamics is to create as much as downforce possible on the car. With aerodynamic downforce at the top speed of a Formula 1 car, can achieve about 2.5 times downforce compared to the weight of the car. The vortical structures that are induced by the aerodynamics in the car are usually the key that helps with the greatest effect on the car performance. Now determine the effects of the forces on the car measurements by CFD and WTT. Fluid dynamics is a part of, mathematical studies of objects, moving in liquid and gas. The fundamental of this study is the "Navier-Stokes equation" equation, which cannot be solved without the help, of powerful computers as it is a very complex equation, which makes it harder to be solved directly.

CFD

Computational fluid dynamics is the science that predicts the fluid-flow phenomena based on the conservation laws, which govern fluid motion. In an F1 car, CFD builds a 3D model of the car and predicts and applies all the forces that will act on the body, using the laws of physics. It also predicts how the car will react to external factors such as wind conditions and the different road surfaces the car will run on [3,7,8].

WTT

Wind Tunnel Testing is used to help manufacturers get a better understanding of the nature of the flow of air around the car and also the effects caused by it. The tunnel creates an inverse of the condition in real life [3,9]. In reality, the car moves with a great velocity through the air, in the tunnel the car is fixed at a position and the air is moved over it by blowing wind from a large fan.

As mentioned before in the introduction each part of the car plays a significant role in the functioning of the car. Some important aerodynamic parts of the car are listed below

1. **Front wing**

The front wing of the car is the first part to meet the airflow across the car, therefore making it the most crucial aerodynamic component. It mainly consists of the main plane, two aero foil flaps and the end plates. The main plain provides the rectangular shape of the wing which furthermore helps in the flow of air to the aerofoil. the front wing also generates 1/3rd of the downforce of the total car [10,11]. The most efficient function of the front wing is therefore to guide the air to the rest of the body.

2. **Rear wings**

The rear wings consist of 2 components which are the 2 sets of airfoils connected to the endplate. The frontal area is reduced as the structure benefits from the reduction of drag. Around 30-35% of the total downforce is produced by the rear wing [12,13].

3. **Rear fans**

2 rear fans are present under the car to suck all the air from the floor to create low pressure, this helps in attaining more speed during the race as it generates more downforce.

4. **Wheels**

A Formula 1 car is an open wheeled car which means that the wheels of the car are highly exposed to the surroundings, and thus have a very complicated aerodynamics [14,15].

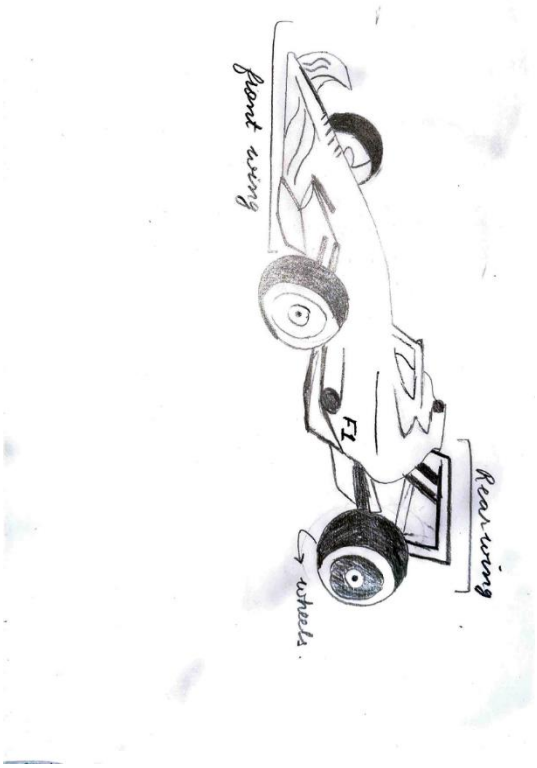

Figure 2 is a Formula 1 car and all the external components of the car

5. Ground Effect

the airflow contacts with the floor of the car between the front wings and the open wheels. The lower surface of the front wheel is close to the road surface, causing the air to be sucked and accelerates between the wing and the road, resulting in a static low pressure generated at the bottom of the car [3,16,17].

6. Diffuser

This increases the suction which results in more generation of downforce. It consists of many tunnels and splitters that help in control of the airflow.

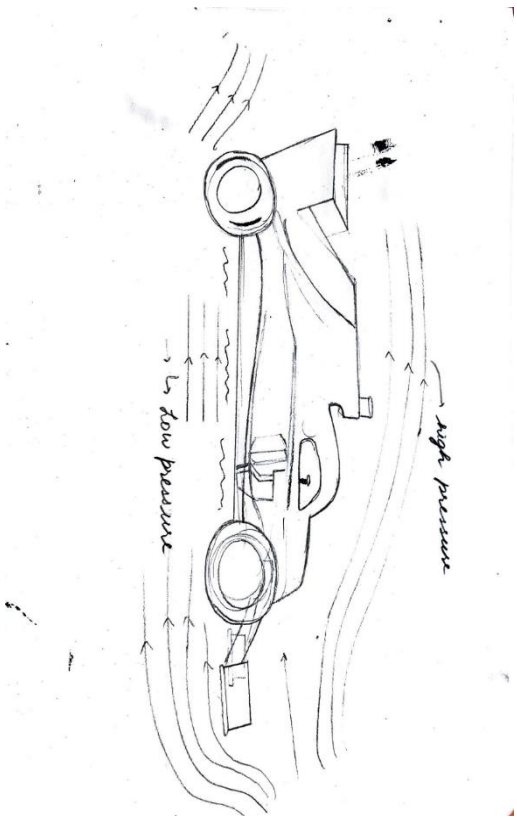

Figure 3 shows the pressure of air which helps the car to speed up (high pressure on the top of the car) and at the same time maintain stability with the ground (low pressure at the bottom of the car

CONCLUSION

From the aforesaid, we can conclude that aerodynamics plays a very important role in the sport car of Formula. The car is among the most aerodynamic motor vehicles. The sport plays a role in boosting the Europe GDP as well. It also creates tourism as well, all of this has been possible because of the growth in this sport with the advancement in aerodynamics. With the help of aerodynamics, the speed of the car has increased moreover also increases the stability of the car with the ground.

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