Design of Formula One Racing Car

Triya Nanalal Vadgama
Student
Department of Aeronautical Engineering
Sardar Vallabhbhai Patel Institute of Technology, Vasad
Gujarat Technological University, Ahmedabad, India

Mr. Arpit Patel,
Assistant Professor
Department of Aeronautical Engineering
Sardar Vallabhbhai Patel Institute of Technology, Vasad
Gujarat Technological University, Ahmedabad, India

Dr. Dipali Thakkar,
Head & Professor
Department of Aeronautical Engineering
Sardar Vallabhbhai Patel Institute of Technology, Vasad
Gujarat Technological University, Ahmedabad, India

Abstract- A modern Formula One (F1) Racing Car has almost as much in common with an aircraft as it does with an ordinary road car. Aerodynamics has become a key to success in the sport and teams spend millions of dollars on research and development in the field each year for improving performance. The aerodynamic designer has two primary concerns:

i. the creation of downforce, to help push the car’s tyres onto the track and improve cornering forces,
ii. to minimise the drag that occurs due to turbulence and acts to slow down the car.

In this project, a Formula One race car will be designed using the CAD software CATIA V5R20. All the dimensions are based on the standards laid down by the FIA (Fédération Internationale de l’Automobile). The car design will be enhanced to streamline the flow over the car. Various parts that will be designed include the wheels, front and rear airfoils, front and rear wings, car body chassis, among other subassemblies. A driver will also be placed in a typical driving position inside the car.

Keywords- Formula One race car, Airfoil, Aerodynamics, Body chassis, driver.

I. INTRODUCTION

On the surface, automobile racing appears simply as a popular sport. But in reality, racing serves as a proving ground for new technology and a battlefield for the giants of automobile industry. Although human factors are frequently publicized as the reason behind the success or failure of one racing team or another, engine power, tire adhesion, chassis design, and recently, aerodynamics probably play a very important role in winning this technology race.

One of the most important aspects of Formula One (F1) car design is aerodynamics. Creating down force, to hold the car to the ground to improve cornering; and minimizing drag, which slows the car down are two primary concerns when designing the car. Modern F1 teams use expensive wind tunnels and computational fluid dynamics systems to analyze the effectiveness of an aerodynamic design for a car. In these analyses, every surface of the car, including the driver’s helmet must be considered. Even an advertising sticker can affect the airflow, and placing a badge on a crucial element could produce a two-to-three percent difference in air pressure. Disrupted air flow can cause turbulence, which will produce drag to slow the car. F1 cars often have small ‘winglets’ before the rear wing, which ‘clean up’ complex air flow in order to maximize down force. The scope of this project includes:

i. Designing of F1 three-dimensional CAD model using CATIA V5 R21 software.

The CAD model will be rectified before simulating it. The corrections are necessary to ensure an accurate representation of the aerodynamic geometry of the car. These will be done in three steps:

i. Assembling missing components,
ii. Redesigning lost parts or parts that were missing,
iii. Resizing components with accurate dimensions and features.

The internal geometry, such as the engine and transaxle, will not be included as the primary focus of this project is external flow. As such, the internal parts will be removed from the CAD model.

A. Formula One Background History

The Formula One (F1) World Championship is the highest class of single-seat auto racing in the world. It is sanctioned by the FIA (Fédération Internationale de l'Automobile). Formula One cars can reach speeds upto 330 km/h. The FIA controls and regulates all the sizes and dimensions of Formula One car. These strict regulations led to similarly-dimensional cars. A typical car will be 463cm long, 180cm wide and 95cm high.

Flexible bodywork, with the exception of the rear-wing, is strictly prohibited. Moreover, any device, system or procedure which uses driver movement to alter the aerodynamic characteristics of the car’s bodywork is strictly prohibited. Sections of bodywork, such as front wing end-
plates, are required to be sufficiently thick to prevent damage to tyres of other cars.

