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B.ENG MANUFACTURING SYSTEMS

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Stress Analysis &  
Dynamics  
ACMA5010

Assessment 1

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## INTRODUCTION

This report studies the aerodynamic profile on a Formula One race car known as a front wing. It focusses on the structural support element for the wing under certain load conditions. It calculates the dimensions of the structural support required to enable adherence to the specifications set out. It looks at the development of this aerodynamic profile since its conception, its potential future development, and applications within Formula One.

It examines individual elements of a front wing and their effect upon the wing and overall vehicle aerodynamic performance.

It also references the design and material specifications to ensure compliance to the FIA regulations in relation to shape, size, materials, availability etc.

This report explores the possible future applications of technical advancement in design and material science within the formula one race series if permitted by the FIA, using technology that is already available in other sectors and their potential uses within the sport.

Finally, the report looks at prototyping to verify calculations and designs. It examines the benefits of prototyping and possible types of prototyping methods that could be used for this application.

## TASK ONE - FRONT WING STRUCTURAL SUPPORT

## CALCULATIONS

$E = 210\text{Gpa} \therefore E = 210 \times 10^9 \text{nm}^2$ , Circular Hollow Tube – Wall thickness 2mm,  $W=1000\text{N}$   
 $= 1\text{KN}$ ,  $L=800\text{mm} = 0.8\text{m}$ ,

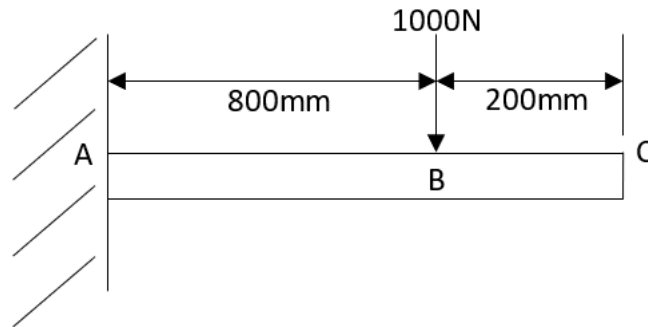
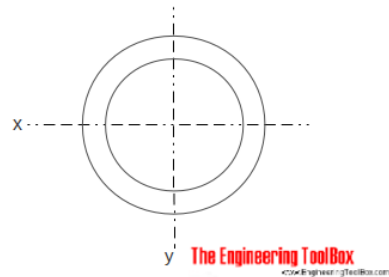


Figure 1 - Diagram expressing front wing as cantilever beam with single point load

## Hollow Cylindrical Cross Section



The Area Moment of Inertia for a hollow cylindrical section can be calculated as

$$I_x = \pi (d_o^4 - d_i^4) / 64 \quad (5)$$

where

$d_o$  = cylinder outside diameter

$d_i$  = cylinder inside diameter

$$I_y = \pi (d_o^4 - d_i^4) / 64 \quad (5b)$$

Figure 2 - Area Moment of Inertia for hollow cylinder section (Engineering-Toolbox, 2008)

$$\text{Moment of inertia for circular tube } I = \frac{\pi \cdot (D^4 - d^4)}{64},$$

**For 50mm O.D,**

$$50\text{mm} = 0.050\text{m}, 46\text{mm} = 0.046\text{m},$$

$$I = \frac{\pi \cdot (0.050^4 - 0.046^4)}{64}, \quad \therefore I = 8.701 \times 10^{-8} \text{m}^4,$$

$$EI = 210 \times 10^9 \times 8.701 \times 10^{-8}, \quad \therefore EI = 18.272 \times 10^3 \text{Nm}^2,$$

For A → B;

$$\gamma_{\max} = \frac{WL^3}{3EI},$$

(Hearn, 1997)

$$= \frac{1 \times 10^3 \times 0.8^3}{3 \times 18.272 \times 10^3}, \quad = 9.340 \times 10^{-3} \text{m}, \quad \therefore \delta_1 = 9.340 \text{mm}.$$

$$\text{Slope} \left( \frac{dy}{dx} \right)_{\max} = \frac{WL^2}{2EI},$$

(Hearn, 1997)

$$= \frac{1 \times 10^3 \times 0.8^2}{2 \times 18.272 \times 10^3}, = 17.513 \times 10^{-3} \text{rad},$$

$$\therefore i = 17.513 \times 10^{-3} \text{rad}.$$

B → C is straight, so;

