TERM PAPER

LOW SPEED AERODYNAMICS

Topic: AERODYNAMICS OF FORMULA 1 CARS

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ABSTRACT:

The main focus of this term paper is to understand the aerodynamics of a Formula 1 car.
This paper will highlight how different parts of the car affect its aerodynamics and how one can build it cost-effectively to get the maximum speed from it.

INTRODUCTION:

Aerodynamics is one of the most important aspects of Formula One (F1) car design. Creating downforce, holding the car to the ground to improve cornering; and minimizing drag, which slows the car down are two primary concerns when designing the car. Modern F1 teams use expensive wind tunnels and computational fluid dynamics systems to analyze the effectiveness of an aerodynamic design for a car. In these analyses, every surface of the car, including the driver's helmet must be considered. Even an advertising sticker can affect the airflow, and placing a badge on a crucial element could produce a two-to-three percent difference in air pressure. Disrupted air flow can cause turbulence, which will produce drag to slow the car. F1 cars often have small 'winglets' before the rear wing, which 'clean up' complex air flow in order to maximize downforce.

Figure 1 – Formula 1 Car

AERODYNAMIC DEVICES OF A FORMULA 1 CAR:

A Formula 1 car has many components that affect its overall performance and economy. Understanding the aerodynamics of the car is necessary to further modify the car. All the parts in a car have their own aerodynamic properties and when added to the mainframe affect the overall flow by a lot, hence one should be careful about the parts that are put in the mainframe, even if it is small compared to the overall structure.
The aerodynamic devices used are:

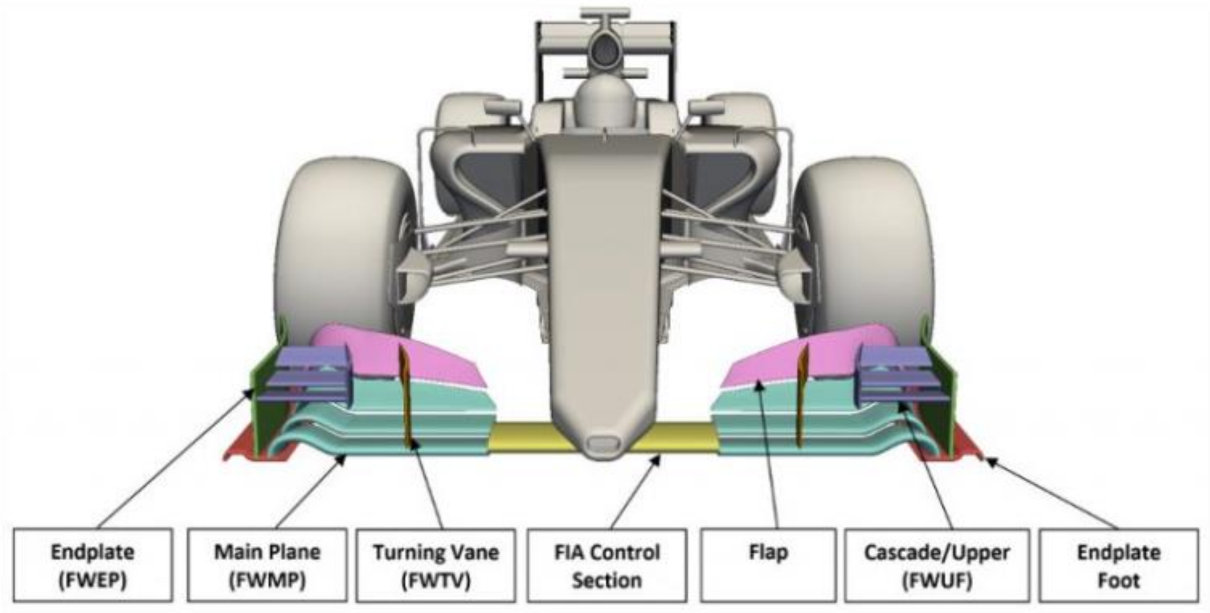
1. Front Wing
2. Rear Wing
3. Diffuser
4. Sidepods
5. Bargeboards
6. Front and Rear Brake Ducts
7. Suspension

Front Wing

In Formula 1 (F1), the front wing is an essential part of the aerodynamics of a race car. Its design plays a vital part in generating downforce, which is the force that pushes the automobile toward the ground and increases its grip and stability through turns.

