

Assignment 1 – Stress Analysis & Dynamics

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Task 1

A) Formulas used for the calculations are below:

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

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

With the known figures:

$$Y = \frac{-450 \times 1^4}{8 \times 210 \times 10^9 \times I}$$

To get final answer:

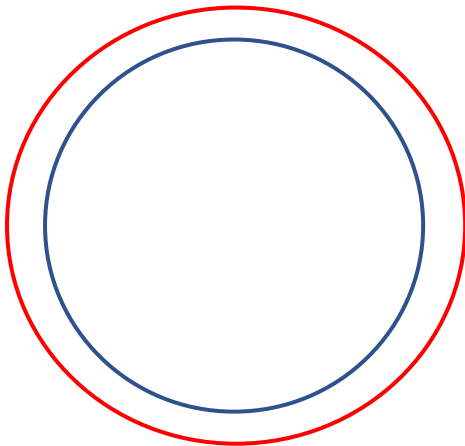
$$I = \frac{w \times L^4}{y_{\max} \times 8 \times E}$$

Using known values:

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

$$I = 2.67857 \times 10^{-8}$$

Diameter calculations:



$$\text{External Diameter: } I = \frac{\pi D^4}{64}$$

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

We can now work the area thickness between the large and smaller diameter:

D (mm)	D (m)	d (m)	I
30	0.03	0.026	1.7329E-08
30.5	0.0305	0.0265	1.82708E-08
31	0.031	0.027	1.92462E-08
31.5	0.0315	0.0275	2.02557E-08
32	0.032	0.028	2.13E-08
32.5	0.0325	0.0285	2.23796E-08
33	0.033	0.029	2.34952E-08
33.5	0.0335	0.0295	2.46473E-08
34	0.034	0.03	2.58365E-08
34.5	0.0345	0.0305	2.70633E-08
35	0.035	0.031	2.83285E-08

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

Simplified to:

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

Thickness between internal and external $\emptyset$:

$$I = \frac{\pi}{64} (0.035^4 - 0.031^4)$$

The final 'I' value is: 2.83285×10^{-8}

We can now work out the full equation:

$$\gamma = \frac{-450 \times 1^4}{8 \times 210 \times 10^9 \times 2.83285 \times 10^{-8}}$$

$$\gamma = -9.455394492 \times 10^{-3}$$

Therefore, the deflection is: **-9.455mm**, so this is less than the 10mm that was specified as the maximum deflection.

B) There were assumptions made during the calculations. The first assumption was that the forces acting upon the splitter were uniformly distributed across the whole cross section and not a point load. In the real application there would be other factors such as weather which would impact where the forces would act on the beam. Research into the downforce usually applied when a formula one car is racing showed that the loading would be between 400-500kg so a figure of 450kg was used for the calculations.

The second assumption made was that the wing would be a cantilever from a fixed point at the centreline of the car and after researching the length from this fixed point it should be 1000mm or 1m from this point. (Anderson, 2022)

The final assumption was that the diameter chosen would be a standard size, or a whole number, so although when calculated on the spreadsheet, the tube diameter could have been smaller, a slightly larger value was chosen to allow for a standard diameter of tubing.

Task 2

The automotive splitter applies the opposite principle to an aircraft wing, as the force required is downwards as opposed to upwards on an aircraft. One of the main disciplines that an automotive wing can be fully utilised in is the automotive racing industry, particularly Formula one. Although consumer vehicles may adopt similar methods they will not be fine-tuned as much as a component specifically manufactured for the race industry.

The Beginning of the Automotive Wing

During the 1960's and 1970's the evolution of aerodynamics was changing. New innovative designs were being produced and tested to gain an advantage on the opposition. One of these new designs was the front wing. In 1963 Jim Hall's Can-Am racing car could be seen to be designed to deflect air around the car and also creating a downforce on the front end, increasing the available grip for the driver and therefore improving the capability of the vehicle. (Kirby, 2020)

Formula One & the use of Front Wings

Following the success of the revolutionary design brought in by the Texas manufacturers and Jim Hall, the formula one industry was quick to follow suit with the first use of a front wing being from Colin Chapman of Lotus on the Lotus 49B at the 1968 Monaco Grand Prix. (Fagnan, 2018) During this period for formula one, aerodynamics was not considered anywhere near as much as it is in the present, meaning the car relied on wide, soft compound tyres to increase grip and stability. This time is formula one also saw and double the capacity of what the manufacturers were previously able to put in their cars; these larger, heavier engines came



Figure 1 - Lotus 49B 1968

with a new problem of grip, so to combat this issue Lotus came back with the front wing to create significant downforce on the front end, allowing for faster cornering and hence improving lap times. When looking at the design of the front wing used, it was clear to see that it was a simple design, with its only purpose being to keep the front end of the car down whilst maintaining a good contact with the surface of the track. The most important factor in the design of these wings is the angle that it should be mounted at; if too much it could have the negative to the desired effect and actually decrease the downforce.