$$\delta_2 = iL,$$

(Hearn, 1997)

$$= 17.513 \times 10^{-3} \times 0.2, = 3.503 \times 10^{-3} \text{m},$$

$$\therefore \delta_2 = 3.503 \text{mm}$$

$$\text{At C, } \delta_{\text{total}} = \delta_1 + \delta_2, \quad \delta_{\text{total}} = 12.843 \text{mm}$$

| W           | L1                   | L2                                                  | E                            | A>B                                           |                                               | B>C                            | Total                                                               |
|-------------|----------------------|-----------------------------------------------------|------------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------------|---------------------------------------------------------------------|
| 100<br>0.00 | 0.8<br>0             | 0.20                                                | 2.10E+<br>09                 |                                               |                                               |                                |                                                                     |
| (N)         | (M)                  | (M)                                                 | (Pa)                         | (mm)                                          | (rad)                                         | (mm)                           | (mm)                                                                |
| D           | d2                   | I                                                   | EI                           | Deflection ( $\delta_1$ )                     | Slope (I)                                     | Deflection ( $\delta_2$ )      | Deflection ( $\delta_{total}$ )                                     |
|             | $[\text{D}] - 0.004$ | $\text{PI}() * ([\text{D}]^4 - [\text{d}2]^4) / 64$ | $\text{D} \$2 * [\text{EI}]$ | $(\$A \$2 * (\$B \$2^3)) / (3 * [\text{EI}])$ | $(\$A \$2 * (\$B \$2^2)) / (2 * [\text{EI}])$ | $[\text{Slope (I)}] * \$C \$2$ | $[\text{Deflection } (\delta_1)] + [\text{Deflection } (\delta_2)]$ |
| 0.04<br>4   | 0.0<br>4             | 5.83205<br>E-08                                     | 122.47<br>31046              | 1.394E+00                                     | 2.613E+00                                     | 5.23E-01                       | 1.92E+00                                                            |
| 0.04<br>5   | 0.0<br>41            | 6.25797<br>E-08                                     | 131.41<br>74545              | 1.299E+00                                     | 2.435E+00                                     | 4.87E-01                       | 1.79E+00                                                            |
| 0.04<br>6   | 0.0<br>42            | 6.70416<br>E-08                                     | 140.78<br>73332              | 1.212E+00                                     | 2.273E+00                                     | 4.55E-01                       | 1.67E+00                                                            |
| 0.04<br>7   | 0.0<br>43            | 7.17108<br>E-08                                     | 150.59<br>26365              | 1.133E+00                                     | 2.125E+00                                     | 4.25E-01                       | 1.56E+00                                                            |
| 0.04<br>8   | 0.0<br>44            | 7.6592E<br>-08                                      | 160.84<br>32607              | 1.061E+00                                     | 1.990E+00                                     | 3.98E-01                       | 1.46E+00                                                            |
| 0.04<br>9   | 0.0<br>45            | 8.169E-<br>08                                       | 171.54<br>91016              | 9.949E-01                                     | 1.865E+00                                     | 3.73E-01                       | 1.37E+00                                                            |
| 0.05<br>0   | 0.0<br>46            | 8.70096<br>E-08                                     | 182.72<br>00553              | 9.340E-01                                     | 1.751E+00                                     | 3.50E-01                       | 1.28E+00                                                            |
| 0.05<br>1   | 0.0<br>47            | 9.25552<br>E-08                                     | 194.36<br>60178              | 8.781E-01                                     | 1.646E+00                                     | 3.29E-01                       | 1.21E+00                                                            |
| 0.05<br>2   | 0.0<br>48            | 9.83319<br>E-08                                     | 206.49<br>68851              | 8.265E-01                                     | 1.550E+00                                     | 3.10E-01                       | 1.14E+00                                                            |
| 0.05<br>3   | 0.0<br>49            | 1.04344<br>E-07                                     | 219.12<br>25533              | 7.789E-01                                     | 1.460E+00                                     | 2.92E-01                       | 1.07E+00                                                            |
| 0.05<br>4   | 0.0<br>5             | 1.10597<br>E-07                                     | 232.25<br>29183              | 7.348E-01                                     | 1.378E+00                                     | 2.76E-01                       | 1.01E+00                                                            |
| 0.05<br>5   | 0.0<br>51            | 1.17094<br>E-07                                     | 245.89<br>78762              | 6.941E-01                                     | 1.301E+00                                     | 2.60E-01                       | 9.54E-01                                                            |
| 0.05<br>6   | 0.0<br>52            | 1.23842<br>E-07                                     | 260.06<br>7323               | 6.562E-01                                     | 1.230E+00                                     | 2.46E-01                       | 9.02E-01                                                            |
| 0.05<br>7   | 0.0<br>53            | 1.30843<br>E-07                                     | 274.77<br>11548              | 6.211E-01                                     | 1.165E+00                                     | 2.33E-01                       | 8.54E-01                                                            |
| 0.05<br>8   | 0.0<br>54            | 1.38104<br>E-07                                     | 290.01<br>92674              | 5.885E-01                                     | 1.103E+00                                     | 2.21E-01                       | 8.09E-01                                                            |
| 0.05<br>9   | 0.0<br>55            | 1.45629<br>E-07                                     | 305.82<br>1557               | 5.581E-01                                     | 1.046E+00                                     | 2.09E-01                       | 7.67E-01                                                            |
| 0.06<br>0   | 0.0<br>56            | 1.53423<br>E-07                                     | 322.18<br>79195              | 5.297E-01                                     | 9.932E-01                                     | 1.99E-01                       | 7.28E-01                                                            |