A high-pressure area is created on the underside of the front wing and a low-pressure area is created on the top side. The downforce this pressure differential produces contributes to the car's increased stability and grip during cornering.

The front wing's position, angle, and shape can greatly impact the car's overall performance. Teams invest a lot of effort and resources into creating new designs to maximize the performance of the front wing, which is always evolving.



The above image highlights the individual components and typical naming convention of a Formula 1 front wing.

Figure 2 – Front Wing of F1 Car

Rear Wing

The aerodynamics of the Formula 1 (F1) car is mostly dependent on the rear wing. Its main purpose is to produce downforce, which increases the vehicle's grip and stability at high speeds, especially during cornering.

Located on the back of the automobile, above the rear wheels, the rear wing is a flat, horizontal structure. It is composed of a main plane and a flap that may be adjusted to change the amount of downforce produced. Depending on the circuit and the weather, either the driver or the pit crew can change the angle of the wing and flap.

A low-pressure zone is created above the wing and a high-pressure zone below it as the car moves. The automobile is pushed down onto the track and give more grip thanks to the downforce produced by the pressure differential. The angle of the wing, the design of the wing and flap, and the vehicle's speed all affect how much downforce is produced.

Figure 3 – Rear Wing of F1 Car

The complicated aerodynamics of an F1 car, which also includes the front wing, side pods, diffuser, and other features, include more than simply the rear wing. Together, these elements produce a highly calibrated airflow that increases downforce while reducing drag. The objective is to obtain the ideal balance of grip and speed, which is crucial for winning races in F1.

Diffuser

A diffuser is a tool used in aerodynamics to slow down and boost the pressure of a fluid passing through it. This is accomplished by expanding the channel's cross-sectional area in the flow direction. The diffuser utilised in Formula One racing cars is referred to as the "F1 diffuser," and it is intended to enhance the vehicle's aerodynamic performance.

