International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

Design of Formula Student Vehicle Fairings

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Abstract: The performance of any car, in this case, any race car depends on elements such as the engine, tires, suspension, road, aerodynamics, and of course the driver. In recent years, however, vehicle aerodynamics gained increased attention, mainly due to the utilization of the negative lift (downforce) principle, yielding several important performance improvements. This review gives a brief explanation of the significance of the downforce and few other factors and how they improve performance. Later different methods to generate downforce, such as inverted wings, diffusers, and vortex generators are discussed. Due to the complex geometry of these vehicles, the aerodynamic interaction between the various body components is significant, resulting in vortex flows and lifting surface shapes unlike traditional airplane wings. Typical design tools such as wind tunnel testing, CFD, track testing, and their relevance to automobile development, are discussed as well. Later in the discussion we have listed few different types of fabrication of these aero parts and methods to best achieve a reliable product.

Keywords — Aerodynamics, Downforce, Drag, Computational Fluid Dynamics, Wind Tunnel Testing, Resin.

INTRODUCTION

1.1 History

Automobile Racing must have started at the beginning of the 20th century when the first two automobiles pulled one beside the other. From that first moment on the sport consistently grew, not always following the evolutionary trends of the automotive industry. For example, contemporary race cars have components such as inverted wings and protruding angular plates, which seem unpractical, and are hence unusable by the automotive industry. In all forms of racing, however, aerodynamics eventually surfaced as a significant design parameter, and by the end of the first 100 years of automobiles, all race car designs have some level of aerodynamic element. The foundations of aerodynamics were formulated over the past 200 years

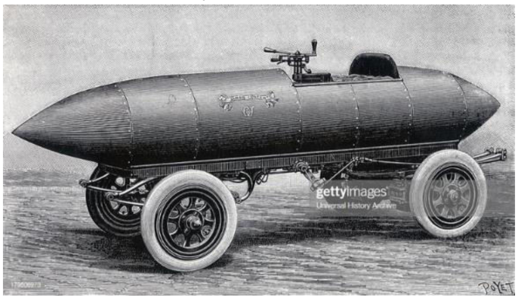


Fig -1 This electric-powered racer had a long cigar shape in an effort to reduce aerodynamic drag.

1.2 Aerodynamics

Aerodynamics is the study of how gases interact with moving bodies. Because the gas that we encounter most is air, aerodynamics is primarily concerned with the forces of drag and lift, which are caused by air passing over and around solid bodies. The motion of air around a moving vehicle affects all of its components in one form or another. Engine intake and cooling flow, internal ventilation, tire cooling, and overall external flow all fall under the umbrella of vehicle aerodynamics.

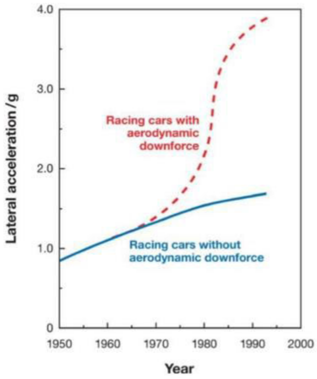


Fig -2: Growth in usage of aerodynamics since 1950s

As we mentioned above the air that moves around the car, will create some drag and resist the motion of the vehicle. The main aim of using aerodynamic design in any race cars is to decrease the drag and increase the downforce, so this can maintain the aerodynamic center of pressure behind the vehicle center of gravity. This will improve both cornering and braking and also allows the control of vehicle stability characteristics (handling).

1.3 Downforce

Downforce is a downwards thrust created by the aerodynamic characteristics of a car. The purpose of downforce is to allow a car to travel faster through a corner by increasing the vertical force on the tires, thus creating more grip.