Evolution of Formula One Wings

During the years there has been a great deal of technological advancement in the design of the front wing on a Formula One car. Shown in the image to the right are some of changes that have been made from 2014 onwards which is a small period of time relatively to introduction in 1968 and already it is clear that there have been significant changes.

These changes include:

The amount the wings can be adjusted. Formula One teams and manufacturers put a great deal of effort into the amount of adjustment which is available to a front wing, before or during a race; which gives a great advantage when looking at the actual loading that will occur during different times in the race or due to changes in humidity.

The introduction of end plates. The end plates either side of the wing, essentially capture the air flow over the front wing, not allowing the flow of air to detach to either side of the vehicle, keeping it straight over the wing, creating more downforce and also redirecting the vortex of air between the wheels reducing drag. (Oggioni, 2019)

The reduction of ride height was an important factor to increasing the downforce able to be created by the front wing, because with the lower ride height there would also come a lower pressure on the under surface of the front wing, meaning less drag but also a lower centre of gravity for the car itself, decreasing the amount of downforce needed for the same amount of grip previously attained, while simultaneously improving the downforce created anyway! (Partridge, 2021)

The introduction of strakes was a revolutionary design, these are vertical columns underneath the front wing which help direct the airflow and reduce the wake, which in turn reduces the drag created.

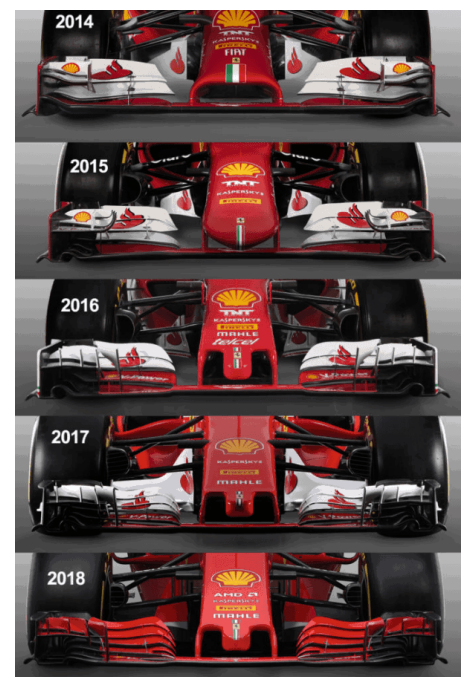


Figure 2 – Evolution of Ferrari Front Wing

Future Development:

There has been a huge amount of development in recent years, to the functionality of front wings, especially but not exclusively in the Formula One industry. It is largely believed that these wings are improving consistently every year and the ways in which they are still yet to be improved are endless. New composite materials, manufacturing possibilities and millions spent on the research to optimise these components can only mean improvements, in private and also the consumer sectors. A potential draw back to research could be the increasing implementation of new regulations within Formula One, which is where the bulk of the money comes from to research the wing.

Task 3

Jim Hall's 1963 Chaparral 2J shell was made entirely of aluminium. During this period in the evolution of racing, aluminium was a great material to use for this kind of manufacturing, as it was light weight, cheap and easy to form into the desired shape of an automobile shell using manufacturing methods such as pressing. Using this manufacturing method and material would also be beneficial because it would not be difficult to fasten each section of the shell together using a mechanical fastener such as a rivet. Aluminium as a material for this kind of manufacture would be perfect due to the fact that it is able to withstand sudden changes in the forces applied to it, with acceleration, but also it is flexible enough to elastically deform under these loads and still return to its required shape on the car. Lotus would have likely employed this same method years later to manufacture their equivalent component.



