

Design and Fabrication of Composite Material Body Parts for EV Go-Kart

Dr. B. Vijaya kumar , O.Ebenezer, R.manoj kumar ,
V.subhash chandra bose

¹professor, gurunanak institute of technology Ibrahimpatnam, ranga reddy district-501506 Telangana

^{2,3,4}Student, gurunanak institute of technology Ibrahimpatnam, ranga reddy district-501506 Telangana

Date of Submission: 20-03-2023

Date of Acceptance: 30-03-2023

ABSTRACT: The aim this project is about design and fabrication of a race car body panel with glass-fiber composite material and is to development of FRP (fiber reinforced plastic) body panel for Imperial of Innovative Engineers race car. The determination of plies and orientation for the composite body work is made based on the highest flexural strength which is the Chopped Strand Mat (CSM) fiberglass. The method of fabricating the composite bodywork is using manual hand lay-up technique for the whole process. The overall body panel weight is measured with the digital weighting scale bodywork section and it has already used composite material which is carbon-fiber. The bodywork also has achieved a high standard of quality and performance to the car. So, the fabrication that will be made through this project will open a new potential to experience the new type of material for bodywork of race car which using composite material instead of using sheet metal.

KEYWORDS : fibre reinforced plastic (frp), CSM(chopped strand mat)

I. INTRODUCTION

COMPOSITE MATERIAL:

Composite material is defined as the materials formed by combining two or more different materials/ constituents macroscopically that are distinct in the properties and they do not dissolve into each other. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix).

Reinforcement+ Matrix= Composite

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials

constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. Composite material is a material system composed of two or more dissimilar materials, differing in forms, and insoluble in each other, physically distinct and chemically inhomogeneous. The resulting products' properties are much different from the properties of constituent materials.

1.2 Evolution of Composite Materials

Humans are using composite material for thousands of years. The first composite was found in 1500 BC when mud and straw were used by Egyptians and Mesopotamians to make their houses.

The Mongols developed the first bow using wood, bone, and animal glue. During World War II the civilization of the composite was enhanced and moved from the laboratory into actual production. Also, the development of components from fiber-reinforced polymer composites was adopted by the industries.

By 1945, the use of fiber-reinforced polymer composites started to use primarily in military applications.

In 1946, the first FPR composite boat hull was introduced and by 1947 the automobile body was made from composite material and successfully tested.

1.3 Types of composites:

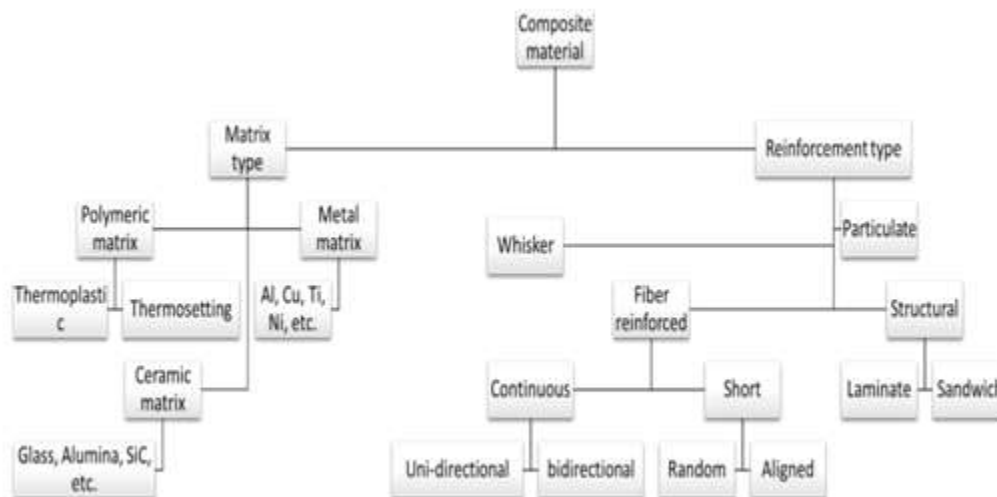


FIG 1: types of composite material

1.4 Matrix material

The primary function of the matrix material in polymer composite is to act as a binder and transfer the load between constituents of the composites, provide the component its net shape, and determines its surface quality.

1.5.1 Polymer matrix:

Polymer composites use generally two types of matrix material viz. thermoplastic and thermosetting. Since the dawn of the composite era, both materials have been used for the development of composites.