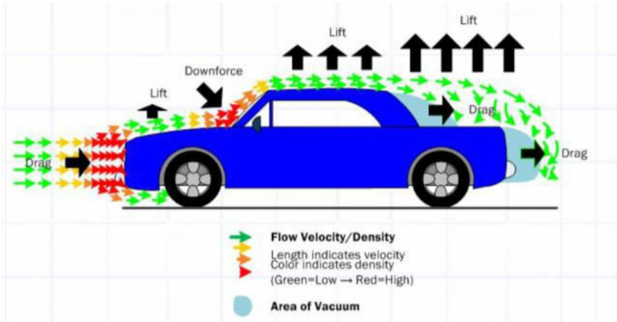


Fig 3: Drag, Lift and Downforce from Over Body Flow

The different types of elements that used to increase the downforce

- Car Wings
- Creating Downforce with the Vehicle's Body
- Diffusers

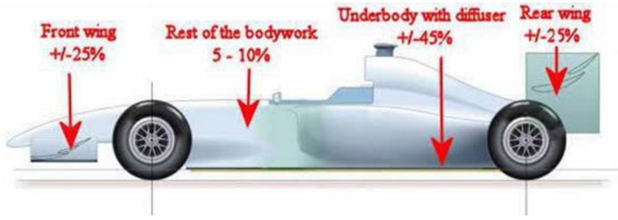


Fig -4: Showing the percentage of downforce created by an F1 car

CONSIDERATIONS

Before designing the we need to consider some of the fallowing things

- Safety
- Rules
- Downforce
- Drag
- Material
- Manufacturing
- Cost

2.1 Safety

According to formula student regulations the each and every aero element should not have the sharp tips. There should have minimum radius of 5 mm for all horizontal edges and 3 mm for vertical edges.

2.2 Rules

There are some rules to be considered

- Any aerodynamic device must be able to withstand a force of 200 N distributed over a minimum surface of 225 cm2 and not deflect more than 10 mm in the load carrying direction
- Any aerodynamic device must be able to withstand a force of 50 N applied in any direction at any point and not deflect more than 25 mm.
- All aerodynamic devices forward of a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set to its most rearward position, must be lower than 500 mm from the ground.
- All aerodynamic devices in front of the front axle and extending further outboard than the most inboard point of the front tire/wheel must be lower than 250 mm from the ground.
- All aerodynamic devices rearward of a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set to its most rearward position must be lower than 1.2 m from the ground.
- All aerodynamic devices lower than 500 mm from the ground and further rearward than the front axle, must not be wider than a vertical plane touching the most outboard point of the front and rear wheel/tire.
- All aerodynamic devices higher than 500 mm from the ground, must not extend outboard of the most inboard point of the rear wheel/tire.
- All aerodynamic devices must not extend further rearward than 250 mm from the rearmost part of the rear tires.
- All aerodynamic devices must not extend further forward than 700 mm from the fronts of the front tires.

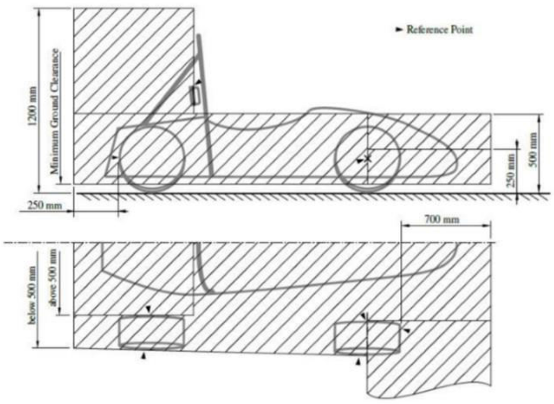


Fig5. Maximum dimensions and positioning of aerodynamic devices. The positioning space is further restricted

2.3 Downforce

As we mentioned in the introduction of downforce our considerations on the downforce is to slightly increase the downforce, less tyre wear and to increase cornering speed and stability

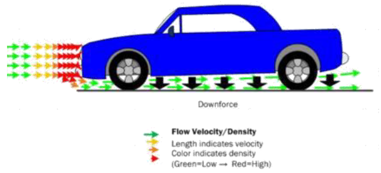


Fig-6: Downforce from raked underbody

2.4 Drag

Drag, in vehicle aerodynamics, is comprised primarily of three forces:

- Frontal pressure, or the effect created by a vehicle body pushing air out of the way.
- Rear vacuum, or the effect created by air not being able to fill the hole left by the vehicle body.
- Boundary layer, or the effect of friction created by slow moving air at the surface of the vehicle body.

We have to consider the drag coefficient by considering the frontal area of the car lesser the area lesser will be the drag.

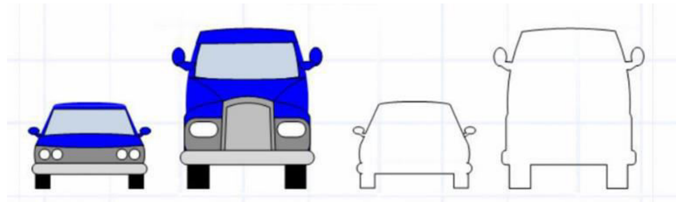


Fig -7: Frontal area of car and truck

Minimizing frontal area in car design is important and easier than reducing the Coefficient of drag which is almost always more difficult.