Figure 3 - Jim Hall's Chaparral 1967

Current Processes

When looking at the modern-day formula one wing, it takes a drastic change from the aluminium, pressed examples from the past; not only have the materials changed, but the manufacturing processes and aerodynamic capabilities have significantly increased in their ability to fulfil the role. Modern day formula one front wings are manufactured from carbon fibre, however, various other metals and minerals may be added to regulate the required flexibility of the wing. (Partridge, 2021) Carbon fibre is an extremely beneficial material to use in formula one due to it being extremely lightweight, very strong, very stiff and its ability to be easily moulded into any shape, meaning the complex contours and forms needed to create the desired front wing can be manufactured easily, yet still remain light enough and strong enough for the intended application. The carbon fibre forming process is carried out after the material has been woven into sheets, these sheets are placed singularly into a mould and bound with a polymer agent. The mould is then sealed and compressed to bind the sheets together; heat can then be applied to reduce the amount of time it takes for the finished form to set and become the solid object, but this is not necessary. Carbon fibre is also beneficial to use due to the lack of corrosion that other materials could experience, corrosion is likely to weaken a material allowing a greater possibility of a plastic deformation. (SMITeam, 2022)

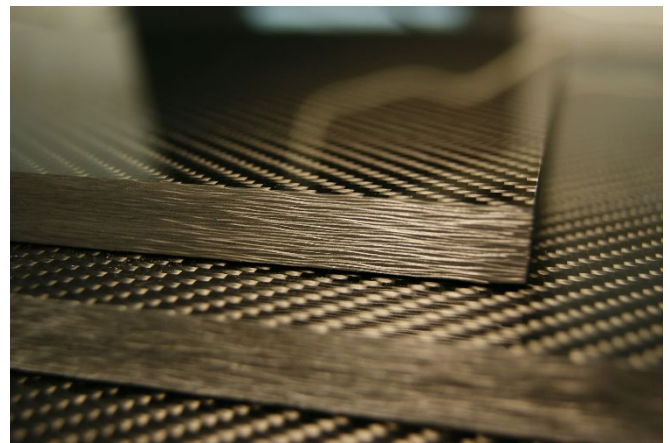


Figure 4 - Carbon Fibre Layered Panel

Task 4

To analyse and prove the calculations during the first task it is proposed that a prototype model be produced using the various parameters given within the spec and researched. The spec states that the material thickness is 2mm thick. The calculations from the first task also prove that a diameter of 35mm would be suitable for the structural element. It was decided that due to the research and regulations within formula one 1000mm from the centre point or the fixed point of the structural beam would be suitable for the test. Also, in the spec it is stated that the

structural section being tested is to be made of steel, therefore, if a test were to be carried out, these factors could be incorporated into the model to make the results more accurate.

To produce a prototype historically, a model of the vehicle to be tested would first need to be produced from drawings, using accurate materials and manufacturing methods, then the model would need to be physically tested using more equipment such as a wind tunnel, which would allow for further analysis into the design. In the present day it is much more likely that to analyse a potential design within the automotive industry, an analytical computer software such as AutoCAD or Solidworks, would be used to draw up the design and then a fluid analysis add on can be used to emulate the conditions that the component may be put up against in a practical application. A great benefit of these simulators is that it is easy to change the conditions and ultimately tweak the design slightly in order to achieve the optimum results (Hasanovic, 2018).

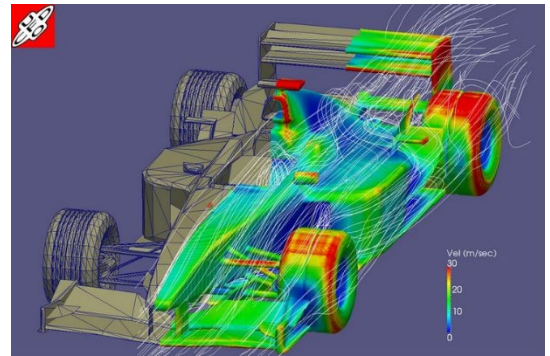


Figure 5 - Solidworks Aerodynamic Simulation

As previously mentioned, it would then be suitable to look at designing and manufacturing a physical model of the proposed design for further analysis. When both computational and physical design methods had been produced, the improvements or lack of improvement, would hopefully be clear for the designers. The designs could then hopefully be fine tuned by increasing or decreasing the number of flaps, strakes, adjusting rake angle or altering end plates. The prototype could also be tested to its failure point to ensure the yield strength of the component and fixing methods would be suitable for the final design.

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[n%20heat%20these%20to%20an%20incredibly%20high%20temperature.](https://smicomposites.com/carbon-fiber-manufacturing-how-its-made/#:~:text=Carbon%20fiber%E2%80%99s%20manufacturing%20process%20is%20both%20chemical%20and,the)

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