Reporte breve

Analysis of the aerodynamics of the MCL35M F1 car

Análisis aerodinámico del auto de F1 MCL35M

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Abstract

Aerodynamics is a key part in the construction of a race car, specially in a Formula 1 single seater, specifically since the 1960s, with the implementation of wings in the Lotus single seater 49B. Since then aerodynamics in F1 have evolved at a fast pace, this happened because the aerodynamics play a big role in the top speed and the grip, this is seen most at high speed of a vehicle. In modern times the aerodynamics are much more complex than when they started in F1. During the year 2020, but due to the Covid-19 the regulation change was delayed, making 2021 the last year of a set of regulations, so it was going to be one of the most advanced cars in that aspect. This analysis is going to observe the airflow through various angles of the F1 single seater MCL35M manufactured by the McLaren F1 team which was used by Lando Norris and Daniel Ricciardo during the 2021 Formula one season.

Keywords: Aerodynamics, downforce, F1, traction, MCL35M.

Resumen

La aerodinámica ha sido una parte esencial en la construcción de los carros de carreras, especialmente en los monoplazas de Fórmula 1, específicamente desde la década de 1960 con la implementación de alerones en el monoplaza Lotus 49B. Desde ese momento la aerodinámica en la F1 ha avanzado con un ritmo rápido, esto sucedió gracias a que la aerodinámica tiene un papel principal en la velocidad punta y el agarre de los vehículos, especialmente a altas velocidades. En tiempos modernos la aerodinámica se ha vuelto mucho más compleja que cuando empezaron en la F1. Desde el año de 2020 se iban a cambiar las regulaciones pero se retrasó un año debido al Covid-19, por lo que se cambió a 2021, por lo que se volvieron de los más avanzados en este aspecto. Este análisis va a observar el movimiento del aire desde varios ángulos en el monoplaza de F1 MCL35M realizado por el equipo McLaren el cual fue pilotado por Lando Norris y Daniel Ricciardo en la temporada 2021 de Fórmula Uno.

Palabras clave: Aerodinámica, carga aerodinámica, F1, tracción, MCL35M.

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Aerodynamics was first considered by Leonardo da Vinci when he observed that the movement of a solid object had resistance to the air, but he attributed this to a compressibility effect. Later, Galileo Galilei established this fact to the air resistance and came to a conclusion that this resistance is proportional to the speed the object has. In the XVII

Christiaan Huygens and Sir Isaac Newton defined that the resistance generated by air, also known as drag, is proportional to the square of the velocity. Because the four laws of motion described by Newton were the bases for the first theories of aerodynamics, he did that by taking into account the pressure and how it acts on an inclined plane (Britannica, 2019). There were more discoveries during the XVIII and the XIX century, but modern aerodynamics were born thanks to the first powered flight made by the Wright brothers during 1903.

According to the Carandbike team (2022) aerodynamics have been a key part in F1 since the introduction of it in the year 1967, when the team Lotus added wings to that year's car, the Lotus 49B. This car was one of the first to introduce wings with the car to generate downforce.

This project started because a particular interest that I had in how aerodynamics affect the functionality and the overall speed of a formula 1 car around a track, specially in how the air flows around it and how it moves the air so it reduces the drag and increment the downforce, even if it seems pretty difficult to obtain. I chose to do this project in a digital aspect because I do not have the proper resources to and knowledge to do it in a physical way.

During this project there will be a lot of learnings that are going to be acquired. Such as the correct use of a 3D digital software like Blender. With this tool I would be able to use in a lot of different possible ways, from a lot of different branches that could come from a scientific aspect. This technology is currently used for things like the design of pieces or simulation of many kinds.

The objective of this work is to carry out an aerodynamic analysis of the McLaren F1 car from 2021 the MCL35M using the Blender digital software. The specific objectives are: (1) learn the basics of aerodynamics; (2) identify the variables to make an aerodynamic analysis of a physical object; (3) learn how aerodynamics affects a car and which are the main variables; (4) learn how to use the Blender software to do an aerodynamic analysis; and (5) write the aerodynamic analysis.