2.5 Material

There are many materials in the industry out their on the base of our frontal pressure we have decided to go with mixture of woven fiber glass and fiber glass mat and the binder that binds the both material together was epoxy resin, About this we will be discussing in detail later.

2.6. MANUFACTURING

There are few processes to built body works, As per our resources we had manufactured our body works by lay-up process. About this we will be discussing in detail later.

2.7. COST

Coming to cost considerations the above materials are little bit cheap and easily available in our locality

DESIGN

We mostly use two software's to design the body works for the formula student vehicle.

1. SolidWorks
2. Fusion360

As we are less on resources, we considered to create downforce with our body, that to by changing the nose design because it will be the starting part of the body and it will develop major contribution for the downforce.

3.1. Initial considerations for starting the design of the nose

There are few considerations for designing the nose

- Impact attenuator volume
- Front bulkhead dimensions
- Thickness to sustain frontal pressure

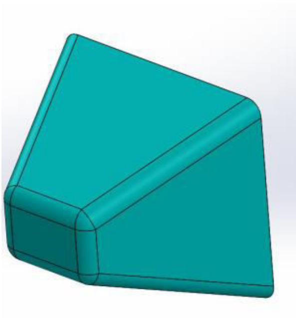


Fig -8: Standard Impact attenuator design

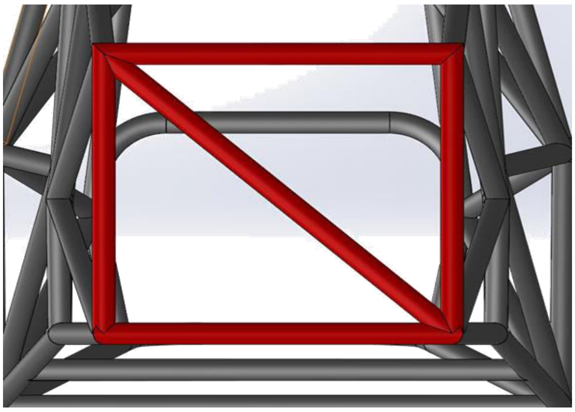


Fig -9: Front bulkhead design

We made three different bodies based on the bases of above considerations

3.2 Iteration 1

In this iteration we reduced the Hight of nose to near to the ground

Fig -10: Iteration 1

3.3 Iteration 2

In this iteration we changed the nose tip to medium height to the ground and changed angles of side faces

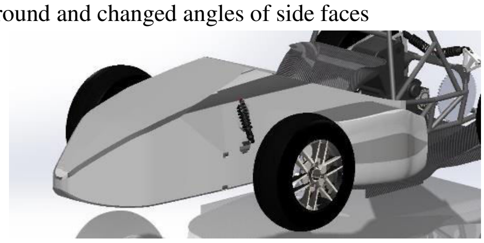


Fig 11: Iteration

3.4 Iteration 3

In this iteration we reduced the height of nose to higher to the ground

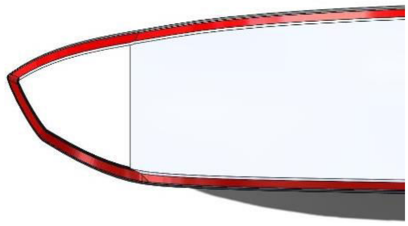


Fig 12: Iteration 3

ANALYSIS

For testing the aero components for a vehicle, we have two ways

- Computational fluid dynamics (CFD)
- Wind tunnel testing
- On-Track testing

As we are less on resources, we considered to create downforce with our body, that to by changing the nose design because it will be the starting part of the body and it will develop major contribution for the downforce.

