

HIGH PERFORMANCE RACE CAR WING

A report going in depth to the design and calculations of a high-performance
race car wing



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Introduction

Engineering has played a huge role in the advancement of high-performance race cars. Every year, engineers find new and advanced ways to improve componentry on race cars to enhance performance. Material selection and testing allows for in-depth experimentation and see the areas in which they can improve.

Back in 1950 when the first formula 1 raced happened, cars were very basic and had very little performance componentry. Drivers would have to buy, repair, and improve their own car (Williamson, 2022). The participants who took part in the sport would be exposed to very dangerous conditions and courses that were very hazardous – some cars being unable to cope with (Williamson, 2022). Fast forward to the 21st century where safety is number one priority in the sport. Cars may contain anti-roll bars and a “Halo” to ensure the drivers safety in an event of a crash (PRETORIUS, 2022). Not only safety but componentry has really developed as well. A lot of hard research and development goes into the design of parts on formula one vehicles. One of those components being the front wing. The front wing is one of, if not the most important aerodynamic components on the car (Anderson, 2022). The job of the front wing is critical-to keep the car stable on the floor by allowing the air to push down, creating downforce (Total Sim, 2016).

This report will go in depth to the development and design of a high-performance race car front wing. Calculations will be shown on how the force acts upon the wing, how to wing reacts to different forces at different speeds and what limitations were found when calculating the force and other factors. The report will then go further into the history of the wing and other wing concepts. Data on different type of materials and how they perform under different situations will also being contained within the report. Lastly, this report will contain data from a test carried out on said wing to show how it performs with a selected material of choice and different variables.

Wing Calculations.

Below will be shown calculations that shows the minimum tube diameter required to prevent a front race car wing from deflecting a maximum of 10mm. There have been figures shown that have been researched and used to enable the calculations to work. These will have indications to show that they have been gathered by research to allow for the sums to work.

Assuming that the load across the wing is a UDL. Below shows an equation that will be used to help solve the question.

$$y_{max} = \frac{-\omega L^4}{-8EI}$$

With the known figures entered,

$$10mm = \frac{-450 \times 1^4}{8 \times 210 \times I}$$

To get the final answer, "I" needs to be found.

$$I = \frac{w \times L^4}{y_{max} \times 8 \times E}$$

With the known figures entered,

$$I = \frac{(450 \times 1^4)}{0.01m \times 8 \times 210000000000}$$

The equation above provides the answer $I = 2.98E-08$

Once the above answer was attained, it then enabled for a Microsoft excel spreadsheet to be done created which allowed for a trial-and-error sequence to find the diameters that were required to carry out these equations.

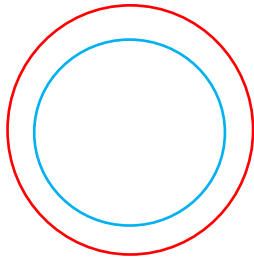
This excel spread sheet allowed for figures to be entered and calculated to give different sized diameters both internal and external. It is to be noted that that the distance from the external to internal diameters is 4mm. From this table it showed that a 35mm diameter pipe was required to continue with the investigation.

Ymax	0.01	I	2.67E-08
W	450Kg		
L	1m		
E	2.10E+11		

Diameter (mm)	Outside Diameter (M)	Inside Diameter (M)	i
5	0.005	0.001	3.06E-11
6	0.006	0.002	6.28E-11
7	0.007	0.003	1.14E-10
8	0.008	0.004	1.88E-10
9	0.009	0.005	2.91E-10
10	0.01	0.006	4.27E-10
11	0.011	0.007	6.01E-10
12	0.012	0.008	8.16E-10
13	0.013	0.009	1.08E-09
14	0.014	0.01	1.39E-09
15	0.015	0.011	1.77E-09
16	0.016	0.012	2.20E-09
17	0.017	0.013	2.70E-09
18	0.018	0.014	3.27E-09
19	0.019	0.015	3.91E-09
20	0.02	0.016	4.63E-09
21	0.021	0.017	5.44E-09
22	0.022	0.018	6.34E-09
23	0.023	0.019	7.34E-09
24	0.024	0.02	8.43E-09
25	0.025	0.021	9.62E-09
26	0.026	0.022	1.09E-08
27	0.027	0.023	1.23E-08
28	0.028	0.024	1.39E-08
29	0.029	0.025	1.55E-08
30	0.03	0.026	1.73E-08
31	0.031	0.027	1.92E-08
32	0.032	0.028	2.13E-08
33	0.033	0.029	2.35E-08
34	0.034	0.03	2.58E-08
35	0.035	0.031	2.83E-08
36	0.036	0.032	3.10E-08
37	0.037	0.033	3.38E-08
38	0.038	0.034	3.67E-08
39	0.039	0.035	3.99E-08
40	0.04	0.036	4.32E-08

Chosen Diameter

The excel spreadsheet shows a green highlighted row. This row will be the reference for the figures that will be shown in the below calculations.