Figure 3 - Table of calculations for nominal steel tube sizes

From the reference table in **Error! Reference source not found.**, I have calculated other nominal steel tube sizes using the calculation above, this shows the minimum outside diameter that must be used to construct the wing's structural support is 55mm. This is highlighted in the table for clarity.

## ASSUMPTIONS

The following assumptions have been made to enable the calculation of the structural component.

1. The overall length of the front wing is assumed to be 1000 mm. This has been determined by using the maximum allowable size in the industry standard race series - Formula1 as defined by the rules and specifications guidance from their governing body; Fédération Internationale de l'Automobile (FIA). (Fédération Internationale de l'Automobile, 2022)

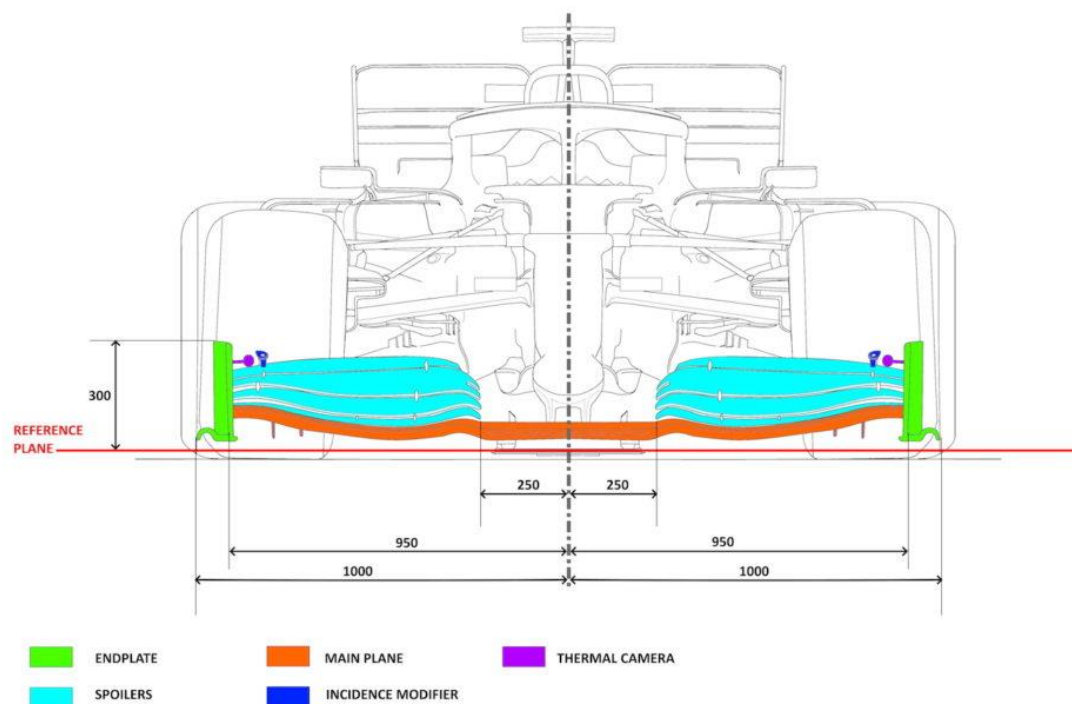


Figure 4 - Diagram of 2022 FIA Front Wing Dimensional Constraints of a FORMULA ONE Race car (Fédération Internationale de l'Automobile, 2022)