4.1. Computational Fluid Dynamics

The integration of computational fluid dynamics (CFD) methods into a wide range of engineering disciplines is rising sharply, mainly due to the positive trends in computational power and affordability. One advantage of these methods, when used in the race car industry, is the large body of information provided by the solution. Contrary to wind tunnel tests, the data can be viewed, investigated, and analyzed over and over, after the experiment ends. Furthermore, such virtual solutions can be created before a vehicle is built and can provide information on aerodynamic loads on various components, flow visualization, etc**.**

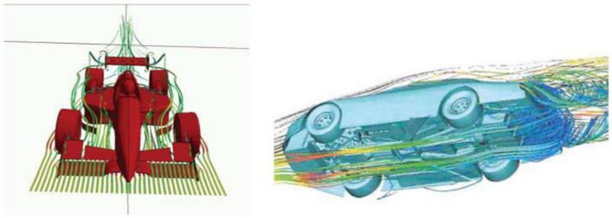


Fig 13: Examples of CFD

4.2. Wind Tunnel Testing

In some wind tunnel tests, the aerodynamic forces and moments on the model are measured directly. The model is mounted in the tunnel on a special machine called a force balance. The output from the balance is a signal that is related to the forces and moments on the model. Balances can be used to measure both the lift and drag forces. The balance must be calibrated against a known value of the force before, and sometimes during, the test.

Fig 14: Wind tunnel testing on wing

4.3. On-Track Testing

With the current ban on full-scale wind tunnel testing, and the potential for even tighter restrictions in 2014, teams have been forced to gather more and more aerodynamic data from track testing in order to validate their scale model and CFD programs. The bulk of this data is obtained by two methods – measuring air pressure at points on the bodywork, and measuring the aerodynamic loads on the aerodynamic surfaces. However, teams will also use non-data-based analysis in the form of flow visualization, more on which later.

The most common method for collecting pressure data is through the use of pitot tubes, sometimes arranged in arrays to analyses flow in a specific area. The latest generation of sensors feature built-in processors to provide individual pressure readings, usually to gauge airspeed, and can often be seen on cars in test configuration mounted high up above the airbox in clean airflow. The processor built into the base of the pitot compares the dynamic and static pressures to provide an accurate airspeed reading.

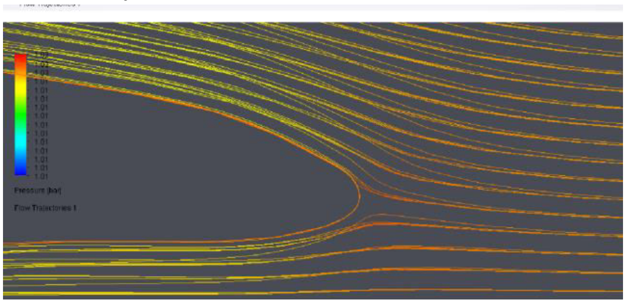
Fig 15: F1 C37 car testing wind flow with the help of fluid

By going through all the processes above we came to conclusion that CFD is the best way to do analysis

