Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

Design, Material Selection and Fabrication of a Race Car Body Panel

Mohit Sinha
Department of Industrial & Production Engineering
S.G.S.I.T.S Indore, India

Askrit Verma
Department of Mechanical Engineering
S.G.S.I.T.S Indore, India

Abstract **- This paper aims at the development of FRP body panel for FSAE race car. The student formula competitions challenges teams of university undergraduate and graduate students to conceive, design, fabricate, develop and compete with small, formula style, vehicles [1]. Various rules and regulations such as the use of an air restrictor limits the power of the engine. Hence to compensate for the loss of power, the objective shifts towards losing weight without compromising the strength of the vehicle in order to achieve high Power: Weight ratio.**

The body panel is an integral part of the vehicle as it incorporates aerodynamics and improves the aesthetic look of the vehicle. Weight reduction in this area also becomes easier as high strength is not required. Hence at a low cost, we get an elegant body panel with adequate strength and flexibility.

This paper elaborates the design and fabrication of the body panel of team GSRacers Formula segment's 2015 race car; Aarjav which participated in SAE SUPRA 2015.

Keywords: Body Panel, FRP, Wind Tunnel Testing, Open Molding Process, Aerodynamics

I. INTRODUCTION

Body panel is the surface covering the chassis which must have less weight as much as possible and be rigid enough to bear the aerodynamic forces along with its own weight. The structure of the panel is designed to provide maximum down force for traction and reduce the drag which lessens the forward acceleration of the vehicle. Good aerodynamic considerations incorporated in the vehicle helps in achieving these objectives.

The use of FRP in making the body panel reduces the weight and provides adequate strength with a minimal cost. The in- house fabrication of the mold saves the cost of manufacturing and eliminates the use of machines such as CNC. The technique gives more flexibility in the design as it can be hand crafted as per the desire and demand. As per the size of the mold to be manufactured, this process turns out to be the most optimal choice as it eliminates transportation issues, mold destruction issues for recycling or disposal etc. The manufacturing material is also easily available at the local markets.

This rare method of manufacturing is vital for individuals pursuing career in Production and Custom Designing.

II. DESIGN AND ANALYSIS

The following objectives had to be kept in mind while designing the body panel:

1. Reducing the aerodynamic drag by external shaping.
2. Generating as much aerodynamic download or lateral force possible as possible with a constraint that the drag should not be too high.
3. It should be light weight and fabricated at a minimal expense.
4. It should be designed for manufacturability.
5. It should be able perform optimally according the operating conditions such as maximum speed, air flow conditions etc.

The body panel which is the external surface of the chassis of the race car should function as a streamline element reducing the drag at high speed. Its design should also enable it to act as a closeout to prevent foreign objects coming into the driver compartment during normal operation.

The panel to be designed must be in conformance with the rules and regulations stated for it in the rulebook. These rules have been mentioned below:

1. In plain view, no part of any aerodynamic device, wing, under tray or splitter can be:

a) Further forward than 762 mm (30 inches) forward of the fronts of the front tires
b) No further rearward than 305 mm (12 inches) rearward of the rear of the rear tires.
c) No wider than the outside of the front tires or rear tires measured at the height of the hubs, whichever is wider.

2. All wing edges including wings, end plates, Gurney flaps wicker bills and under trays that could contact a pedestrian must have a minimum radius of 1.5 mm (0.060 inch).

3. No power device may be used to move or remove air from under the vehicle except fans designed exclusively for cooling. Power ground effects are prohibited.

4. Egress from the vehicle within the time set by the rule of driver egress must not require any movement of the wing or wings or their mountings.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

5. The wing or wings must be mounted in such positions, and sturdily enough, that any accident is unlikely to deform the wings or their mountings in such a way to block the driver's egress.

Working within tight constraints of the FSAE regulations and the pre-decided team objectives, it was concluded that the best configuration of the body panels would be a single nose cone with two side panels. Fundamental principles of aerodynamics were incorporated while deciding the shape of the body panel especially of the nose cone. Hence, the first 3-D model was made in Pro-E as shown in the Figure 3. The chassis was taken as the reference to determine the shape, dimensions and fitment. It was designed so that there was no interference with any other part of the vehicle to affect its workability.