2. Loading Force will be determined by the test loading procedure applied to 2022 Formula One race series front wings as stipulated in the 2022 Formula One Technical Regulations Section 3.15.4. This states that 1,000N will be applied to the wing at the co-ordinate positions 800mm in front of the front axle (centre of the wing), and 800mm outboard from the centre of the car (800mm from fixing point).

### 3.15.4 Front Wing Bodywork Flexibility

The flexibility of **Front Wing Bodywork** will be tested by applying a load of  $[0, 0, -1000]\text{N}$  at points  $[X_f, Y, Z] = [-800, \pm 800, 250]$  or  $[-1000, \pm 800, 250]$ .

The load will be applied in a downward direction using a 50mm diameter ram on a rectangular adaptor measuring 350mm in the X-direction and 150mm in the Y-direction. This adaptor must be supplied by the team and should:

- a. Have a flat top surface without recesses.
- b. Be fitted to the car so as to apply the full load to the bodywork at the test point and not to increase the rigidity of the parts being tested.
- c. Be placed with the inner face 725mm from  $Y=0$ .
- d. Be placed with its forward face at  $X_f=-1100\text{mm}$ .
- e. Be placed with its top face at  $Z=250$
- f. Have a mass of no more than 2kg.

The deflection will be measured relative to the survival cell and along the loading axis.

When the load is applied symmetrically to both sides of the car the vertical deflection must be no more than 15mm.

When the load is applied to only one side of the car the vertical deflection must be no more than 20mm.

Figure 5 - 2022 FIA Front wing Flexibility test specification (Fédération Internationale de l'Automobile, 2022)

3. The wing is of simple geometric design, i.e., a single un-interrupted aerofoil, with a uniform structural beam running through the centre of the wing with no internal strengthening components.
4. Supporting ribs and fins do not affect the properties of the structural beam.
5. The weight of the structural beam is not taken into consideration.
6. The weight of the aerofoil materials is not taken into consideration.
7. Nominal tube sizes are disregarded, for the purposes of calculating minimum tube OD.
8. Material is homogenous across its entirety.
9. The attachment of the wing to the vehicle is holding the wing in all 6 degrees of freedom.

## LIMITATIONS OF CALCULATIONS

Due to the assumptions made, there are limitations to the calculations. These calculations are calculated under test condition loading, in the same manner the FIA enforce a 'fixed' aerodynamic component ruling. This means the loadings are not simulated under race conditions. They are a standardised loading applied to the same co-ordinates of the wing, irrelevant of the wing design. For example, under race conditions, force loadings could be much higher and acting upon the wing in combinations of UDL and concentrated loads at different positions along the length of the wing (depending on the design of the aerofoil profile). This also creates a scenario where the wings and can change because of the deflection upon the beam caused by increased aerodynamic loadings (aeroelasticity). During a Formula One race, the front wing can generate as much as 25-30% of the total downforce of the vehicle. With vehicles consistently producing over 2000KG of downforce, the front wings can produce up to 6000N of aerodynamic load along its length, in a combination of load types (both point and UDL).

(Kachare, 2017)

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## HOW THEY MAY BE OVERCOME?

To overcome these limitations, it is proposed to create accurate CAD models of an aerofoil attached to vehicle bodies with differing structural support beam sizes. These models can be transposed into CFD software to simulate aerodynamic conditions upon each design and thus both visualise and calculate the associated loadings under different conditions. This would allow for more accurate selection of tube size which still conforms to the stated maximum deflection. It would also allow the selection of alternative materials such as polymer composites or additive manufactured components.

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## ALTERNATIVE PRINCIPLES AND METHODOLOGIES THAT COULD HAVE BEEN USED

- CAD models created to quickly create and adapt designs
- CFD analysis to determine effectiveness and allow for more precise measurement and modelling
- Scale modelling and wind tunnels, bluff bodies, drafting, moving floor (ground effect), etc.

