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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-dimensioned 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 endplates, 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 Marlbolo.

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 Cm^3
Piston Bore: 98 Mm
Weight: 95 Kg
Injection: Magneti Marelli
Digital Electronic Injection
Iginition: 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"

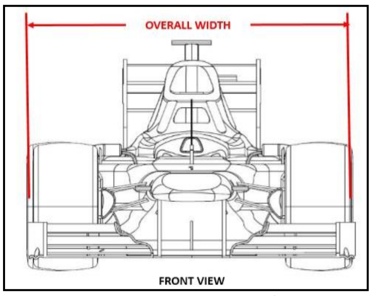


Fig. 1 Front View of F10

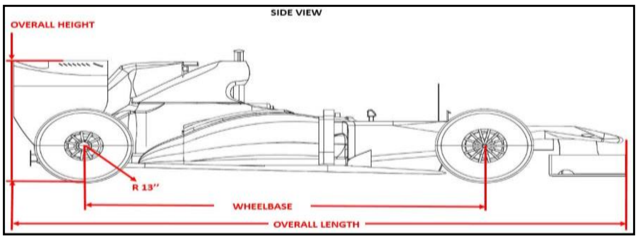


Fig. 2 Side View of F10

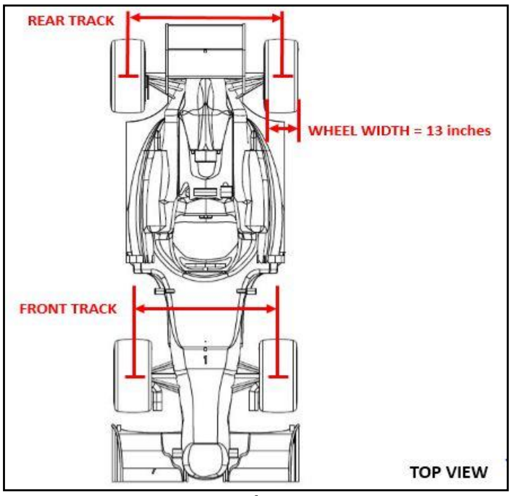


Fig. 3 Top View of F10

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]*

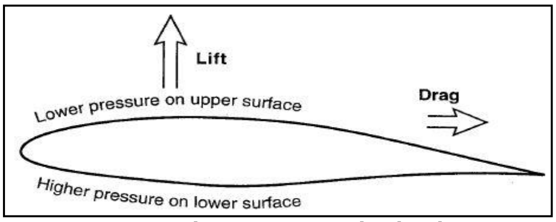


Fig. 4 Flow Over A Streamlined Body
(Courtesy of Race Care Aerodynamics – By Joseph Katz)

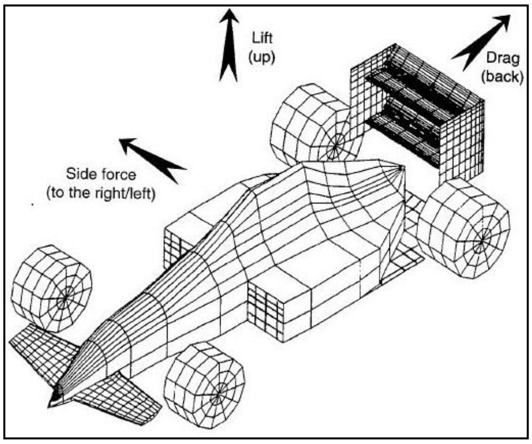


Fig. 5 Aerodynamic Forces
(Courtesy of Race Care Aerodynamics – By Joseph Katz)

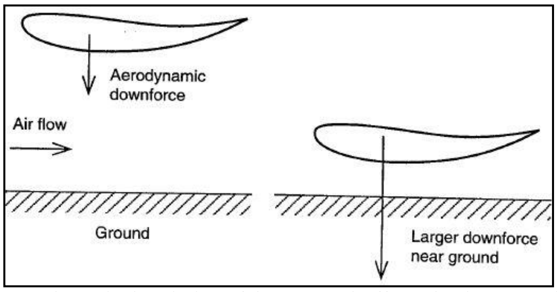


Fig. 6 Schematic description of the "Ground Effect" that increases the aerodynamic lift of the wings when placed near the ground.
(Courtesy of Race Care Aerodynamics – By Joseph Katz)

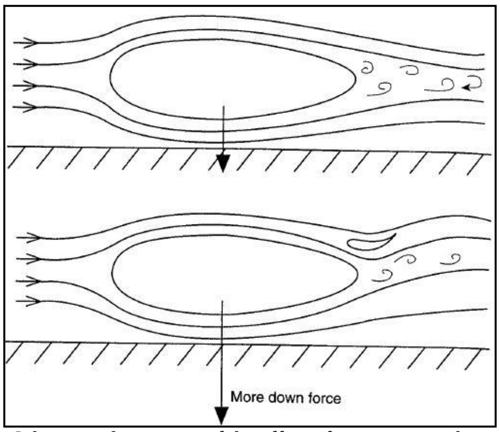


Fig. 7 Schematic description of the effect of rear wing on the streamlines nearby a generic body. (Courtesy of Race Care Aerodynamics – By Joseph Katz)

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.

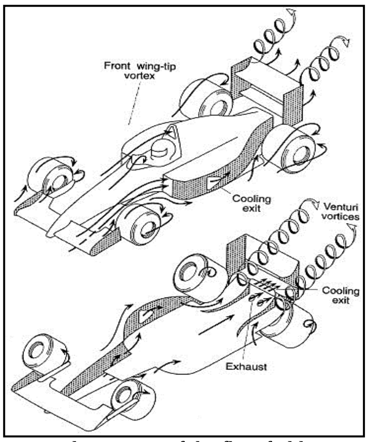


Fig. 8 Schematic description of the flow field over an open-wheel F1 race car. (Courtesy of Race Car Aerodynamics – By Joseph Katz)

D. Selection of Airfoil

NACA 4-series airfoils are the most widely used airfoils for Formula One race cars. The NACA four-digit wing sections define the profile by:

i. First digit - maximum camber as percentage of the chord.
ii. Second digit - the distance of maximum camber from the airfoil leading edge in tens of percentage of the chord.
iii. Last two digits - maximum thickness of the airfoil as a percentage of the chord.