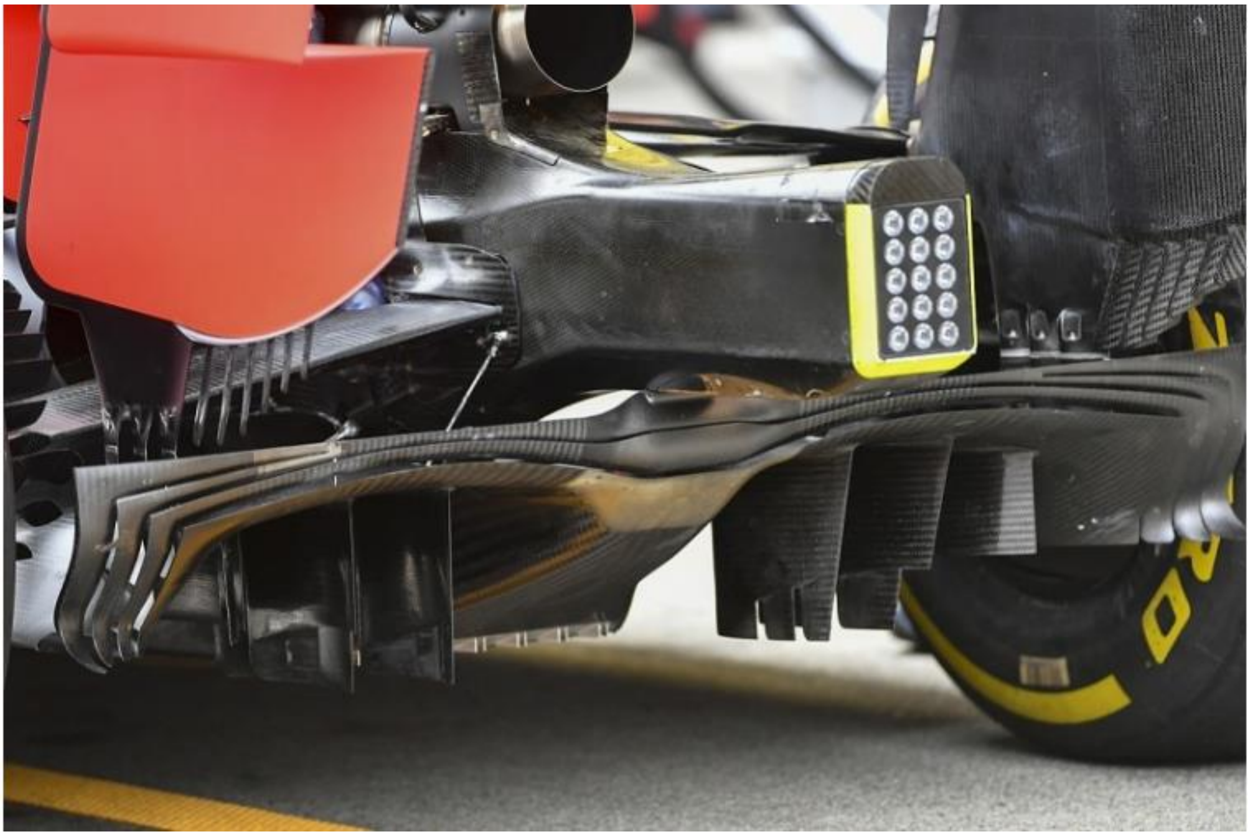


Figure 4 - Diffuser

A vital part of the car's aerodynamic design, the F1 diffuser is essential for producing downforce. The force that the airflow surrounding the automobile creates, known as downforce, pushes the vehicle down onto the track and enhances its stability and grip. The air traveling beneath the car is slowed down and its pressure is raised by the diffuser. This lowers the pressure in the area above the diffuser, which aids in sucking the car onto the track.

Sidepods

The sidepods play an important part in packaging the car as tightly as possible, housing the radiators and manifolds compactly, and minimizing drag.

The main radiator inlets are positioned on either side of the car and must accept enough air to provide sufficient cooling to the power unit.

Without enough cooling the engine and its other components are liable to overheat, lose performance, and potentially fail.

The inlets have to be carefully designed to be as efficient at cooling as possible while remaining as small as possible, and must also be positioned to be fed with the maximum amount of clean air.

The deformable safety structures on either side of the cockpit are a very important part of an F1 car.