**TASK TWO – DIFFERENT TYPES OF AUTOMOTIVE FRONT WINGS****HISTORICAL DEVELOPMENT**

When motorsport was first created, there was a desire to develop vehicles in such a way as to achieve higher straight-line speeds. This provided emphasis on developing low-drag cars that were very streamlined and provided less aerodynamic resistance. However, as advancements were made in other areas such as engines, materials, construction methods, etc. the cars become faster and the need to develop more grip during corners became evident. In 1929, the Opel-designed rocket race car was the first to employ wings. Those wings extended sideways, oriented at a negative angle of attack to create downforce. This major innovation was completely ignored at the time, and it took another 35 years to further realize the significance of this principle. (Katz, 2006)

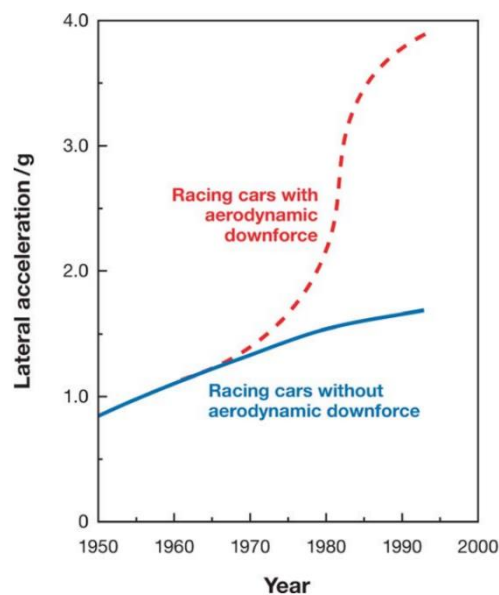


Figure 6 - Trends in maximum cornering acceleration over time (Katz, 2006)

During the 1960s, engineers started to realise the potential of aerodynamic downforce for improving the stability and handling of vehicles and achieving higher cornering speeds and have since developed these principles to create modern Formula One race cars that are capable of lateral acceleration forces of up to 4G. This is shown in Figure 6 - Trends in maximum cornering acceleration over time .

Front Wings first appeared in Formula One in 1967, around the same time as rear wings were introduced into the sport. After recognising the importance of these aerodynamic elements to the vehicle's overall performance in a race, there has been vast research and improvements to the design and regulation of front wings within Formula One. The front wing of a Formula One race car generates around 30%-35% of the vehicle's total downforce and as it is the first part of the vehicle to meet the airflow, it determines the airflow over and underneath the rest of the vehicle also. (Seljak, 2008)

Researchers and engineers have identified three key areas which affect downforce: proximity to ground (ground clearance), angle of attack and effect of Reynolds number.

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## GROUND CLEARANCE

It has been discovered through multiple studies that as the ground clearance decreased, the wing would generate more downforce. The peak value of downforce was generated at 10% ground clearance. The wing would then generate less downforce as ground clearance moved below 10% and causes a 'stall' phenomenon. It was also observed during the studies that drag peaked at 8% ground clearance and the wake and wing tip vortices became smaller as ground clearance decreases. This is because as the ground clearance gets smaller, the effective angle of attack of the wing increases and causes separation on the lower surface. (Kachare, 2017)

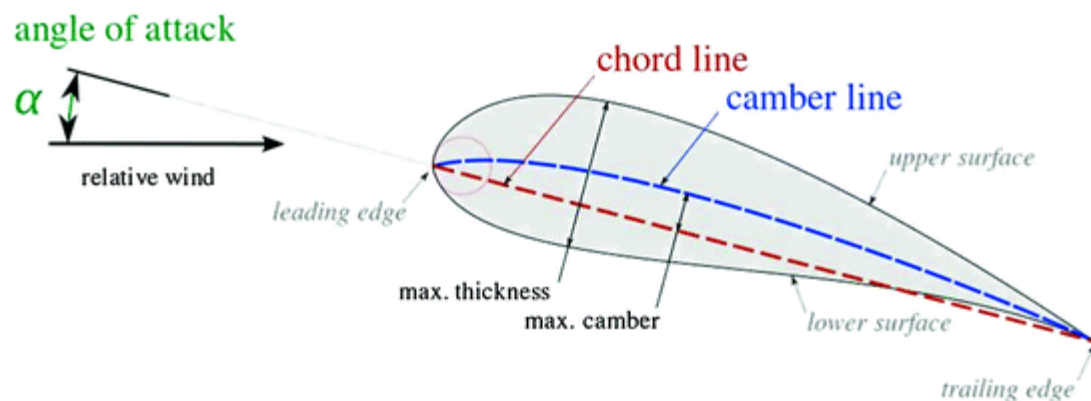


Figure 7 - Schematic of a conventional aero foil (Sathyadevan, 2014)