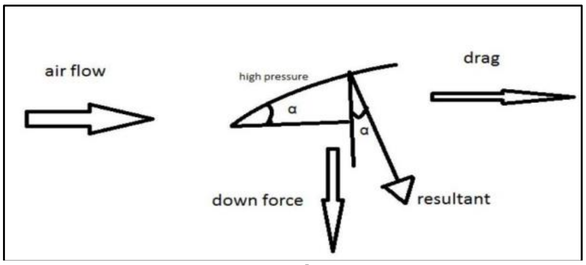

Figure 1: Panel Geometry

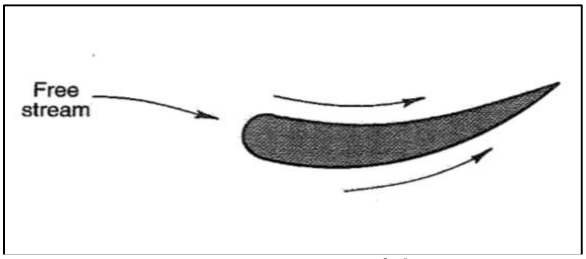

Figure 2: Negative Aerofoil

From the Figure 2, it is observed that when the air moves towards the panel, it creates a high pressure zone above it. This high pressure zone is created as the shape employed is that of a negative aerofoil. This pressure generates two main forces namely:

- Down force
- Drag

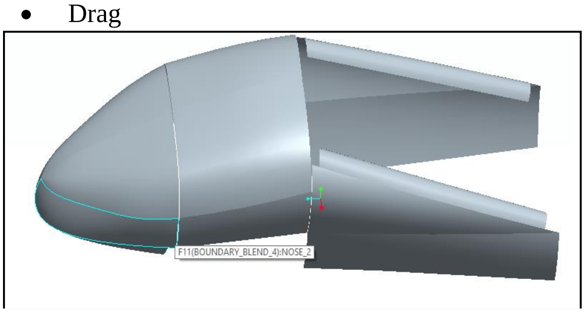

Figure 3: First Cad Model

For better performance, we need more down force with minimum drag. Hence the shape of the cone should be such that it gives the most optimal angle (α) as per the operating conditions of the vehicle and the limitations put forth by the constraints. The best design was chosen after several iterations through the wind tunnel testing of the model in ANSYS.

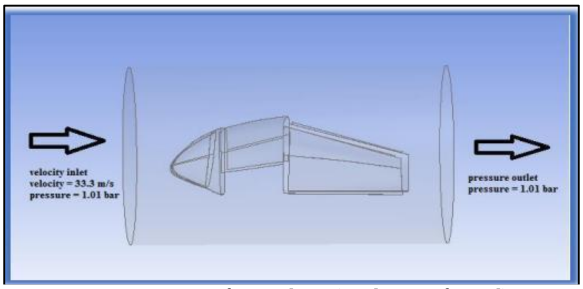

Figure 4: Criteria for Analysis (Enclosure of Panel)

The Computational Flow Dynamics (CFD) analysis was performed and Fluid Flow (Fluent) module was used.