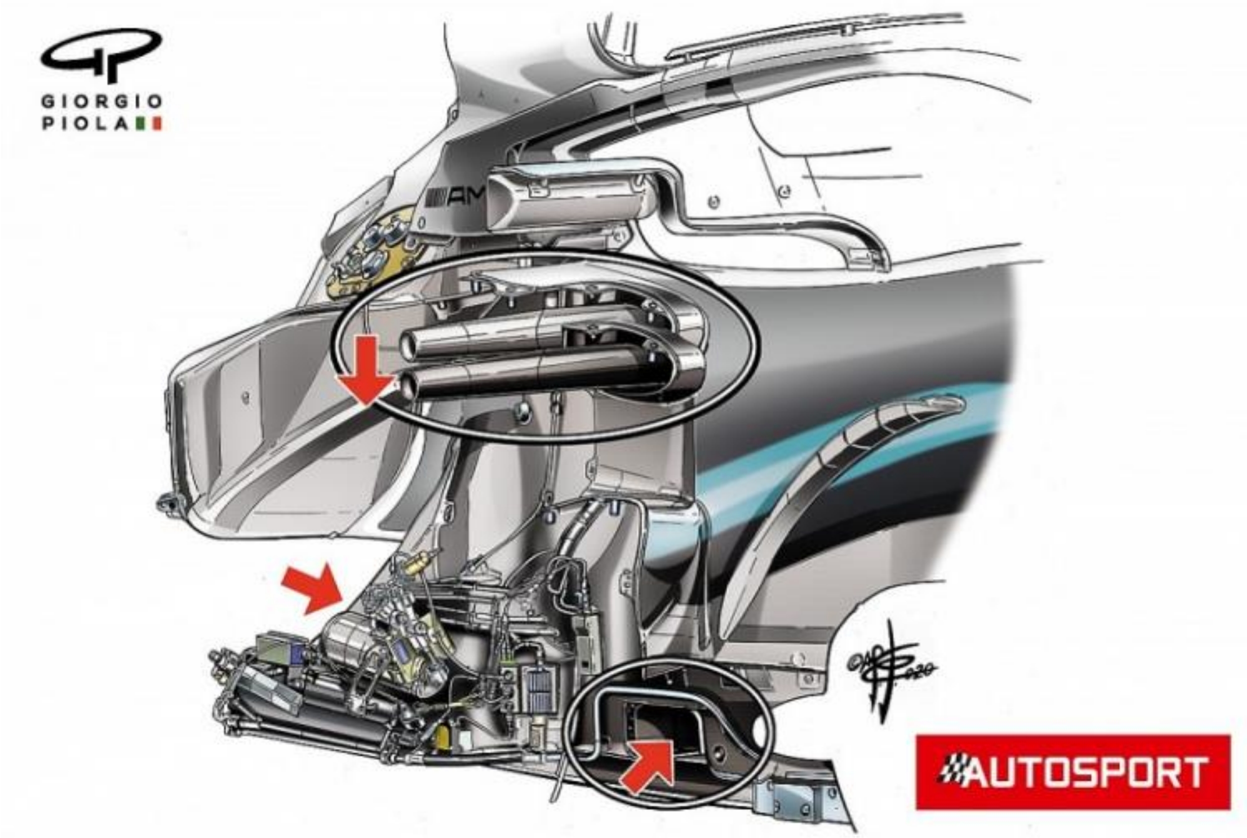


Figure 5 – Location of Sidepods

To reduce drag, this is a better distance from the front axle, helping to prevent the negative influence of the airflow from the tyre, thereby improving cooling.

Since the early 2000s, the sidepods have also featured a distinctive undercut around the bottom, channeling airflow around the top of the floor in a streamlined fashion to shorten its path.

This airflow can also be used around the edges of the floor, effectively providing a seal. The sidepods also open up at the rear in order to expel any hot air and teams often flare these openings up at circuits renowned for their high temperatures.

Suspension

The suspension is the link between a car and its wheels, dictating how it reacts to the road and to the driver's inputs. On an F1 car, teams are allowed up to six structural members per wheel, typically made up of two double wishbones, the pushrod or pull-rod, and a steering arm or track rod, depending on if it is the front or the rear suspension.

The suspension affects the handling, stability, and aerodynamic performance of Formula One (F1) race cars, making it a crucial component of these vehicles.

A Formula One car's suspension system comprises several parts, including wishbones, uprights, anti-roll bars, dampers, and springs. Together, these parts maintain the tyres in contact with the track, enhancing stability and grip.

The geometry of the suspension, which includes the ride height, camber, caster, and toe, can significantly affect the car's aerodynamics. For instance, lowering the ride height can close the space between the automobile and the ground, increasing downforce and enhancing cornering ability. However, if the riding height is too low, it can cause the car to bottom out and lose performance.

Figure 6 – Arrangement of Suspension

Overall, the suspension system plays a crucial role in the aerodynamic performance of an F1 car, and designers and engineers work hard to find the optimal balance between grip, stability, and aerodynamic efficiency.

Bargeboards

The bargeboards are positioned in the Formula One (F1) race car's side, right in front of the sidepods. They can significantly affect the car's overall aerodynamic performance because they are made to control the airflow around the vehicle.

Most bargeboards are made up of several vertical vanes arranged in a curved or angled pattern to direct airflow toward the back of the vehicle. They function by forming a "fence" that divides the air flowing around the front of the car at high pressure from the air flowing behind it at low pressure. This enhances the overall effectiveness of the car's aerodynamics by lowering turbulence.

Bargeboards can be used to direct airflow to particular parts of the automobile, like the diffuser or the floor, in addition to its aerodynamic role. Designers can improve the balance of the car overall, decrease drag, or increase downforce by manipulating the airflow.

