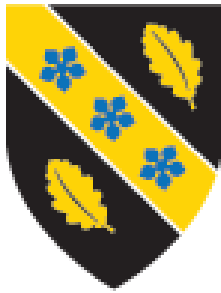


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The Evolution of Aerodynamics in Formula 1

Academic Skills (ACHA4005)

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Contents

1	Introduction	1
1.1	Justification	1
1.2	Aims	1
1.3	Objectives	1
2	Background	2
3	Discussion	3
4	Conclusion.....	5
Figure 1 - CFD Testing the McLaren MP4/2 (Phillips, 2021)		3
Figure 2 - DRS in Action (Philpot, 2023).....		3
Figure 3 - The angle of attack variance with changing Coefficient of Lift and Drag values (Syal, 2020)..		4

1 Introduction

The purpose of this report is to identify and analyse the change/developments of aerodynamics in motorsport with the use of real-world statistics. Specifically, the aerodynamical advancements made in the sport of Formula 1 (F1) over the years.

The object of this report is to compare how differing techniques and new technology have made an impact on the efficiency and effectiveness of a Formula 1 car. This will give the opportunity to contrast the performance of the cars over the lifetime of the sport.

1.1 Justification

The aerodynamics of Formula 1 vehicles is a crucial component to creating interesting competition between teams and allow the limits of the car to be fully tested. This has seen many stages of development over the course of nearly 80 years and the cars have evolved immensely in this time.

1.2 Aims

A large part of this report will be based on the downforce and drag the cars produce at speed as this is a very comparable way to show the difference between old, new and the development from one to another.

1.3 Objectives

The objective of this report is to highlight how the aerodynamics on Formula 1 cars have changed and how this has been effective and how it has been negative.

2 Background

The changes in overall shape of Formula 1 cars have changed drastically from 1947 to the present day and lots, but not all, of this is to improve the aerodynamic capability of the vehicles to perform better in ways such as producing more downforce and creating less drag. With the first sights of wings appearing in Formula 1 in 1968 (Fagnan, 2018), this opened a lot of opportunity for large amounts of development to take place. During the early years of Formula 1, aerodynamics was described as 'some sort of black art' as it was a big uncertainty as to what was effective and what was not; this was more than likely to be because there was no highly accurate method of replicating and measuring the aerodynamics, such as a wind tunnel. (Fagnan, 2018).

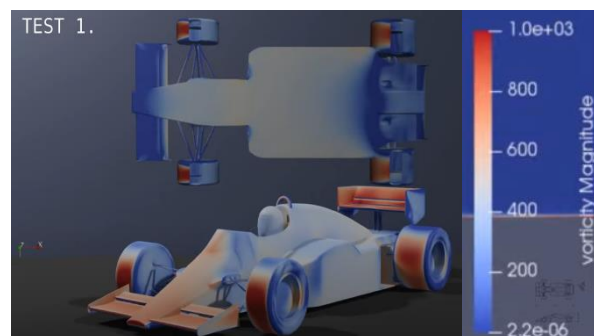
A large challenge of aerodynamics in motorsport, more specifically Formula 1, has always been the relationship between downforce and drag; greater downforce = greater drag. This is all about finding a good balance that will perform well in high-speed corners but minimizes overall drag on the straights – avoiding unnecessary slowing of the car. Systems have been put in place to reduce this from the sport, such as Drag Reduction System (DRS). Around 50% of the downforce on a current day Formula 1 car is produced solely from the underfloor diffusers of the car, acting as a suction to the track to allow high grip thresholds.

The efficiency of Formula 1 cars has changed very dramatically across the sport's development. For example, the modern day F1 car (on average) is over 50% efficient at peak thermal running order (Webb, 2023) and the 2007 cars only stood at around 29% efficiency (Zodhya, 2022). This shows that in just over 15 years the efficiency has improved by over 20%, some of this will be due to engine changes however this is also due to the increasing technology and understanding around aerodynamics – reducing unnecessary drag, inefficient components and improving essential components.