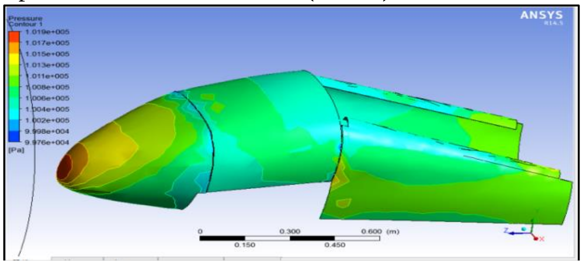

Figure 5: Pressure Contour in First Iteration

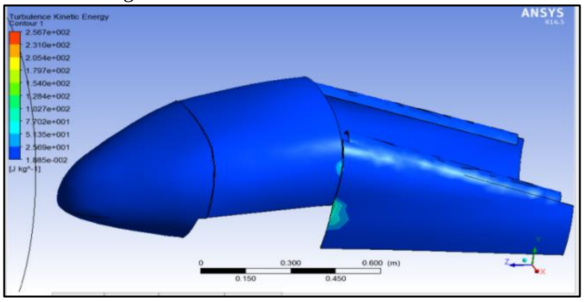

Figure 6: Turbulence Kinetic Energy in First Iteration

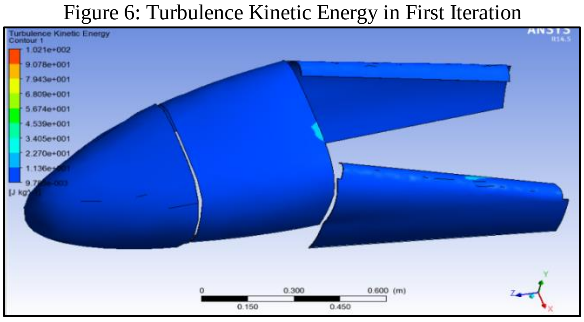

Figure 8: Turbulence Kinetic Energy in Subsequent Iteration

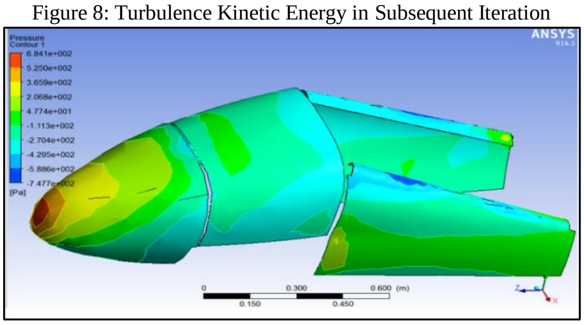

Figure 7: Pressure Contour in Subsequent Iteration

Wind tunnel testing is one of the standard ways to determine the characteristics of a bluff body such as automotive shapes.

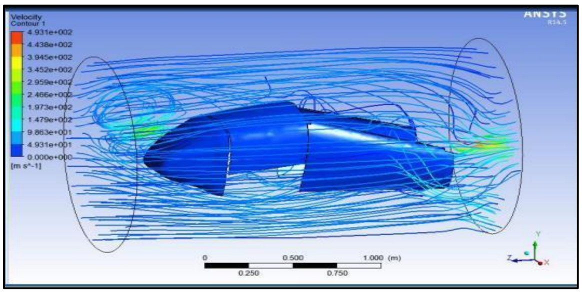

Figure 9: Velocity Contour in Final Iteration

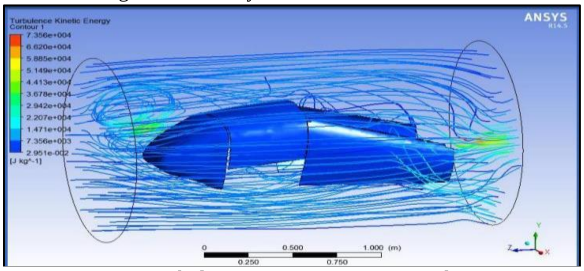

Figure 10: Turbulence Kinetic Energy in Final Iteration

This testing may take place in the form of a model or a full scale wind tunnel testing. As the testing of the physical model was not possible, the simulation was made in ANSYS to get the results. In this analysis, the panel was put in an enclosure which acted as a wind tunnel. Air flows into the tunnel as shown in the Figure 4.

Figures 5 to 11 shows the simulation results of various wind tunnel testing iterations which were done in order to determine the best possible design for the body panel under the operating conditions.