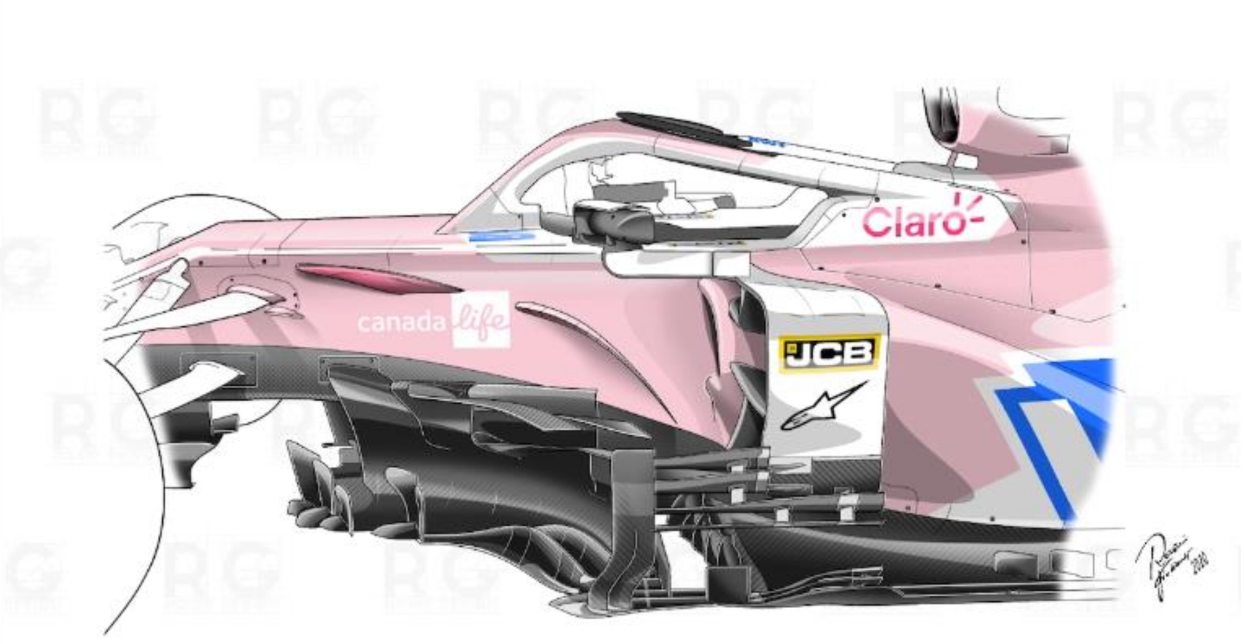


Figure 7 – Bargeboards of the F1 Car

In recent years, teams have used computational fluid dynamics (CFD) and wind tunnel testing to improve the complexity and sophistication of bargeboards. Bargeboards can sometimes feature exquisite cut-outs and shapes that are almost like works of art, all of which are intended to regulate the airflow as effectively as possible.

Front and Rear Brake ducts

Brake ducts play a crucial aerodynamic role on Formula One (F1) race vehicles. They control the airflow around the car and are in charge of cooling the brakes and tyres. Just behind the front wheels, on the front of the car, are the front brake ducts. They are made to cool the front brakes, which can get as hot as 1,000 degrees Celsius during a race. The brake assembly is cooled by air coming from the front of the automobile through channels and fins in the ducts, which also prevent overheating.