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## ANGLE OF ATTACK

Angle of attack is defined as the angle between the chord line and the direction of airflow. The effective camber of an aerofoil is increased with the increase of angle of attack, resulting in a higher co-efficient of lift or in an inverted aerofoil application such as a race car front wing, increased downforce. This continues until the angle of 46 degrees, at which point the maximum downforce is achieved and any further increase results in separation of flow (stalling) at the trailing edge, reducing downforce and increasing drag. (Kachare, 2017)

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## MULTI ELEMENT WINGS

From 1984, McLaren introduced the concept of multi element wings, it has proven to be one of the best ways to generate downforce. Multiple aerofoil profiles within a single wing allows for downforce to be generated across a large surface area without the plan profile of the wing becoming any larger. FIA regulations allow for the angle of attack of the second element to be modified to allow front wing loading to be changed to 'balance' the handling of the vehicle. (Seljak, 2008)



Figure 8 - 2022 FORMULA ONE Multi-Element Front Wing (Newbon, 2021)

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## GURNEY FLAPS

Gurney Flaps, a small vertical reinforcement mounted atop of the aerofoil trailing edge, were introduced in 1971 and have remained in use to this day, they allow for a higher angle of attack to be used without increasing drag. This is achieved as they create a low-pressure area underneath the wing tip which sucks the air back into the aerofoil profile and prevents the 'stall' phenomenon which occurs at high angles of attack when the flow of air separates from the surface.



Figure 9 - Diagram showing effect of Gurney flap on aerodynamics of front wing (Formula 1 Dictionary, n.d.)

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## END PLATES

End tip vortices are generated by finite wings such as race car wings and as such, create drag which is detrimental to the aerodynamic profile when it interacts with elements such as the wheels and

sidepods. To overcome these end tip vortices, end plates are fitted to the wings which nullify these forces by directing air flow around the front wheels. (Kachare, 2017)

#### POTENTIAL FUTURE DEVELOPMENT

Future development of FORMULA ONE front wings could allow for active aerodynamics. This means that the aerodynamics could be changed during a race depending on what desired outcome would be i.e., increased drag (air-braking during deceleration), increased downforce (increased traction used during acceleration) or altering downforce between each side of the vehicle (used during cornering to stabilise). There could also be scope to deliberately create a more turbulent wake of air to disrupt a following vehicles aerodynamics and gain advantage.

One way this could be achieved is using hinged aerodynamic profiles and actuators on the front wing which could be triggered automatically using data gathered from sensors such as vehicle speed, steering angle, lateral acceleration, longitudinal acceleration, and yaw rate, or manually via the driver's steering wheel controls.

This principle and technology are already used in FORMULA ONE in the form of DRS and is used extensively in the hyper car sector to increase a cars performance.



Figure 10 - Rear Wing and DRS actuator on the Williams FW44 (Sutton, 2022)

DRS (Drag reduction System) is operated manually by the driver and reduces the angle of attack of only the rear wing. Its use is highly regulated during a race and is typically used during long straights to decrease aerodynamic drag and enable a higher top speed and faster acceleration, useful for overtaking.

**TASK THREE – AUTOMOTIVE FRONT WING MATERIALS AND MANUFACTURING PROCESSES**

There has always been strict governance over that materials that are permitted for use during Formula One race car construction.

This is for many reasons, such as competitive advantage (access to proprietary technology), cost, and most importantly safety. However, as technology has been developed over the years and more complex manufacturing processes and materials have become available, such as additive manufacturing or polymer composite layering, these have been included in the permissible materials for competition.

**15.3.3 Permitted Polymer Composite Materials**

**Matrix Systems:** the matrix system utilised in all polymer composite materials must be based on one of the following:

- a. Epoxy
- b. cyanate ester
- c. bismaleimide
- d. phenolic
- e. polyurethane
- f. polyester
- g. Thermoset resins not derived from petrochemicals – subject to approval.