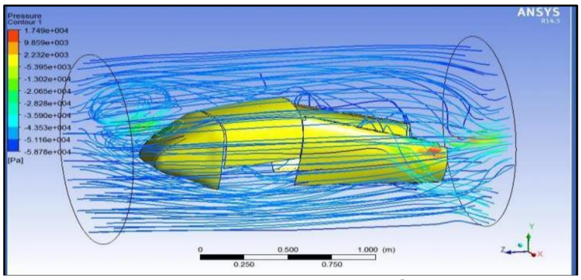

Figure 11: Pressure Contour in Final Iteration

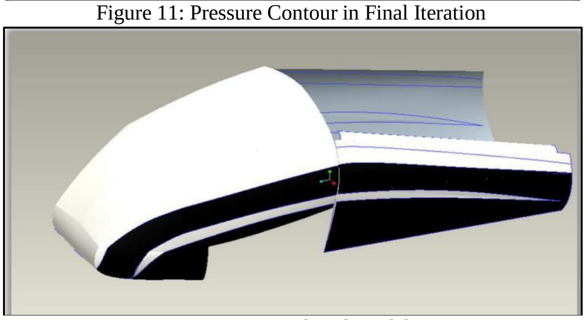

Figure 12: Final Cad Model

The various profiles of the body panel were judged according to the parameters such as pressure contours, turbulence kinetic energy and flow velocity. Subsequently, the final Pro-E model (Figure 12) was created to ensure fitment with the chassis and to serve as a template to cut the mold.

III. MATERIAL SELECTION

The material for the body panel must be such that it fulfills all the pre-determined objectives and serves its purpose. Some of these objectives are:

1. It should be of low density in order to reduce the weight of our vehicle.
2. It must have adequate strength to bear the aerodynamic forces as well as its own weight.
3. It should be manufactured with ease.
4. The material must be readily available at a minimal expense.

On the basis of these criteria the following comparison was made between various alternative materials suitable to make the panel as mentioned in Table 1.

After the primary screening of the available material for body panels, Carbon Fiber and Polypropylene were discarded as the Carbon Fiber was very expensive and the process of Injection Molding for Polypropylene was beyond our reach. The other remaining alternative materials were comparatively thoroughly investigated as per Table 2.

For ABS, there were some restrictions like the negative bends and angles could not be included in the design. Despite having the advantages of having more impact strength, machinability, durability, toughness etc over FRP, it was overlooked. As per the operating conditions of the vehicle and pre-decided objectives, FRP was selected to make the entire body panel because of its low weight, minimal cost of material and fabrication, high load bearing strength, high shape holding property at high speed, excellent reparability etc.

IV. MATERIALS USED

Gelcoat is a material used to provide a high-quality finish on the visible surface of a 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. This is usually pigmented to provide a colored, glossy surface which improves the aesthetic appearance of the article, such as a counter made with cultured marble. Gelcoats are designed to be durable, providing resistance to ultraviolet degradation and hydrolysis.

The *catalyst or hardener* is a clear, colorless, 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).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

MATERIAL	DENSITY (g/cm^3)	FEASIABLE MANUFACTURING PROCESS	AVAILABILITY	COST
Fiber Reinforced Plastic (FRP)	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	Moderate	Moderately High

Table 1: Initial Evaluation of the Suitable Materials for Panel Manufacturing

PROPERTIES	FRP	ABS
Load Bearing Strength	High	Low
Impact Strength	Low	High
Holding on the Shape at High Speed	High	Low
Weight	Low	High
Brittleness	High	Low
Machining	Difficult to machine with standard tools	Easily machined using standard tools
Insulation	Good	Excellent
Durability	Low	High
Toughness	Low	High
Reparability	Very High	High

Table 2: Comparison between FRP and ABS as a Panel Material

For Hand lay- up technique of FRP molding at ambient temperature of 25°C, 2-3% hardener with 2-3% accelerator will give satisfactory results with most of the resins.

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.

There are several types of resins used with natural fibers, carbon fiber, aramid, fiberglass and other composites. For the open molding process the commonly used resins are polyester resins, vinyl ester, hybrid resins, polyurethane resins etc. Each of them has unique characteristics and associated costs. *Polyester resin* selected 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 [3]. They are the primary resin matrix used in SMC (sheet molding compounds) and BMC (bulk molding compounds).

Fiberglass is a fiber reinforced polymer made of a plastic matrix reinforced with fine 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 molded into complex shapes [2]. The fiberglass employed in this fabrication process is E-glass, which is alumino borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics.

Aluminum and thermocole sheets were used as the primary material to make the mold.

Putty (a soft, malleable grayish-yellow paste, made from ground chalk and raw linseed 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 the mold and FRP body panels.

V. FABRICATION OF THE BODY PANEL

The body panel was designed in three parts- two side panels and a nose. The nose was further divided into two parts to simplify the manufacturing process. These two parts were separately manufactured and joined together to form the complete nose. The manufacturing process of open molding was selected to manufacture FRP body panel.