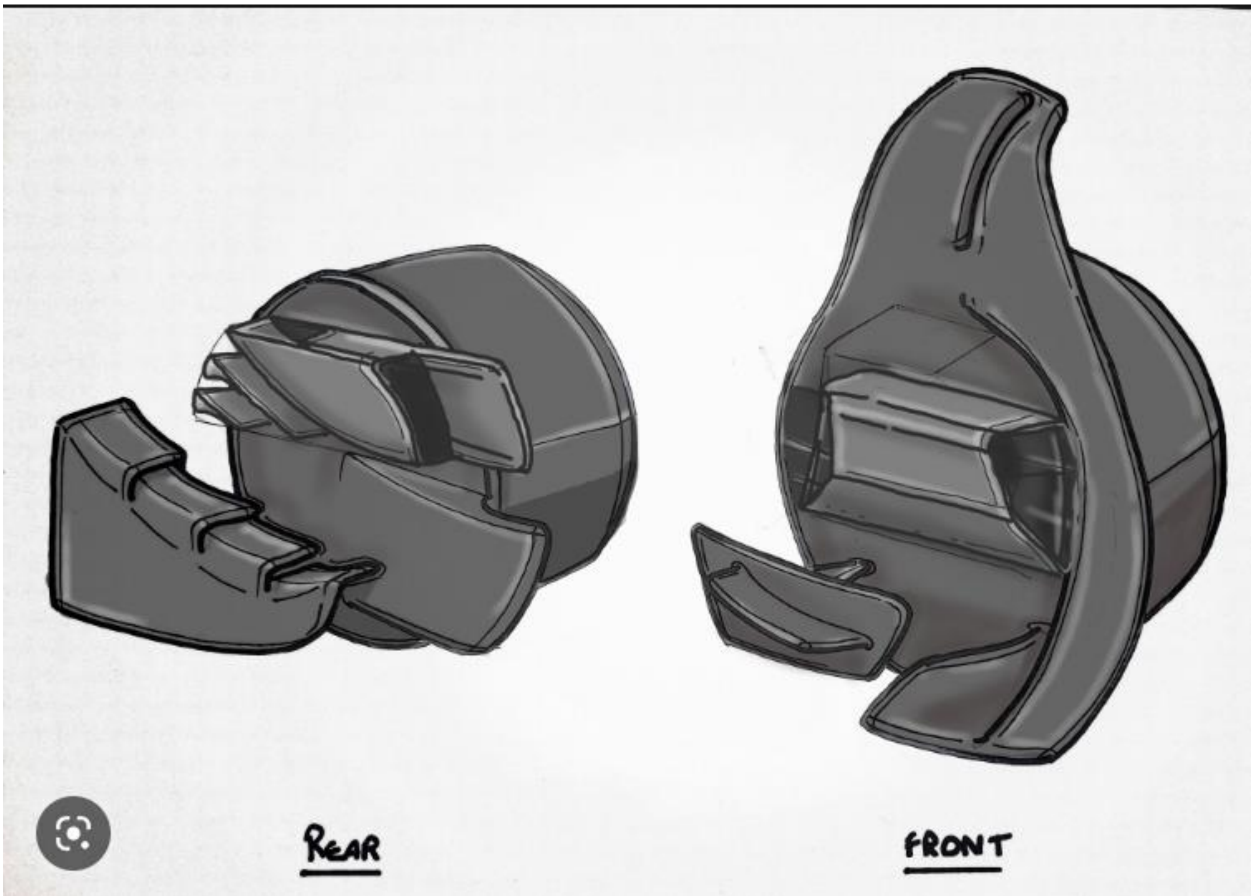


Figure 8 – Rear and Front Brake Ducts Shape

The rear brake ducts are just in front of the rear wheels, on the back of the vehicle. In addition to regulating the airflow around the car, they are crucial for cooling the brakes and tyres. The ducts have a number of vanes and fins that assist in directing the hot brake air away from the vehicle, lowering drag and enhancing the aerodynamic performance of the vehicle as a whole.

The rear brake ducts can be employed to produce downforce just like the front brake ducts can. Designers are able to create a low-pressure area behind the car that pulls it down towards the track and increases traction and stability by adjusting the size, shape, and location of the ducts.

Overall, brake ducts are an important aerodynamic component on F1 race cars, and designers and engineers work hard to optimize their design to improve the car's performance on the track.

AERODYNAMIC TESTING OF F1 CARS:

Aero Rakes

An aero(dynamic) rake is a series of 'pitot tubes', which are sensors designed to measure off-body flow structures.

By measuring the dynamic pressure, they can then paint a picture of the flow structures that are coming off things like the front wing and the front wheels.

The flow and vortex structures coming off various parts of the car send information back to the aerodynamics team, who then use the data to optimize the car further.

Figure 9 – Aero Rakes being used in Testing

Flow-vis Paint

Figure 10 – Flow-vis Paint applied to the F1 Car

Flow-vis paint is a fluorescent powder mixed with light oil – usually paraffin. It is then applied to the car, and when the car is moving at speed around corners, the paint dries, allowing teams to visualize the flow structures.