Reasons for choosing of CFD over other two

1. Insufficient resources
2. No availability of wind tunnels and tracks in our locality

4.4. CFD Analysis On Nose



4.4.1. Iteration 1

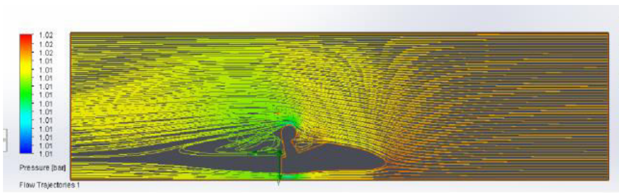


Fig 16: CFD Analysis for iteration 1

4.4.2. Iteration 2

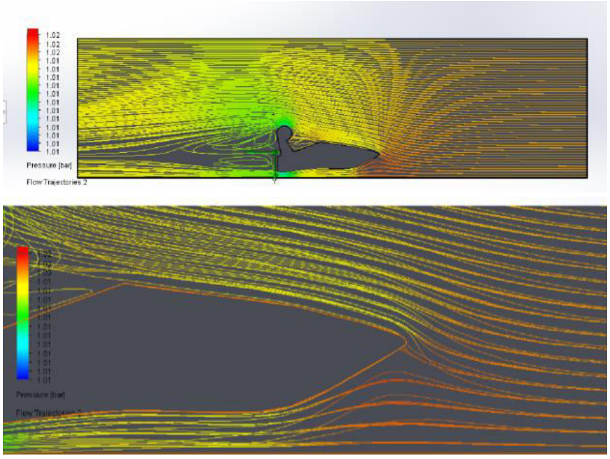


Fig 17: CFD Analysis for iteration 2

4.4.3. Iteration 3

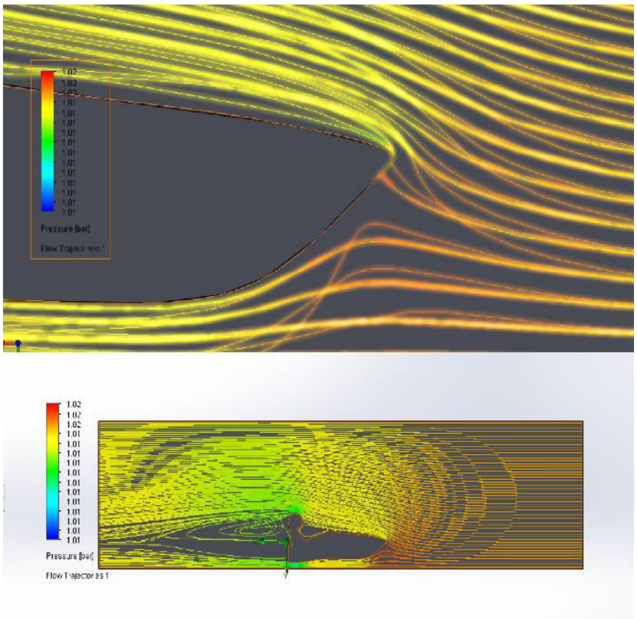
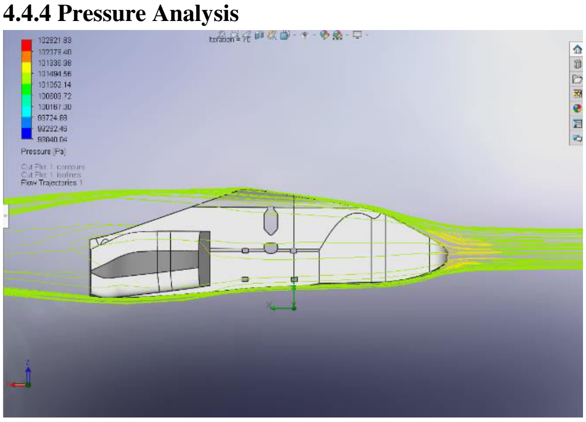
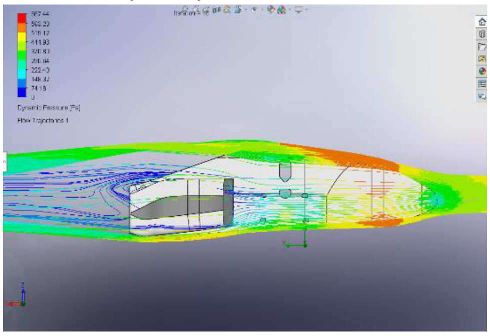


Fig 18: CFD Analysis for iteration 3

4.4.4 Pressure Analysis



4.4.5 Velocity Analysis



MATERIAL

- Glass fiber
- Carbon fiber
- Acrylonitrile butadiene styrene
- Polypropylene

From the below comparisons we considered woven glass fiber as our desired fiber the material used in fabrication of bodyworks are

- Gelcoat
- Catalyst & Hardener
- Polyester resin
- Fiberglas
- Aluminium and thermocol sheets
- Putty

5.1. COMPARISON BETWEEN THE ABOVE MATERIALS

Table 1

MATERIAL	DENSITY (g/cm3)	FEASIABLE MANUFA-CTURING	AVAIL-ABILITY	COST
W1-A E-glass Woven Rovings	1.8 -1.9	Open Molding	High	Low
Carbon Fiber	1.76	Open Molding	Very Low	Very High
Acrilonitrile Butadiene Styrene (ABS)	1- 1.05	Vacuum Molding	High	Moderate
Polypropylene	0.946	Injection Molding	Mode-rate	Moderately high

5.2. Gelcoat

Gelcoatis a material used to provide a high-quality finish on the visible surface ofa fiber-reinforced composite. The most common gelcoats are based on epoxy or unsaturated polyester chemistry. Gelcoats are modified resins which are applied to moulds in the liquid state. They are cured to form cross linked polymers and are subsequently backed with composite polymer matrices, often mixtures of polyester resin and fiberglass or epoxy resin with glass.

5.3. Hardener

Hardener is a clear, colourless, slightly viscous liquid with sharp, pungent smell.Freely soluble in most organic solvents, it is Methyl Ethyl Ketone in Phthalate plasticizer. Dilute solution of MEPK initiates Polymerization of Polyester Resins in glass-reinforced plastic, and casting. For Gel coat formulations and FRP Molding the quantity of Accelerator 2% and Resin hardener required for room temperature (25°C - 45°C) curing may be so adjusted that the resin gels to a tacky condition within the required time (Approx. 20-30minutes).