1) Front Wing Airfoil – NACA 4412

The Front Wing of a Formula One car creates about 25% of the total car's downforce. This is one of the most widely used spoiler airfoil, but needs to be enhanced as per speed. Such a thicker airfoil is used to obtain the desired higher downforce from the front end of the car, at a given speed.

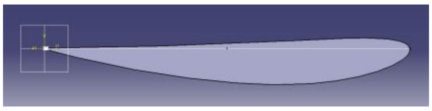


Fig. 9 NACA 4412

2) Rear Wing Airfoil – NACA 2408

Due to location of engine at the rear end of the car, more downforce is generated. Hence, to compensate for minimization of downforce from rear end, a thinner airfoil is used. Thinner airfoil also helps to maintain the continuity of the flow without flow separation. Thus, NACA 2408 is employed at the rear end.

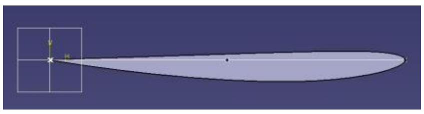


Fig. 10 NACA 2408

II. CAD (COMPUTER-AIDED DESIGN) MODEL DEVELOPMENT USING CATIA V5R20

A. Wheel :

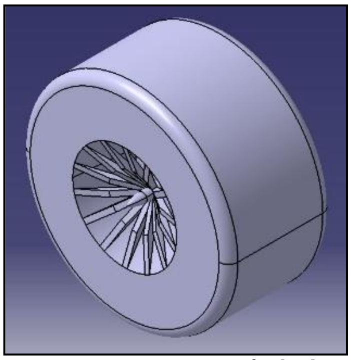


Fig. 11 Isometric View of Wheel

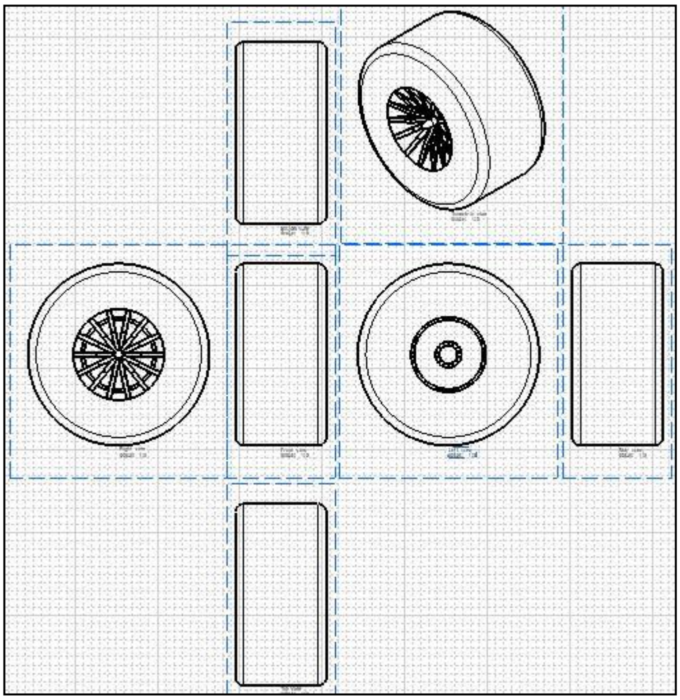


Fig. 12 Different Views of Wheel

B. Front Wing :

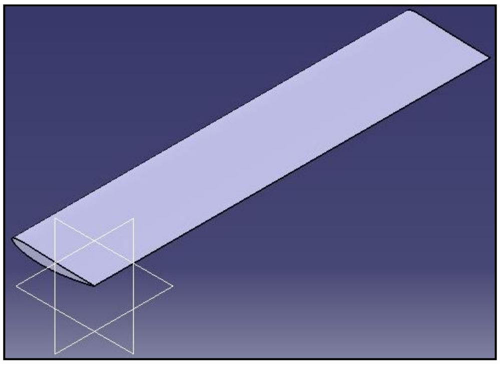


Fig. 13 Airfoil – NACA 4412

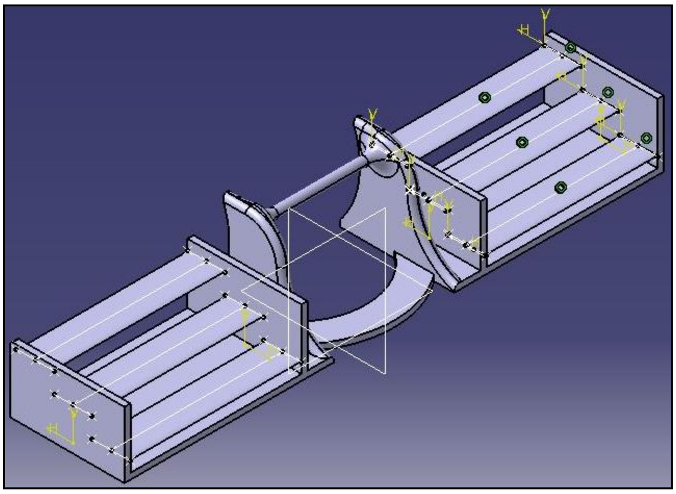