ANSYS ANALYSIS:

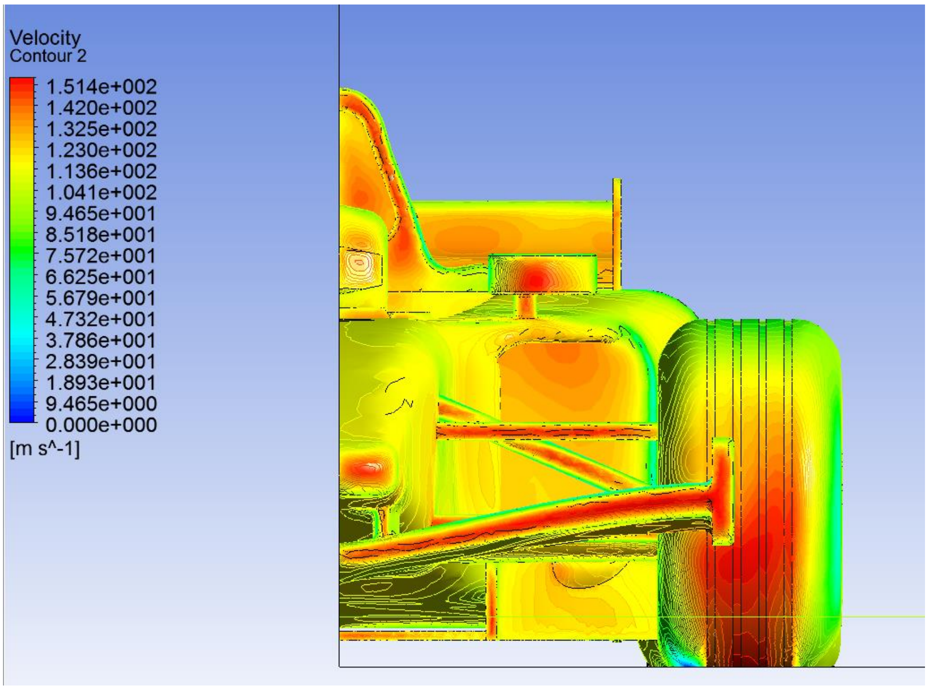


Figure 11 – Velocity Contour

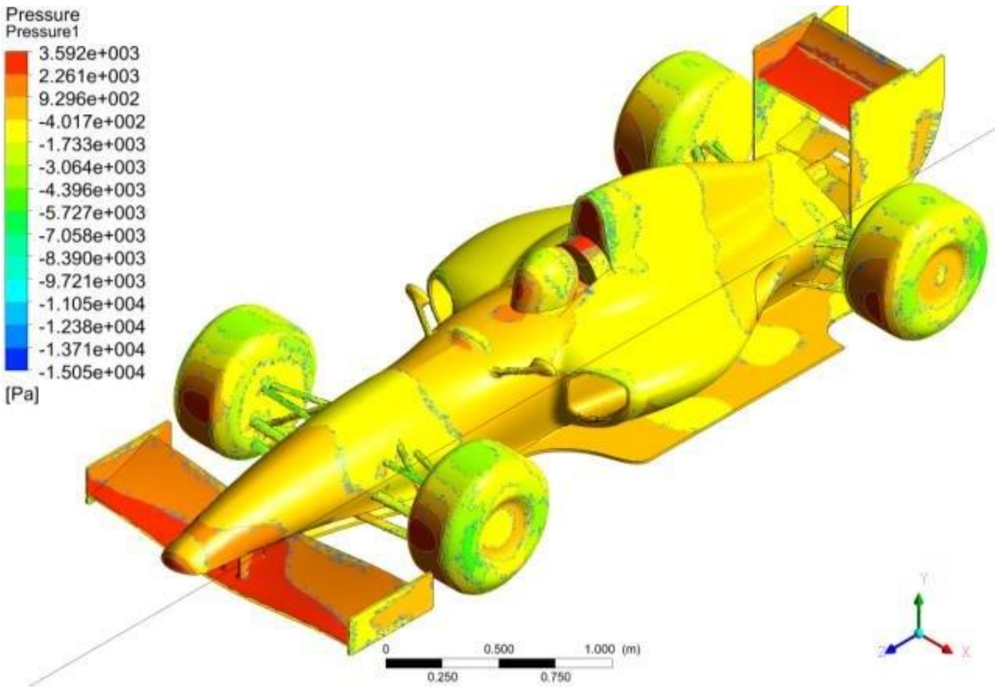


Figure 12 – Pressure Contour

CONCLUSION:

Aerodynamics is critical in Formula 1 racing for several reasons. Firstly, it helps to determine the speed and stability of the car. By optimizing the aerodynamics of a car, engineers can reduce drag and increase downforce, which allows for higher speeds and better handling in corners.