To obtain a smooth surface for the body panel it was decided to make a positive (male) mold. For the two side panels and middle cover, aluminium sheets were used to make the mold. The dimensions of the sheet to be cut were determined for the Pro-E model of the vehicle. It was bent manually as per the design and very minor modifications were made after some hit and trial fitment with the chassis.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

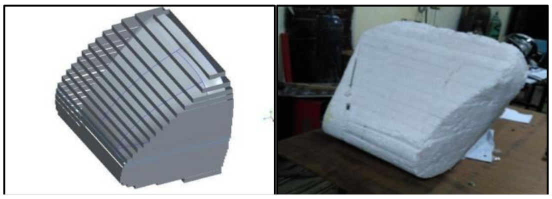

Figure 13: Cad Model for making the Mold and Figure 14: Actual Thermocole Mold

The mold of the nose was manufactured using thermocole sheets. Every sheet was cut and glued in a manner such that it takes the shape of the designed nose after some grinding. Manufacturing of the mold using aluminium and thermocole sheets was relatively easier and low in cost as compared to wood, cardboard, 3-D printing etc.

The simplest of the fabrication processes, hand lay-up open molding process was used in the production of the body panels. The mold was first covered with a polythene sheet of low density without affecting it's shape. Wax was applied over it to act as a releasing agent. Following it a pigmented gel coat was first sprayed onto the mold for a high-quality durable surface. When the gel coat had cured, glass reinforcing mat in the form of chopped stranded mats from a woven roving was placed on the mold and the catalyzed polyester resin was poured and brushed. Manual rolling then removed the entrapped air, compacted the composite, and thoroughly wet the reinforcement with the resin. Additional layers of mat and resin were added for providing thickness. A catalyst along with the accelerator (MEKP catalyst mixed with Cobalt 2% proportionately) initiates curing in the resin system, which hardens the composite without external heat. Further, the clamps were rigidly fixed using finishing mats and resin at their respective locations. After drying, the body panel was carefully removed from the mold and putty was applied on it for finishing. It was spread using various grades of emery paper in the increasing order of its fineness. Subsequently, a developer was thoroughly spread using a sponge and the body panels were painted using spray paint. The final step was to apply the sponsor stickers and trim the panels for mounting.

Figure 15: The Racecar with Body Panels

VI. CONCLUSION

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

1. 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.
2. 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.
3. 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.

VII. FUTURE SCOPE

In addition to being an engineering exercise, the formula SAE competition is about making an exhilarating formula style car that would entice a customer to purchase a ride [4]. The key to improvisation is the analysis and critical testing of the present design and products. This opens the gates for further modification to improve the product's cost effectiveness, ease of manufacturability, durability, aesthetics, ergonomics etc.

The first thing the potential customer sees is the body. The use of FRP in this manufacturing process has many advantages. It provides a strong scratch resistant surface which is easy to install, maintain and repair. It is light weight, provides sufficient strength and can be fabricated using simple tools. However, manufacturing the body panels by Hand- layup open molding process is clumsy and time consuming. The same limitation applies in manually manufacturing of molds.

Mold making process can be done more effectively using CNC machine, 3-D printing etc by using more durable molding materials. It would provide accurate tolerances and exact shapes enhancing its workability. Similar improvements in the technique, materials and manufacturing methods of FRP would yield better results.
The body panel of the FSAE race car is still an unexploited domain where several opportunities for innovations and improvements lie. FRP has also a vast potential not only in the automobile industry but in all spheres of technological advancements.
In future, additional consideration should also be given to the aerodynamic loads as well as the refinement of design for the ease of manufacture with a very serious consideration.

VIII. REFERENCES

[1] SAE SUPRA 2015 Rulebook.
[2] http://www.moldedfiberglass.com/materials/reinforcements (Accessed: 09/04/2016; 2250 hrs IST)
[3] http://www.indiamart.com/croda-pigmentpastes/products.html#resin-hardener (Accessed: 09/04/2016; 2256 hrs IST)
[4] Mike Ornstein, "Race Car Body Design" Presentation, Carnegie Mellon University, USA, Fall 2011.