Fig. 14 Assembly – Zero Angle of Attack

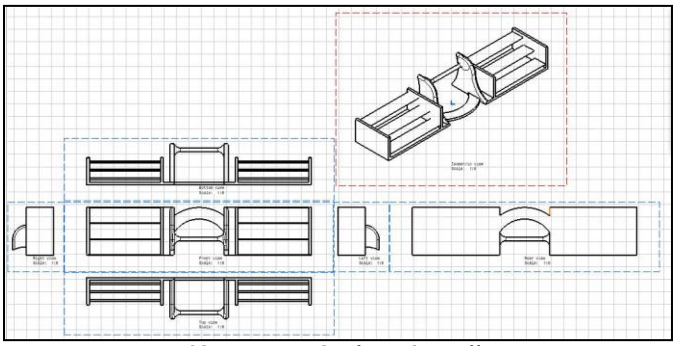


Fig. 15 Assembly – Zero Angle of Attack – Different Views

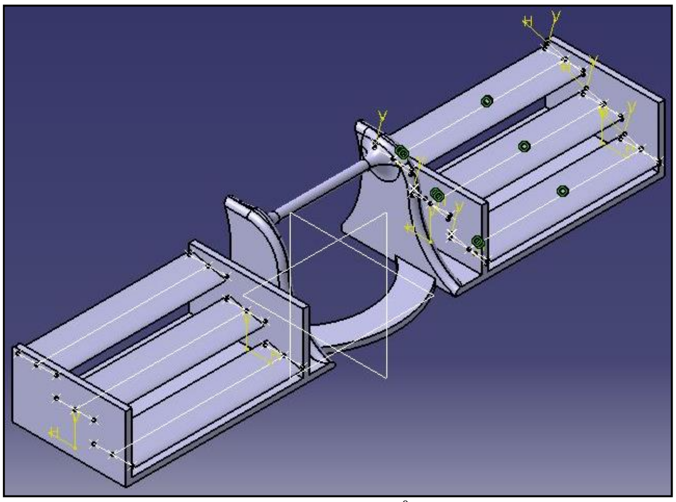


Fig. 16 Assembly – Negative (-15^0) Angle of Attack

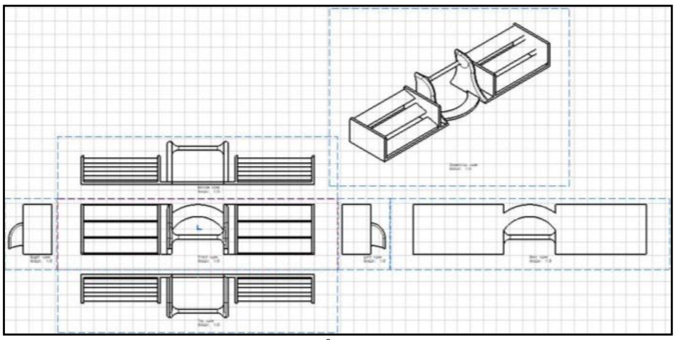


Fig. 17 Assembly – Negative (-15^0) Angle of Attack – Different Views

C. Rear Wing :

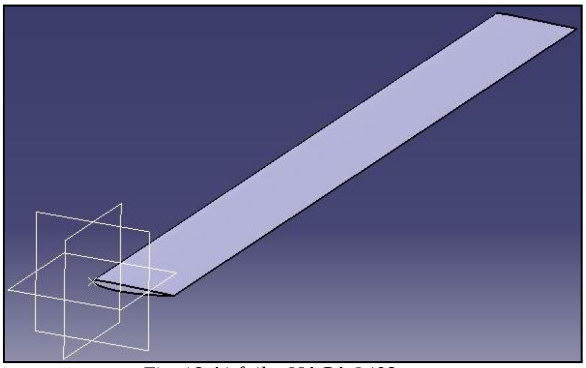


Fig. 18 Airfoil – NACA 2408

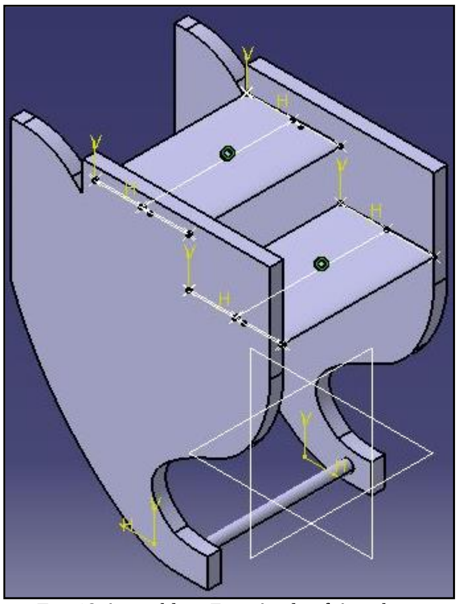


Fig. 19 Assembly – Zero Angle of Attack

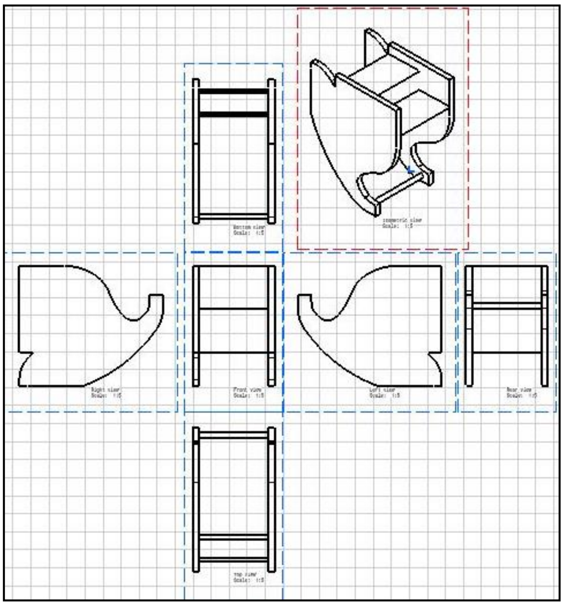