**Reinforcing:** unidirectional or planar reinforcing is permitted using the following materials:

Figure 11 - FIA 2022 FORMULA ONE Regulations - Permitted Polymer Composite materials (Fédération Internationale de l'Automobile, 2022)

As the rules for permissible materials have changed over the years, some teams have discovered ways to use this to their advantage. An example of this is the characteristics of re-enforcing fibres used within a polymer composite material, FIA governance has allowed for unidirectional or planar re-enforcement of these composites. This is important as some teams have discovered a way to use this for aerodynamic advantage during a race. Redbull Racing use this principle on their front wing to allow it to flex under high aerodynamic load (high speed) to decrease its angle of attack and reduce drag. This is achieved using increased re-enforcement of the composite with fibres laid in a certain axis only. This allows for stiffness in one axis and elasticity in another.

A specific point of note of prohibition in the 2022 FIA regulations is the use of shape memory materials.

#### **15.4 Specific Prohibitions**

**15.4.1** Notwithstanding the list of permitted materials in Article 15.3, the following materials or processes are forbidden:

- a. Metal Matrix Composites, except where allowed under article 15.3.2
- b. Shape Memory Materials except for piezoelectric materials used in electrical sensors.

Figure 12 - FIA 2022 Formula One Regulations - Prohibition of Shape memory materials (Fédération Internationale de l'Automobile, 2022)

This is an interesting point as it is theoretically possible to create a component (front wing) from a material that has a certain shape under normal conditions, however when exposed to light, thermal, chemical, or electrical stimulation can deform and change shape to a desired form. (W.M. Huang, 2010)

This could be particularly challenging to govern as it could allow a team to pass regulation compliance under testing, however deviate from that standard under race conditions, which could not only pose a safety concern, but also create unfair advantage to other teams.

#### TASK FOUR – PROTO-TYPING

After determining that the minimum O.D for the structural tube should be 55mm, using the calculations in Task 1. I would model the design using simulation software to expose the design to simulated stress and loads. If this was not possible, or upon completion of this activity, I would propose to create a prototype which can be exposed to both non-destructive and destructive testing to guarantee its performance prior to introduction to the race series. The prototyping process would require the production of a small batch of the front wing component, at full dimensional scale. This could then be equipped with sensitive measuring equipment (such as strain gauges) and exposed to testing protocols to determine its performance against the original design criteria. The benefit of carrying out small batch prototype testing is that it allows you to conduct testing and ensure the design meets the requirements, with minimal risk to investment (time and money). It captures the unforeseeable effects at an earlier stage and allows them to be studied and if needed, remedied.

For example, if the design is flawed and fails to meet the testing criteria in some way, you have not wasted time, money, and materials, creating multiple components which would then require re-design, re-work, or re-manufacture.

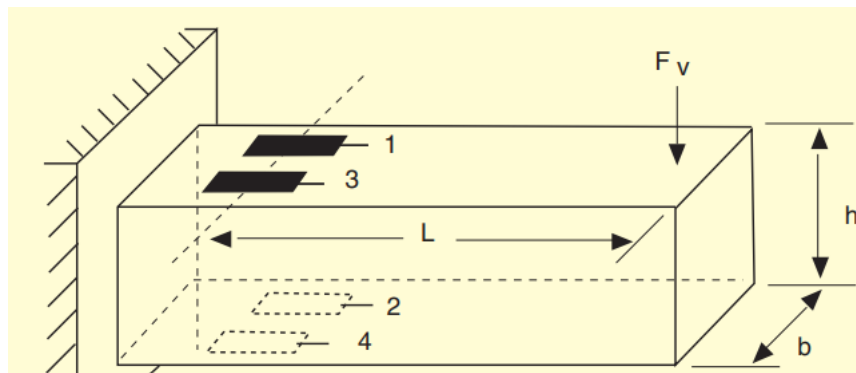
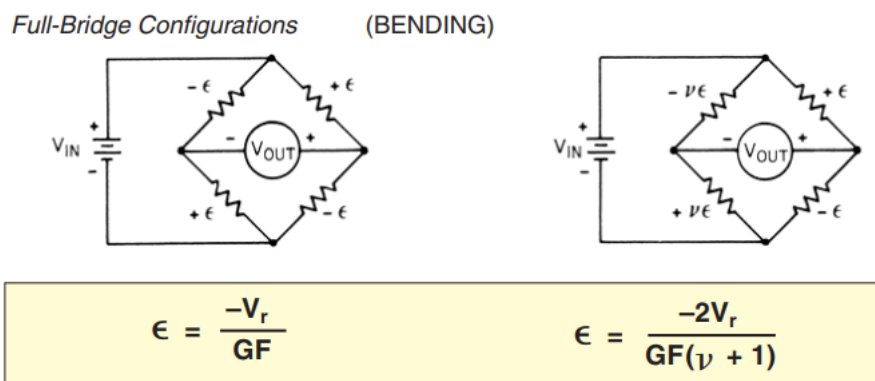