**B. Ferrari F10 Background**

The Ferrari F10 is built by Scuderia Ferrari Marlboro.

1) **Specifications**:
   - Chassis: Carbon fiber and honeycomb composite structure
   - Gearbox: Ferrari 7-speed (+reverse) longitudinal gearbox
   - Differential & gearbox: Limited slip differential, Semi-automatic sequential electronically controlled gearbox
   - Brakes: Ventilated carbon fibre disc brakes
   - Suspension: Independent suspension, push rod activated torsion springs, front and rear

2) **Engine**:
   - Engine: type 056
   - Cylinders: V8 90°
   - Cylinder Block: Cast Aluminium
   - Number of Valves: 32,
   - Pneumatic Distribution
   - Total Displacement: 2398 Cm³
   - Piston Bore: 98 Mm
   - Weight: 95 Kg
   - Injection: Magneti Marelli
   - Digital Electronic Injection
   - Ignition: Magneti Marelli
   - Static Electronic Ignition
   - Fuel: Shell V-Power
   - Lubricant: Shell Helix Ultra

3) **Dimensions**:
   - Wheelbase: 3050mm
   - Front Track: 1470mm
   - Rear Track: 1405mm
   - Overall Length: 4545mm
   - Overall Height: 959mm
   - Overall Width: 1796mm
   - Overall Weight: 600kg, including driver and camera
   - Wheels, Front And Rear: 13”

**C. Aerodynamics Background**

Aerodynamics is a branch of dynamics concerned with studying the motion of air, particularly when it interacts with a moving object. Aerodynamics is a subfield of fluid dynamics and gas dynamics, with much theory shared between them. It is often used synonymously with gas dynamics, with the difference being that gas dynamics applies to all gases.

Understanding the motion of air (often called a flow field) around an object enables the calculation of forces and moments acting on the object. Typical properties calculated for a flow field include velocity, pressure, density and temperature as a function of position and time. By defining a control volume around the flow field, equations for the conservation of mass, momentum, and energy can be defined and used to solve for the properties.

Aerodynamics has become key to success in the Formula One sport and spends of millions of dollars on research and development in the field each year. The aerodynamic design has two primary concerns.

i. The creation of downforce to help push the car’s tires onto the track and improve the cornering force.

ii. To minimizing the drag that caused by turbulence and act to slow the car down.

The drag over a body can be minimized by streamlining it (smooth exterior surface). As a result, there will be potential improvements in fuel economy. [Fig.4 & 5]
An inverted airfoil to generate a negative lift force – Downforce. This leads to major improvements in race car performance, especially on tracks with numerous high-speed, unbanked turns. Aerodynamic downforce increases the tires’ cornering ability by increasing loads on the tires without increasing the vehicle’s weight. The result is increased cornering ability, with no weight penalty, which gives a reduction in lap times.
II. CAD (COMPUTER-AIDED DESIGN) MODEL DEVELOPMENT USING CATIA V5R20

A. Wheel :

Fig. 11 Isometric View of Wheel

Fig. 12 Different Views of Wheel

B. Front Wing :

Fig. 13 Airfoil – NACA 4412

Fig. 14 Assembly – Zero Angle of Attack

Fig. 15 Assembly – Zero Angle of Attack – Different Views

Fig. 16 Assembly – Negative (-15°) Angle of Attack

Fig. 17 Assembly – Negative (-15°) Angle of Attack – Different Views
C. Rear Wing :

Fig. 18 Airfoil – NACA 2408

Fig. 19 Assembly – Zero Angle of Attack

Fig. 20 Assembly – Zero Angle of Attack – Different Views

Fig. 21 Assembly – Negative (-15°) Angle of Attack

Fig. 22 Assembly – Negative (-15°) Angle of Attack – Different Views
D. Car Body Chassis :

Fig. 23 Isometric view

Fig. 24 Different Views
E. Human Driver:

TABLE 1. HUMAN POSTURE ANALYSIS

<table>
<thead>
<tr>
<th>Segments</th>
<th>Angle</th>
<th>Degree Of Freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm (Left &amp; Right)</td>
<td>60°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Forearm (Left &amp; Right)</td>
<td>20°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Full Spine (Lumbar=Thoracic)</td>
<td>56.568°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Head</td>
<td>8°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Leg (Left &amp; Right)</td>
<td>45°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Line of Sight</td>
<td>0°</td>
<td>Up</td>
</tr>
<tr>
<td>Lumbar</td>
<td>37.441°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Thigh (Left &amp; Right)</td>
<td>30°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Thoracic</td>
<td>14.381°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Hand (Left &amp; Right)</td>
<td>-20°</td>
<td>Extension</td>
</tr>
<tr>
<td>Index 1 (Left &amp; Right)</td>
<td>25°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Index 3 (Left &amp; Right)</td>
<td>80°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Middle Finger 1 (Left &amp; Right)</td>
<td>10°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Middle Finger 3 (Left &amp; Right)</td>
<td>80°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Annular 1 (Left &amp; Right)</td>
<td>10°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Annular 3 (Left &amp; Right)</td>
<td>80°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Auricular 1 (Left &amp; Right)</td>
<td>10°</td>
<td>Flexion</td>
</tr>
<tr>
<td>Auricular 3 (Left &amp; Right)</td>
<td>80°</td>
<td>Flexion</td>
</tr>
</tbody>
</table>
F. Car:

Fig. 26 Isometric View
<table>
<thead>
<tr>
<th>Specification</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL LENGTH</td>
<td>4545 mm</td>
</tr>
<tr>
<td>OVERALL WIDTH</td>
<td>1800.06 mm</td>
</tr>
<tr>
<td>TOTAL HEIGHT</td>
<td>959 mm</td>
</tr>
<tr>
<td>REAR TRACK</td>
<td>1405 mm</td>
</tr>
<tr>
<td>FRONT TRACK</td>
<td>1470 mm</td>
</tr>
<tr>
<td>WHEEL WIDTH</td>
<td>330.2 mm</td>
</tr>
<tr>
<td>WHEELBASE</td>
<td>3069.8 mm</td>
</tr>
</tbody>
</table>

![Fig. 27 Front view](image1)

![Fig. 28 Back view](image2)
III. FUTURE PLANS

- Computational Fluid Flow and Structural Analysis of Front wing airfoil NACA 4412.
- Computational Fluid Flow and Structural Analysis of Rear wing airfoil NACA 2408.
- Computational Fluid Flow and Structural Analysis of Front Wing Assembly.
- Computational Fluid Flow and Structural Analysis of Rear Wing Assembly.
- Computational Fluid Flow and Structural Analysis of the entire car model.

[Validations will be based on Zero AOA results]

ACKNOWLEDGEMENT

It is always a pleasure to remind the fine people who helped me throughout my project.

I am extremely thankful to Dr. Dipali Thakkar for giving me an opportunity to undertake this project. I would like to give a special thanks and express my deep sense of gratitude to Mr. Arpit Patel for his assistance, expert guidance, and suggestions throughout this project work. Without the help of their knowledge and expertise in every facet of the study, from helping to find the relevant data and in analyzing the results, this project would not have been completed.

I sincerely thank all other faculty members of the Aeronautical Department for helping me in all possible ways for the betterment of my project.

Last, but certainly not the least, I am very thankful to my family and friends who have been giving me unconditional support throughout the entire period of my project, because without them, none of this would have been possible.

REFERENCES

[1] A rear spoiler with adjustable aerodynamic profiles for a high performance road vehicle (WIPO; Patent No.: EP2631160; Application No.: 13156647; Inventor: de Luca Marco; Applicant: Ferrari SPA)
[3] Computational Fluid Dynamics – by J.D. Anderson