Fig. 20 Assembly – Zero Angle of Attack – Different Views

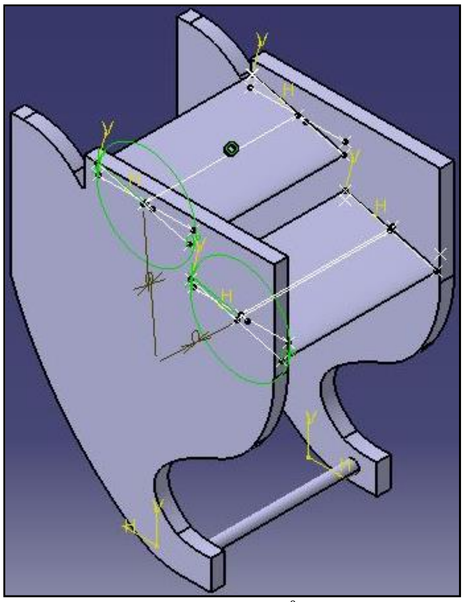


Fig. 21 Assembly – Negative (-15^0) Angle of Attack

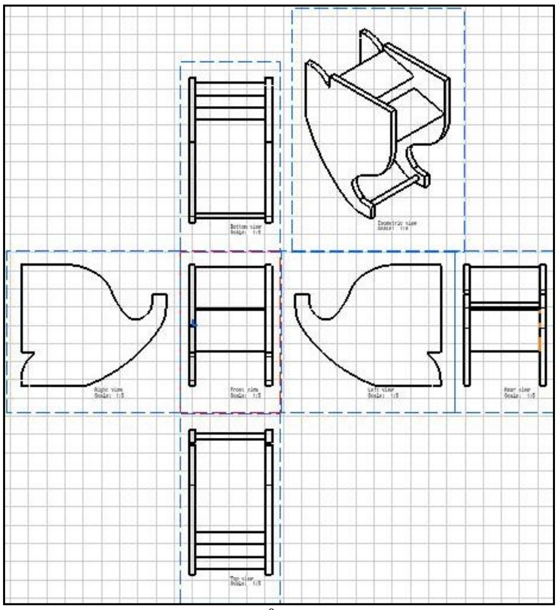


Fig. 22 Assembly – Negative (-15^0) Angle of Attack – Different Views

D. Car Body Chassis :

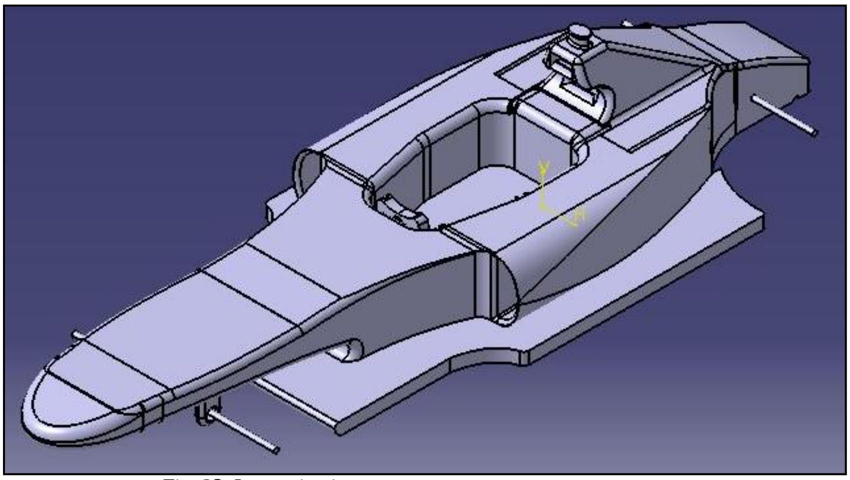


Fig. 23 Isometric view

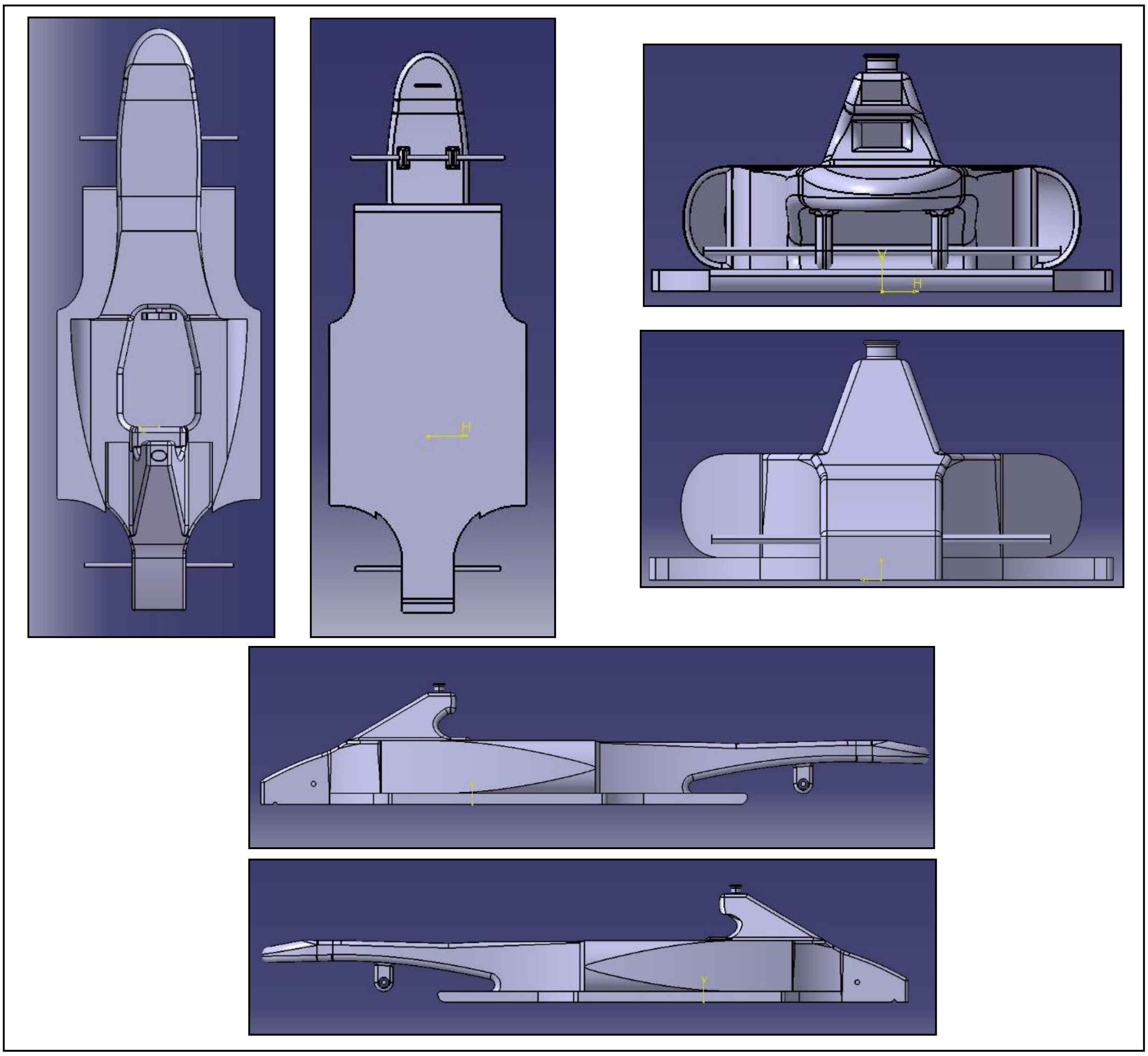


Fig. 24 Different Views

E. Human Driver :

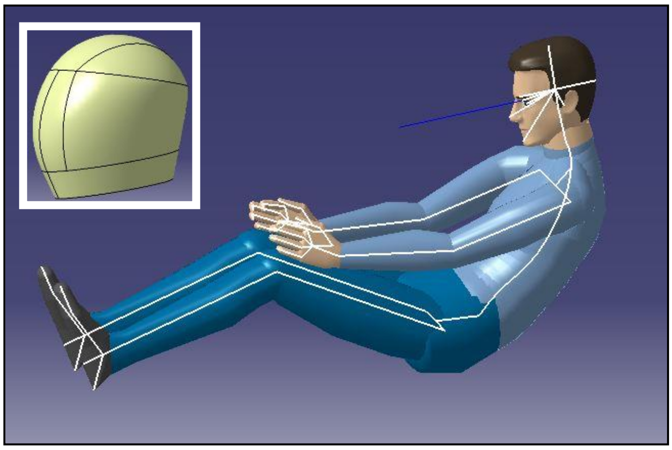
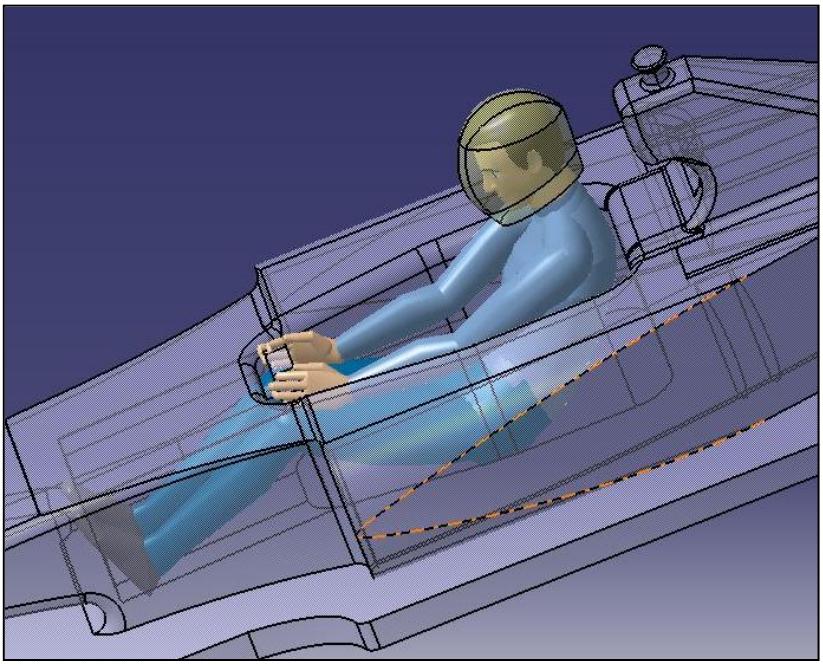
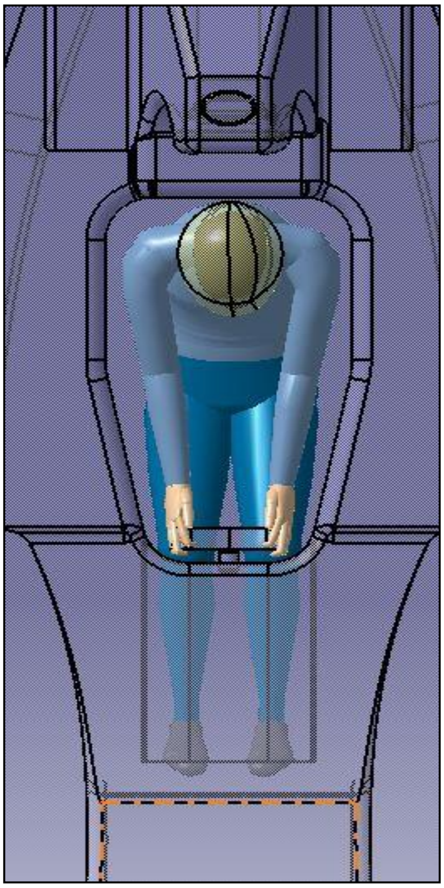