Figure 13 -- Diagram of strain gauge positioning for measurement of bending moment (OMEGA®, n.d.)

The testing protocols could be either conducted using a variety of measuring equipment to measure results. An example which I would suggest for testing of this component for this application is to install strain gauges. These strain gauges work under the piezoresistive effect principle and would be bonded to the surface of the component and measure bending moment stresses as the test load is applied to the component, this application is depicted in Figure 13.

The bending of the component would result in a change of length along its bending area, strain gauges would capture this change in length in its element (wire or foil) as a change in resistance or imbalance of resistance across the circuit (depending on circuit type used), through either a Half bridge or Full bridge Wheatstone bridge circuit. This is expressed as the calculations shown in Figure 14. It would also be possible to use strain gauges to measure forces during real world application (such as in a race), to measure the performance during different conditions and over time, where perhaps material fatigue becomes a factor if the component is repeatedly exposed to forces that can cause plastic deformation, or even unexpected scenarios, such as a collision etc.



sign is correct for  $V_{IN}$  and  $V_{OUT}$  as shown  
 GF = Gage Factor     $\nu$  = Poisson's ratio:

$V_r = [(V_{OUT}/V_{IN})_{\text{strained}} - (V_{OUT}/V_{IN})_{\text{unstrained}}]$ :  
 $\epsilon$  = Strain: Multiply by  $10^6$  for microstrain:  
 tensile is (+) and compressive is (-)

Figure 14 - Full Wheatstone bridge circuit configuration and equation (OMEGA®, n.d.)

Another method of measurement to ensure that the parameters are not exceeded is to attach a Dial Test Indicator (DTI) to the top surface of the component and measure the deflection accurately to within 0.0001 mm when the test load is applied to the component. With this method, as it is a direct contact method of measurement, stiction within the gauge and the resultant force from contact upon the surface has potential to influence, both these factors must be considered when using this method.

Another prototyping technique that is used, is scale prototyping, this is where testing is completed on components that are a scale version of their original size. Although results are usually representative of the full-scale equivalent, there is interpretation and transposition of the data which needs to occur (opportunity for human error) and some physical attributes and phenomenon which may not be present at smaller scales. Under other circumstances, where load testing would not be required, a technique known as rapid prototyping through additive manufacturing can be used. This is particularly well suited to dimensional checks and assembly interactions and would be interpreted as a purely indicative result.

Another benefit of prototyping is it allows you complete destructive testing of the component. This is where you apply test parameters which exceed the real-world or expected parameters under normal conditions. In this example, I would continue to increase the force load applied to the structural beam until it surpasses the elasticity boundary of the material and moves into the plastic deformation region and then then into the failure region. This would allow you to measure the forces that the component would be able to perform under and ensure adherence to these parameters.

## CONCLUSION

A Formula One Race Car Front wing is a very important component due to its high effect on vehicle aerodynamics - 30%-35% of the vehicle's total downforce is generated by the front wing and is the first part of the vehicle to meet the airflow, it determines the airflow over and underneath the rest of the vehicle (Seljak, 2008). Throughout the years of Formula One, engineers have realised the front wing's importance and studied the effects the profile has upon the vehicle aerodynamics and the component's structure itself. This has resulted in very tight regulation by the governing body (FIA) in the shape, size and material specifications allowed. Advancements in design processes and technologies have enabled the creation of race cars that can generate over 4G of lateral acceleration forces, which makes for a more competitive and entertaining race series and shows that competitive need has driven advancements in material science, manufacturing technology and design principles. This high performance has obvious safety implications for the drivers and spectators, which requires strict governance to ensure safety is maintained. This means that testing must be carried out to enforce adherence to the regulations, these tests (in addition to the regulations) require specific considerations when designing components as the tests are often not true representation of real-world conditions.

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