Aerodynamics

Aerodynamics are a “branch of physics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies passing through such a fluid” (Britannica; 2019). According to Hitt et al. (2015), the basics of aerodynamics are: weight, downforce/lift, drag and thrust:

- Weight: This force comes from gravity pulling down on objects.
- Downforce/Lift: Downforce is the push that makes the object go down without the aid of gravity. Lift is the push that makes an object go up. The shape is the variable of this part, for example the shape of the front and rear wing of an F1 car are curved on bottom and flatter on the top, that shape makes air flow under the bottom faster than over the top. So, less air pressure is below the wing. This condition makes the wing and the car that is attached to get pushed down, and in the case of a wing of a plane is the opposite direction of the shape so the airplane is pushed up. According to Benson (2022) the equation to calculate lift is: “The lift equation states that lift L is equal to the lift coefficient Cl times the density r times half of the velocity V squared times the wing area A. L = Cl * A * .5 * r * V^2”.
- Drag: Is the force that slows down an object by the friction it generates with the air, the shape also affects the amount of drag an object generates, a flat surface generates more drag than a round shape, this is also true with wide and narrow objects. The equation to know the value of drag is D = Cd * A * .5 * r * V^2 where D is equal to drag, Cd to the drag coefficient, r to the density, V to velocity and A to the reference area (Benson, 2021).
- Thrust: The force that pushes an object forwards in this case it is the motor of the F1 car. For a car to keep accelerating it needs to have more thrust than drag.

There are also more concepts that are important to understand the aerodynamics of an object, these concepts are the upwash and the downwash. The upwash is the air that is pushed upwards of the object because of the shape it has. The downwash is the opposite of the upwash, so it is the air pushed downward of the object in movements. (Portugal et al, 2014). The professional way to calculate the aerodynamics in real life is by special technologies, according to the Australian Grand Prix Corporation (2023). They use two different things to understand the flow of the air through the car. The first one is a specific kind of paint known as flow-vis, which is usually a mix between a light oil like paraffin with a fluorescent powder. When this is moved at high speeds and through corners it starts moving around the car and drying until it can be analyzed where the air flows. The second one is with aero rakes, which are some sensors in the forms of tubes that analyze the dynamic pressure changes made by the flow of air.

The downforce in an F1 usually varies depending on the specific track where they run, because increasing and decreasing it can improve the performance of the car. The effects of increasing downforce are: the car gains more traction during corners and straights, and it brakes faster, it reduces the sliding, so the tires wear less, but it reduces a little bit the acceleration and the top speed. Reducing the downforce makes the rear tires lose traction, it slides more so the tires wear faster, it loses speed during corners, but it reduces drag so it makes a faster acceleration and a bigger top speed (AMG Petronas F1 team, 2022).

Method

The hypothesis of this research is the aerodynamics of the MCL35M that the amount of air will flow around the car with some parts having a downwash, specially in the sidepods and a small amount from the front wing. But the biggest amount of air where it will be directed will be by upwash so they could generate the biggest amount of downforce and to avoid the drag some parts, like the front wing, will generate an outwash to the sides of the car.

Materials used in this experimental design include computer and blender.

The 3D model of the MCL35M may not be the most accurate model of it because the original blueprints are not shared to the general public. The main difference of the 3D model from the real one is basically the flexibility of the front and rear wing, because if they were totally stiff the pressure would end up breaking some parts of t he real car. So the fidelity can vary from some centimeters, there are not big differences and is easily observable. This model is copied from the Emilia Romagna Grand Prix. Which circuit is the Autodromo Enzo e Dino Ferrari. According to (2021 Emilia Romagna Grand Prix - Preview, 2021) the tyre supplier (Pirelli) suggested that the proper level of downforce for this specific circuit was a medium spot from the total that can be generated. This means that the level of downforce can change from circuit to circuit, but in this model can be used as an average. The 3D model of the MCL35M is not made from scratch because it would require much more time to try to make a more realistic model because of the difficulty to create a model. These 3D model credits are "F1 2021 McLaren MCL35M" (https://skfb.ly/onIvF) by Excalibur, is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).

Figure 1.

3D model of the MCL35M

The process that will be followed for this project was: to learn how to use the physics of blender to do a digital wind tunnel, this so the particles generated in blender can assimilate a little bit to the real physics of the real air.

After that I would like to use these physics in the MCL35M so we could analyze how these particles fly by the car so the particles can be analyzed and see where the “air fly by”.

Finally I would be able to analyze these particles to understand how the air flows and may be able to calculate the drag generated by it and understand how much this can affect the performance of the MCL35M.

Results

The results I managed to obtain is the data of a simulation of the air, by generating some particles to substitute the air and to collide with the MCL35M. This simulation also helps me understand in a simple way how the air collides and travels through the car. Because it is a simulation it is possible to be seen from a lot of different angles, some of the most important ones are the next ones.