Fig. 25 Human Driver built using Human Builder of Ergonomics Design & Analysis module of CATIA (Inset view : Helmet*)*

TABLE 1. HUMAN POSTURE ANALYSIS

Segments	**Angle**	**Degree Of Freedom**
Arm (Left & Right)	60^0	Flexion
Forearm (Left & Right)	20^0	Flexion
Full Spine (Lumbar=Thoracic)	56.568^0	Flexion
Head	8^0	Flexion
Leg (Left & Right)	45^0	Flexion
Line of Sight	0^0	Up
Lumbar	37.441^0	Flexion
Thigh (Left & Right)	30^0	Flexion
Thoracic	14.381^0	Flexion
Hand (Left & Right)	-20^0	Extension
Index 1 (Left & Right)	25^0	Flexion
Index 3 (Left & Right)	80^0	Flexion
Middle Finger 1 (Left & Right)	10^0	Flexion
Middle Finger 3 (Left & Right)	80^0	Flexion
Annular 1 (Left & Right)	10^0	Flexion
Annular 3 (Left & Right)	80^0	Flexion
Auricular 1 (Left & Right)	10^0	Flexion
Auricular 3 (Left & Right)	80^0	Flexion





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F. Car :

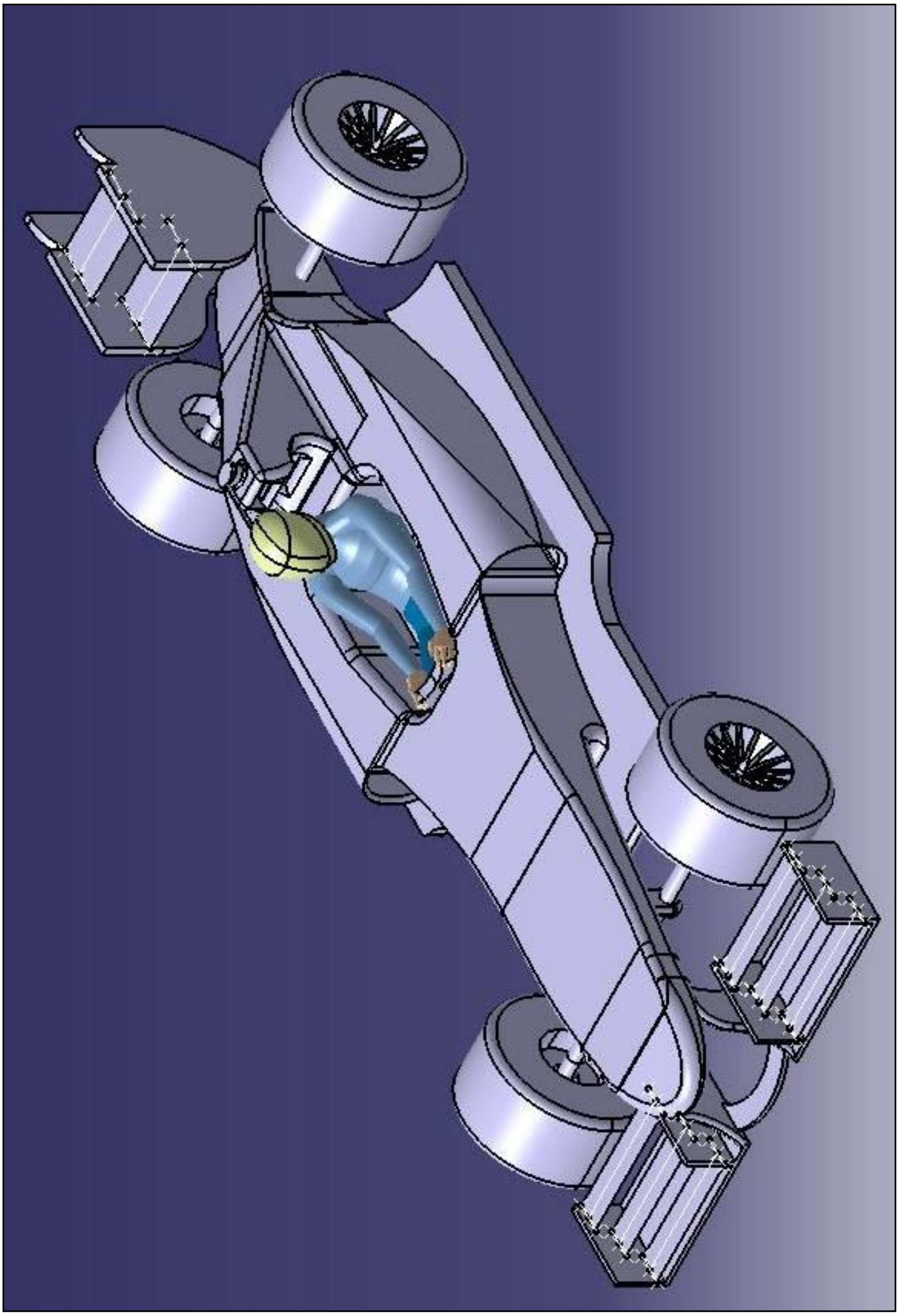

Fig. 26 Isometric View

OVERALL LENGTH = 4545mm
OVERALL WIDTH = 1800.06 mm
TOTAL HEIGHT = 959mm
REAR TRACK = 1405mm
FRONT TRACK = 1470mm
WHEEL WIDTH = 330.2mm
WHEELBASE = 3069.8 mm