5.4. Cobalt Accelerator 2%

Cobalt Accelerator 2% reacts with MEKP catalyst to begin the hardening/curing process. Adding extra cobalt to pre accelerated systems can result in very quick gel cure times.

5.5. Polyester resin

Polyester resinselected for the manufacturing. Polyesters offer ease of handling,low cost, dimensional stability, as well as good mechanical, chemical-resistance and electrical properties. Polyester resins are the least expensive of the resin options, providing the most economical way to incorporate resin, filler and reinforcement. They are the primary resin matrix used in SMC (sheet molding compounds) and BMC (bulk moulding compounds).

5.6. Fiberglass

Fiberglass is a fiber reinforced polymer made of a plastic matrix reinforced withfine fibers of glass. The glass fibers are made of various types of glass depending upon the fiberglass use. These glasses all contain silica or silicate, with varying amounts of oxides of calcium, magnesium, and sometimes boron. Fiberglass is a strong lightweight material and is used for many products. Although it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily moulded into complex shapes.

5.7. GI Sheets

GI Sheets of varyingthicknesses were used as the primary material to make the cavity.

5.8. Putty

Putty(a soft, malleable grey-yellow paste, made from ground chalk and rawlinseed oil, that hardens after a few hours and is used for sealing glass in window frames and filling holes in wood) was used as the polishing material.

Besides these hand tools, glues, measuring instruments, heat lamps etc were employed in the fabrication of body panels of polyester resin and fiberglass or epoxy resin with glass.

VI. RESULT

As was our aim, we were successful in designing and fabricating bodyworks or fairings for our formula student vehicle as per the given guidelines and researched techniques. The techniques that we used were seen to be more often efficient than not. Although we have noted few areas such as mould making and plug fabrication where there was a slight problem encountered. In further projects we have decided to use GI sheet as a mould material and get a good finish by giving attention to symmetry and bendings. As per the design part, we have seen that there was reasonable drag achieved and stability was seen during the test laps when compared with the performance without the bodyworks. We have decided to take the design a step ahead in our future projects by exploring wings. We finalized our body design as per our rules and requirements is shown below.

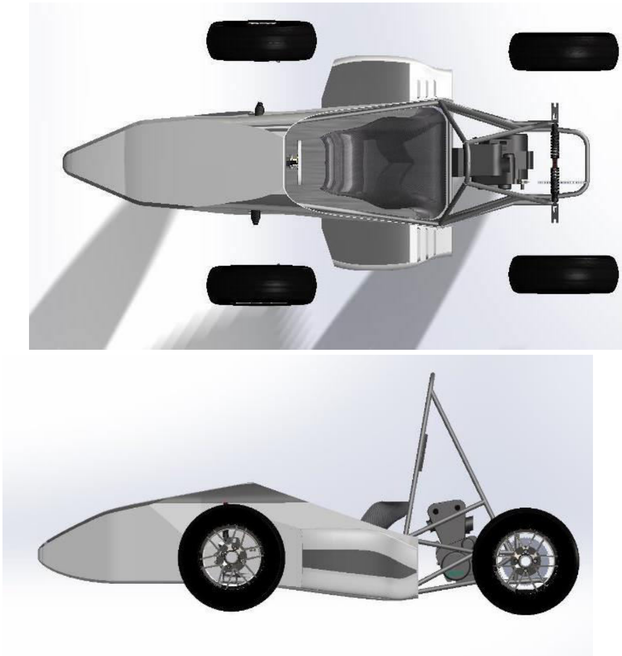


Fig 19: Top and Side views of the finished design model

CONCLUSION

After the completion of the process, some of the notable conclusions drawn were as follows:

- The design was accurate complying fairly with the rules and regulations of the rulebook. It incorporated the aerodynamic features, safety and aesthetics in the vehicle and the most optimal design fulfilling all the pre- requisite objectives were attained after sufficient periodic iterations.
- FRP was selected as the material for making the body panels as it turned out to be the most optimal choice among the alternatives abiding the constraints and meeting the requirements.
- The fabrication of the mold and body panel turned out to be simple, cost effective but time consuming. It is also worthwhile to seek outside insight and expertise when it comes to design, modelling and fabrication of the body panels.

ACKNOWLEDGMENT

We thank our respected Head of the department Dr. B. Vijaya Kumar and all our professors for their guidance and support.

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