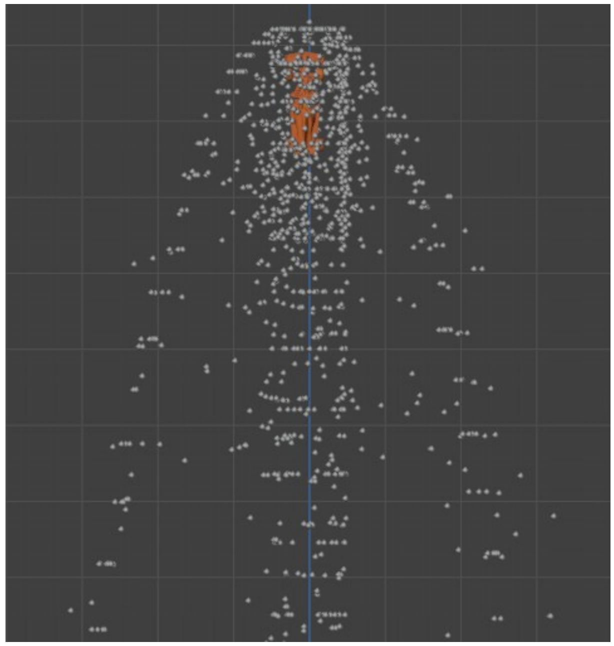

Figure 2.
Particles moved by the MCL35M from a view from above

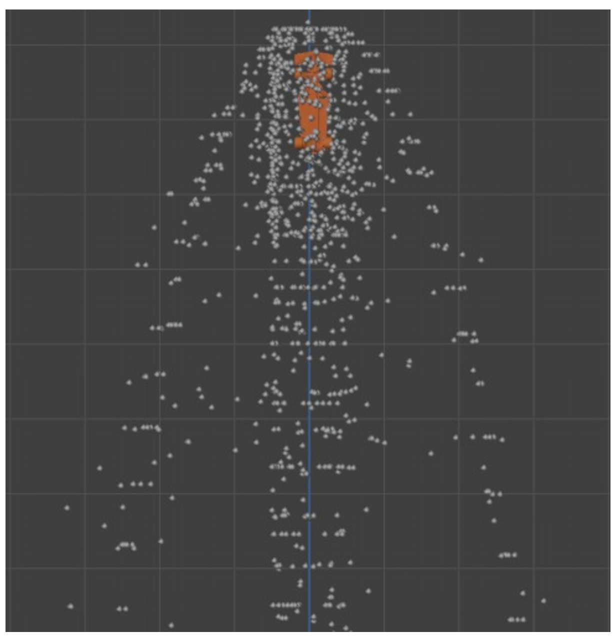

Figure 3.
Particles moved by the MCL35M from a view from down

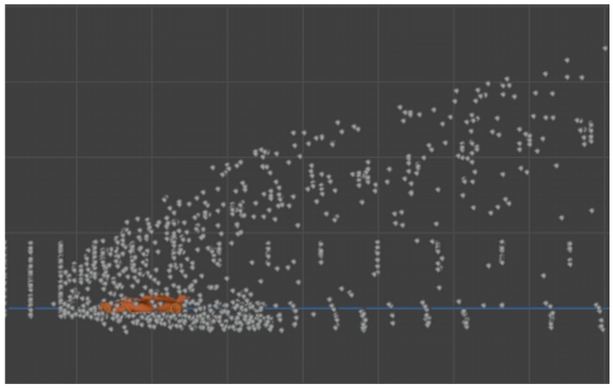

Figure 4.
Particles moved by the MCL35M from a view from the side

Discussion

This simulation showed that the MCL35M mostly generates upwash, with an exaggerated upwards angle. This happens because the F1 cars are specially designed to generate a lot of downforce to add more grip to the tyres. It also pushes a lot of air to the sides, but not as much as it pushes upwards, this probably happens to reduce the drag generated at high speeds. Because in this case the car is adapted to a track that is most optimal to use a medium amount of the downforce that can be generated by an F1 car, it may be pushed more to the side to reduce the drag, even if it reduces the speed in the corners.

Lastly the direction where the MCL35M pushes the least amount of air is down by itself, this happens because there is not an advantage to push air directly down of the car, because of the angle it has it also generates drag and reduces downforce. The main amount of air that travels between the car and the ground is the one that does not encounter any part of the car. The ground of the car is the one with the least amount of details because the main benefits that can be achieved from

Conclusion

The conclusion of this project is that the main direction where the air is moved is up, then to the side and finally the direction where it is less moved is down of the car, because if it does not generate any real benefit to push the air down. According to continental autosports (n.d) a regular F1 car generates in average 750kg at 100 mph.

This project determines that downforce is still very important, even if it needs a careful design to produce the best amount for the specific track.

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