External Diameter-

$$I = \frac{\pi D^4}{64}$$

Internal Diameter - $I = \frac{\pi d^4}{64}$

Using these equations, it will now allow to work out the area thickness between the large and smaller diameter.

$$I = \frac{\pi D^4}{64} - \frac{\pi d^4}{64}$$

Simplified to,

$$I = \frac{\pi}{64} (D^4 - d^4)$$

This will now give the second moment of area of a tube,

Small "d"

$$I = \frac{\pi \times 0.031}{64} = 1.52$$

Large "D"

$$I = \frac{\pi \times 0.035}{64} = 1.71$$

Now using one last formula to get the thickness between the internal and external diameter,

$$I = \frac{\pi}{64} (D^4 - d^4)$$

$$I = \frac{\pi}{64} (1.71^4 - 1.52^4)$$

The final given answer is, "I" = 0.158 mm.

Now that the missing figures have been calculated it is now possible to refer to the original equation which was,

$$y_{max} = \frac{-\omega L^4}{-8EI}$$

And insert the found figures, $10mm = \frac{-450 \times 1^4}{-8 \times 250 \times 0.158}$

Which gives a final answer of = 1.424 mm.

This final figure means that which the applied force of 450Kg, the race car wing is enabled to perform under the 10 mm permissible bend movement.

Assumptions made

As access to real statistics and data was very limited, assumptions were made to make the calculations possible in this question. For example, one assumption that was made was that the downforce on the front wing was uniformly disrupted. In the real world that will not be the case as weather would be a factor causing some figures to be produced. By researching a downforce weight of 450 kilograms was found and was used in the equation (Technical , 2009). Having this figure gave a good range of figures to work with.

Next was the length of the wing itself. Due to Formula 1 rules changing yearly, it was difficult to narrow it down to specific dimensions. After some research, it was found that the typical length for a F1 race car front wing was 1000mm (Giuliana, 2020). By having this dimension, it then allowed for the calculations to be carried out to consider the force acting down on the wing itself.

Finally, as mentioned an excel sheet was used to carry out trial and error values to see what diameter pole was required for the front wing. Once again, due to very little knowledge-using a spreadsheet to give multiple answers allowed for narrowing down to one specific value. The trial and error were again assumed as the figures that were being produced weren't 1000 percent accurate to what was expected. Although the figures weren't accurate it still allowed for numbers to be produced and give an ideal number to work with.

Different types of automotive front wings.

In the world of high-performance racing, different components have been tested to their max to gain every increase of performance. During Nineteen sixty, development of cars really started to progress. To be specific, nineteen sixty-eight was the year in which formula one teams started to realise that added wings to the front and rear of the car give the vehicle great benefits (Minocha, 2018). One of these added benefits were increased downforce to corner efficiently and faster (Minocha, 2018).

Below is 1 style of front wing from the past. Then two current formula 1 teams which both have front wings but have utilised testing and development to gain different performance increases.

Lotus 49

Here is one of the first of many Formula 1 car to be fitted and trialled with a functional front wing. An engineer who worked at Lotus named Colin Chapman introduced the front wing to the cars. He looked at previous styles of wing which were operated via a pedal on the inside of the vehicle (Fagnan, 2018). When the driver of the vehicle operated the pedal, it allowed for the front wing to go into a flat position meaning less drag on the car (Fagnan, 2018). Although when the front wing was in the standard position it would allow the driver to have increased traction due to the downforce-this system is very similar to current day technologies known as DRS (Drag Reduction System) (Fagnan, 2018).



Figure 1- Lotus 49

Alfa Romeo C38

Alfa Romeo have utilised their wing to have a noticeable drop on the front. The reason they have gone for this design is to "leave a lot of clear space directly ahead of the tyre, this making it simpler to turn the flow around the tyre but robbing the wing of downforce-producing flap area" (Hughes, 2019). By teams having different styled wings means that in different areas of a race they will have a higher advantage over other competitors. In this case Alfa Romeo have opted to have quicker cornering and less traction. The traction is reduced by the front wing leaving additional space.