Additionally, aerodynamics plays a crucial role in the cooling and efficiency of the car's components. A well-designed aerodynamic package can help channel air to cool the engine and brakes, essential for ensuring the car can operate at optimal temperatures throughout the race.

It can be seen how much each part contributes to the aerodynamic drag and downforce.

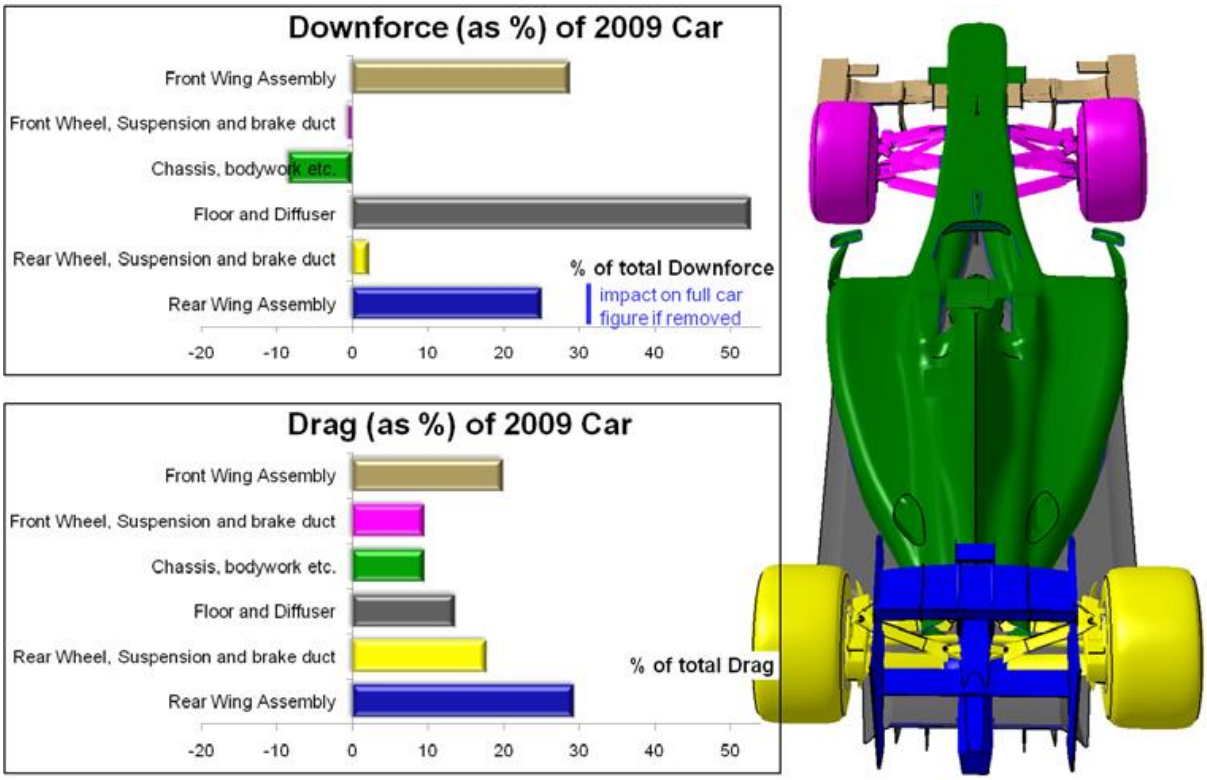


Figure 13 – Downforce and Drag due to various parts

In conclusion, aerodynamics is undoubtedly one of the most critical aspects of Formula 1 racing. Its impact on the car's speed, handling, efficiency, and overall performance is significant, and teams that are able to optimize their aerodynamics stand a better chance of success on the track.

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