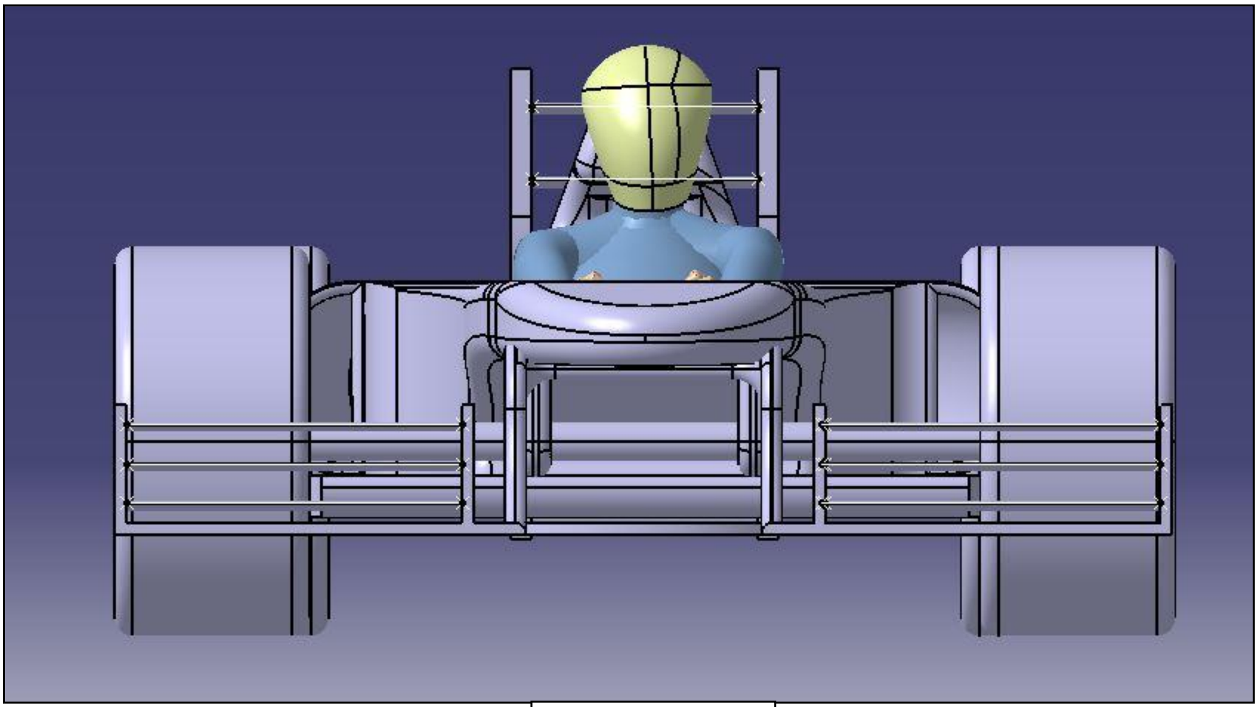

Fig. 27 Front view

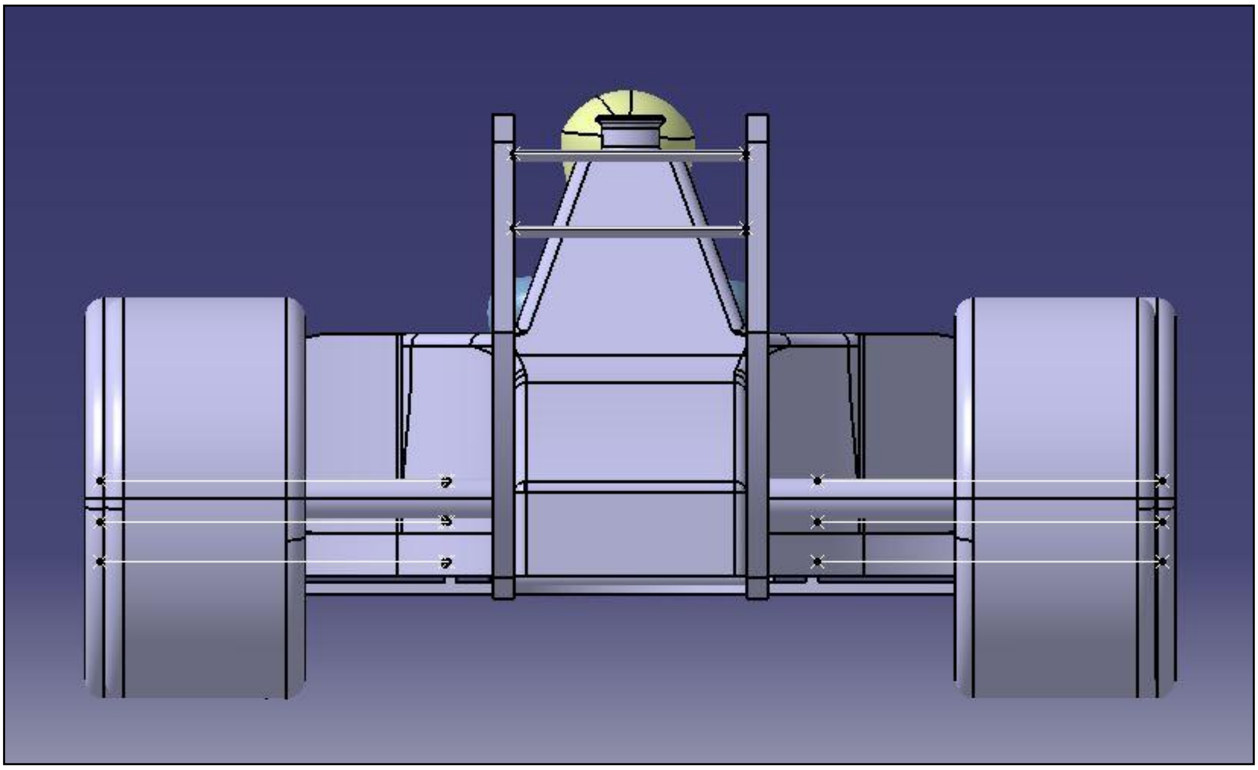

Fig. 28 Back view

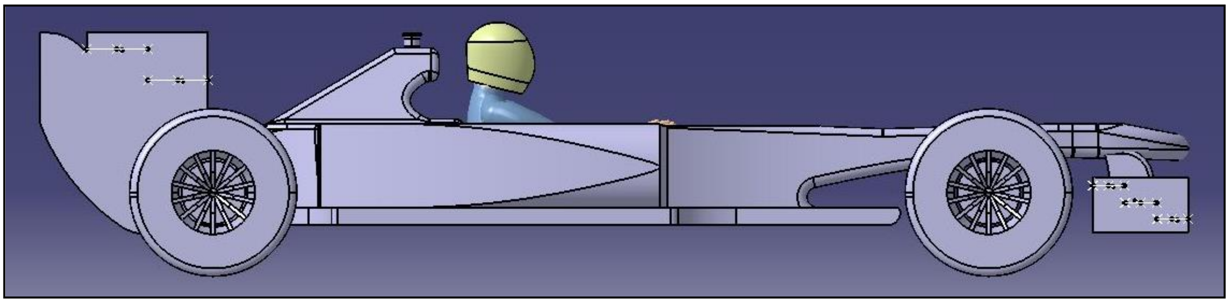

Fig. 29 Left-hand side view

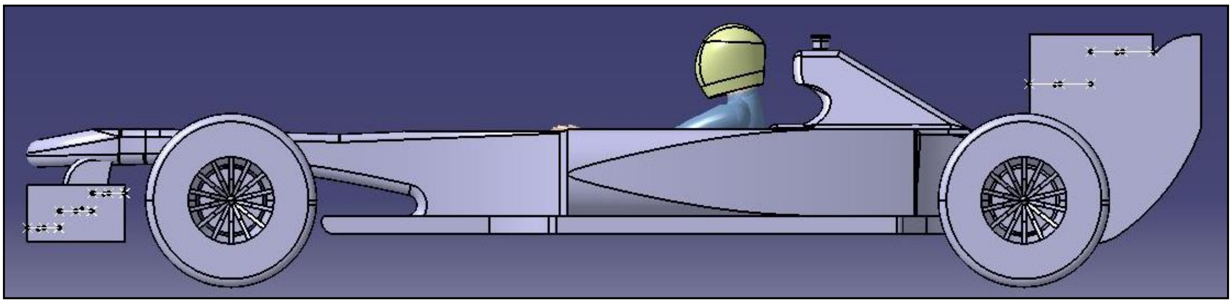

Fig. 30 Right-hand side view

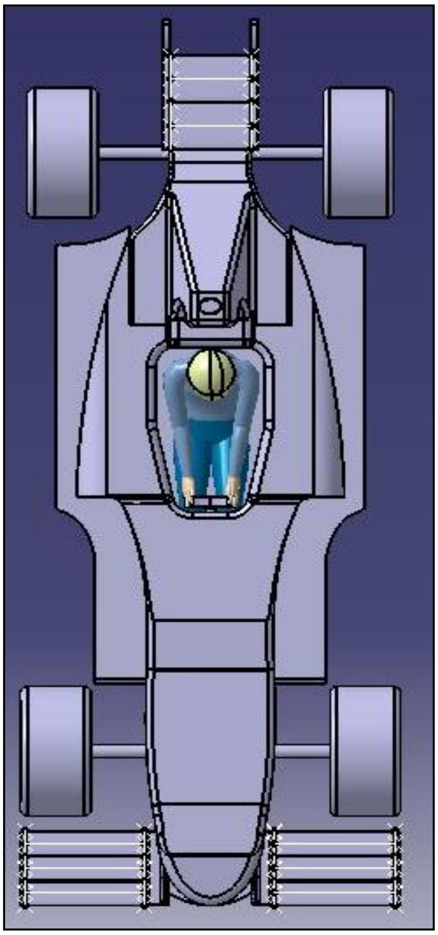

Fig. 31 Top view

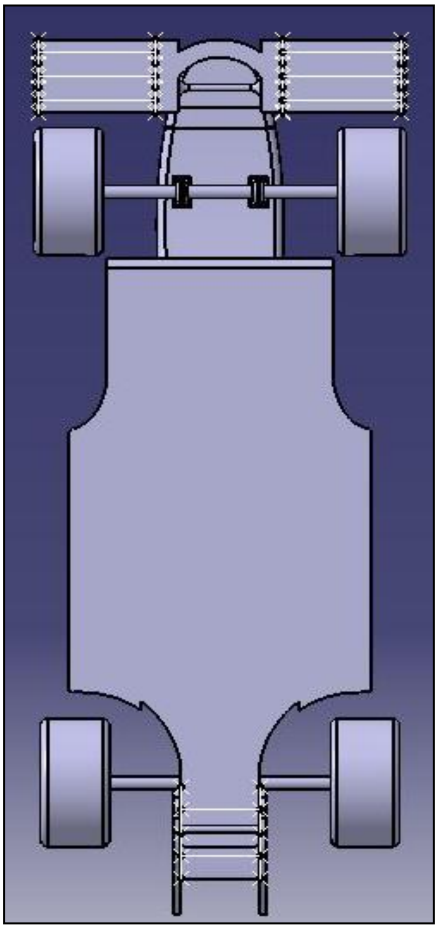

Fig. 32 Bottom view

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.

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[8] Study of Front-Body of Formula One Car for Aerodynamics using CFD (ISSN: 2319-4847; International Journal of Application or Innovation in Engineering & Management (IJAIEM) - Volume 3, Issue 3, March 2014)