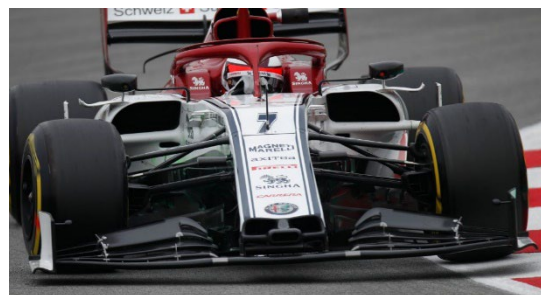


Figure 2- Alfa Romeo C38

Mercedes W10

On the other hand, the Mercedes W10 has elected their wing to be much thicker and closer to the tyre of the vehicle (Hughes, 2019). By doing this the front wing is creating an outwash effect. An outwash is when the front wing has two fins on either side allowing clean air to be pushed into the car to allow less drag (Hughes, 2022). Although a positive for the Mercedes car, once the clean air has been passed through the car benefiting the driving, the air then turns "Dirty". The dirty air makes a turbulent effect on cars at the rear (The Race, 2020).



Figure 3- Mercedes W10

From the above comparisons it can be clearly seen that thankfully due to testing and advancement of engineering, front wings have become not only a component on the front of the performance car, but a very crucial part to allow for increased traction and driving whilst going at very high speeds. Development of these front wings have not only allowed for great aerodynamic performance but also adequate and effective air flow around the whole vehicle (Kim, 2014).

Manufacturing and materials processes used in wing development.

The racing automotive industry has been known for trying various types of materials for components to gain some advantages over others. Different materials are trialled and tested to see how the material performs, how it reacts when under relevant forces and what it's like in different weather conditions.

The Renault Formula 1 team is a perfect example of this. The team have been trialling a Kevlar and Nomex type material due to its structural composition (BUTCHER, 2020). The materials structure is identical to a honeycomb pattern which has been noticed to have a very strong structural integrity (BUTCHER, 2020). Although, noted on the sources it states that "We've changed the thickness of the papers used, the geometry of the honeycomb and developed more advanced systems". This shows that by testing, the team has found that by increasing the honeycomb patterns thickness, it allows for a much stronger wing on the car.

Another well-known material in the Formula 1 world is carbon fibre. The material has been trialled and tested for many years now since discovered. The material has positive properties such as a high strength to weight ratio. Although, for the material to be strong it is crucial that the fibres run lengthwise as that's founded to be its strongest state (Groote, 2002). The process of building the wing is by layering the fibres layer by layer and then having an epoxy type resin poured over the material (Groote, 2002). By having this resin incorporated into the carbon fibres, it permits for an even stronger bond to improve the materials strength (Groote, 2002).

Wing testing and how it should be carried out.

To find out if a front wing of a formula 1 car works, it is crucial that it goes under testing before being released and fitted to the car. One type of testing used is point load testing which will be discussed below.

Point load testing.

The idea behind point load testing is to physically see how a material reacts when under stress in on specific location. The test is carried to see the characteristics of a material to see if it is suitable for its indented use (atatus, 2021).

When testing the point load of a Formula 1 front wing there are crucial specifications that the wing needs to perform at. The new test states that the wing must be able to withstand a point load of 60N/m at any trailing edge of the wing flap (Somerfield, 2015). Once the test has been carried out and achieved, the wing must not have exceeded the 3mm tolerance which is stated in the new test regulations (Somerfield, 2015). If the wing exceeds this upper limit tolerance, then its needs to be re-developed to decrease the flexibility of the wing. An example of a team who had the re-develop their wing was Red Bull Racing. During a race in the Abu Dhabi GP, it was found that the teams front wing had both extreme mechanical and aero flex resulting in an exclusion from the race (Scarborough, 2014).

Calculation verification and how it could be physically tested.

Once data has been collected and calculated, it is crucial that you put the calculations to the test. Even though it may be correct on paper there sometimes may be flaws in the figures that are produced.

One way this test maybe carried out is by ensuring that a fair test is carried out. For example, if you have steel with a GPa for 210 (which is stated in the brief) it is crucial that you match that figure. If not, then other material may react poorly or inefficiently in the test. If you have steel with a lower GPa figure, then it won't be able to achieve the maximum loading figure of 10mm which means it would have failed the test.

Once the correct material has been selected It must then be ensured that the hollow tub is fixed and connected to a fixed point which is again, stated in the brief. Once fixed the test may go ahead with the correct load attached uniformly over the tube. Once loaded, measure the deflection from the fixed point to see if the tube has deflected more than 10mm. If not, the test is a success, if the test has failed then it must be investigated to see where and why the pole deflected more than its allowed to.

Conclusion

In conclusion the findings above states that there are many factors to take into consideration when design and producing a high-performance front race wing. From the results it's clear that correct material selection, material testing and component testing is key to provide a well performing component.

Although over-looked, Formula 1 development has really had a massive impact on overall development of publicly used cars. Formula 1 team engineers help develop hybrid used cars (World News Today , 2020). The F1 teams have also been focusing on increase overall comfort and drive of cars that the public are able to purchase (EuroSport , 2022).

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