3 Discussion

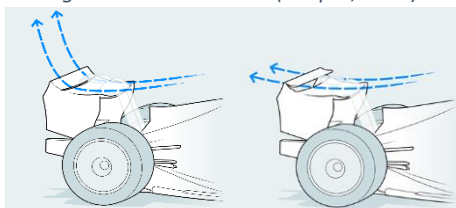
The use of the wind tunnel was first used in the late 1960s and early 1970s when the sport found use of the technology to enhance the understanding of how the cars interact with air as they reach high speeds. This was first done by Lotus, with the Lotus 49B (Thakur, 2023). Moving into the 1980s, Figure 1 shows a modern day CFD test performed on the bodywork of the iconic McLaren MP4/2. This is showing that the use of front and rear wings, lower bodywork and smoother, rounder angles on the car were starting to be used. “This is a highly innovative car that does all the basic aerodynamic things right. Not brilliantly, but right,” (Orlove, 2021). Figure 1 displays this as the high-pressure areas are the points of most downforce: rear and front wing. This was the first car of its time to really grasp the concept of aerodynamics and develop a better performing car under the use of changing the shape of the bodywork and angle of both wings.

Figure 1 - CFD Testing the McLaren MP4/2 (Phillips, 2021)



With the cars of the 1980s weighing between 540-580kg. In 1980 specifically, these aerodynamical changes produced an additional 1000kg in downforce at 150mph (240kmh). This went further in the following year, 1981, as Formula 1 saw yet another increase in downforce from 1000kg to approximately 2000kg at 150mph (Musashi, 2007). This, however, was banned during the 1983 season to put a spotlight on ground effect and pushing teams to amplify and develop the underside of the cars to produce more downforce or aerodynamic grip.

Figure 2 - DRS in Action (Philpot, 2023)



Translated into the modern day, these changes have resulted in the front wing & endplates being simplified and rear wing mounting point changing for a higher option. The challenge of balancing good downforce while minimizing drag has been approached in many different ways, one of these being the Drag Reduction System. Introduced in 2011 allowing the cars to open a flap within the rear wing, as shown in Figure 2, to reduce drag in the rear of the car which allows for a higher top speed. When DRS is active, the top speed advantage to the car ahead is 6.2-7.5mph (10-12kmh) (Mrkonjić, 2022) which is a significant increase in the straights, however it is no use in the corners as the downforce is what allows the cars to grip to the track so well and take turns at such high speeds.

Partly due to safety reasoning, the cars have become much larger as the seasons have gone by. This creates new challenges for the engineers as developing a similar car in a more polished fashion can not be done. These challenges resulted in the development of the front and rear wings, changing the

size, shape and length. The angle of attack that the wings are set at have a high impact on the type and strength of downforce that the car will undergo.

Figure 3 shows values of the Coefficients of both lift (Cl) & drag (Cd) and finally Cl/Cd which represents the Lift-Drag ratio. The lift coefficients are all negative, this is because it represents a negative direction (down). The higher positive the angle of attack becomes, there is a noticed decrease in lift, however there is also an apparent increase in drag too.

Figure 3 - The angle of attack variance with changing Coefficient of Lift and Drag values (Syal, 2020)

Angle of Attack	Cl	Cd	Cl/Cd
-1	-1.09	0.39	-2.79
0	-1.14	0.4	-2.85
1	-1.21	0.412	-2.94
3	-1.25	0.423	-2.96
4	-1.3	0.438	-2.97
5	-1.27	0.454	-2.80

This data was taken from Computational Fluid Dynamics (CFD) in an investigation to find the 'Optimum angle of attack for the front wing of an F1 car' (Syal, 2020).

The air scoop (intake) plays a large part in a well running engine and this is also a huge obstacle in the sense of aerodynamics as, like attack angle, there are two major factors that need to be considered. The amount of air taken in over certain time and the drag caused by this. As more air is pulled into the intake, the drag coefficient will be greater; this means there is an optimum ratio that will be most efficient for the car to use.

To highlight how this has changed, the air intake on the early Formula 1 cars was placed at the very front (occasionally on the sides of the front end) of the car. With no front wing and a large air intake, this would produce a margin of unwanted air flow on the underside of the front end. The result of this is unwanted air pressure under the front end, meaning lift – this reduces downforce and therefore the car will have a harder time both putting power down and rounding corners at higher speeds.

4 Conclusion

In conclusion, the way Formula 1 has evolved using aerodynamics is increasingly beneficial with technology and data management allowing many kinds of advancements including the massive improvement in efficiency, both fuel and engine. The ability to redesign and reinvent the downforce components opens opportunities to minimize drag while maximizing downforce which is a very beneficial piece of design in all aspects.

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