1.5 Types of matrixes:

The characteristic of the thermoplastic and thermosetting are as follows:

Table 1: Thermoplastic characteristics

Thermoplastic

Introduction	Thermoplastics can be heated and softened and then moulded or shaped and upon cooling it hold the desired shape. It has one- or two-dimensional molecular structure and they tend to show an exaggerated melting point at an elevated temperature.
Benefits	Can be recycled Remould and reshape capability with the application of heat Easy to manufacture high volumes quickly Chemically retardant and impact resistant Costlier than the thermosets Environment friendly processing adhesive to metal
Types	Some thermoplastic material used in polymer composites: Acrylonitrile Butadiene Styrene (ABS) Poly (methyl methacrylate) (PMMA) (Acrylic) Polybenzimidazole Polyethylene Homopolymer Copolymer Polyurethane Styrene Acrylonitrile Polypropylene (PP) Polyamide (PA) Polycarbonate (PC) Polyether


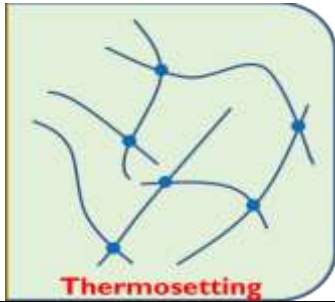
	ether ketone (PEEK) Polylactic Acid (PLA) Polyvinyl chloride (PVC) Teflon
Structure	 <p style="text-align: center;">Thermoplastic</p>

Table 2: Characteristics of thermosetting plastic

Thermosetting

Introduction	Thermosetting materials endure an irreversible chemical bond reaction bond i.e., cross linking or curing during process to change the phase from liquid to solid state. The cross linking enables to eradicate the component remelting with application of heat.
Benefits	Cannot be recycled Once cured than cannot be reshaped or remold Better dimensional stability Cost effective More Resistant against high temperature Hard and Rigid Excellent aesthetics finishes Better mechanical properties
Structure	 <p style="text-align: center;">Thermosetting</p>
Types	Some thermosetting material used in polymer composites: Resin Unsaturated polyester Vinyl ester Phenol Silicone Cyanate esters Methyl Methacrylate (MMA) Bismaleimide (BMI) Urea Formable hydro Fluoro polymers Melamine

1.5.2 Metal matrix:

A metal matrix composite (MMC) is a composite material with fibers or particles dispersed in a metallic matrix, such as copper, aluminum, or steel. The secondary phase is typically a ceramic (such as alumina or silicon carbide) or another metal (such as steel). When at least three materials are present, it is called a hybrid composite. MMCs can have much higher strength-to-weight

ratios, stiffness, and ductility than traditional materials, so they are often used in demanding applications. MMCs typically have lower thermal and electrical conductivity and poor resistance to radiation, limiting their use in the very harshest environments. MMC manufacturing can be broken into three types—solid, liquid, and vapor.

□ Solid state methods

- Powder blending and consolidation (powder metallurgy): Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, degassing, and thermo-mechanical treatment (possibly via hot isostatic pressing (HIP) or extrusion)
- Foil diffusion bonding: Layers of metal foil are sandwiched with long fibers, and then pressed through to form a matrix

□ Liquid state methods

- Electroplating and electroforming: A solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material
- Stir casting: Discontinuous reinforcement is stirred into molten metal, which is allowed to solidify
- Pressure infiltration: Molten metal is infiltrated into the reinforcement through use of a kind of pressure such as gas pressure
- Squeeze casting: Molten metal is injected into a form with fibers pre-placed inside it
- Spray deposition: Molten metal is sprayed onto a continuous fiber substrate
- Reactive processing: A chemical reaction occurs, with one of the reactants forming the matrix and the other the reinforcement

□ Semi-solid state methods

- Semi-solid powder processing: Powder mixture is heated up to semi-solid state and pressure is applied to form the composites.^{[4][5][6]}

□ Vapor deposition

- Physical vapor deposition: The fiber is passed through a thick cloud of vaporized metal, coating it.

1.5.3 Ceramic matrix

Ceramic matrix composites (CMCs) are a subgroup of composite materials and a subgroup of ceramics. They consist of ceramic fibers embedded in a ceramic matrix. The fibers and the matrix both can consist of any ceramic material, where by carbon and carbon fibers can also be regarded as a ceramic material. The motivation to develop CMCs was to overcome the problems associated with the conventional technical ceramics like alumina, silicon carbide, aluminum nitride, silicon nitride or zirconia – they fracture easily under mechanical or thermo-mechanical loads because of cracks initiated by small defects or scratches. The crack resistance is very low, as in glass. To increase the crack resistance or fracture toughness, particles (so-called monocrystalline whiskers or platelets) were embedded into the matrix. However, the improvement was limited, and the products have

found application only in some ceramic cutting tools. So far only the integration of long multi-strand fibers has drastically increased the crack resistance, elongation and thermal shock resistance, and resulted in several new applications. The reinforcements used in ceramic matrix composites (CMC) serve to enhance the fracture toughness of the combined material system while still taking advantage of the inherent high strength and Young's modulus of the ceramic matrix. The functional role of this fiber is (1) to increase the CMC stress for the progress of micro-cracks through the matrix, thereby increasing the energy expended during crack propagation; and then (2) when through-thickness cracks begin to form across the CMC at higher stress (proportional limit stress, PLS), to bridge these cracks without fracturing, thereby providing the CMC with a high ultimate tensile strength (UTS). In this way, ceramic fiber reinforcements not only increase the composite structure's initial resistance to crack propagation but also allow the CMC to avoid abrupt brittle failure that is characteristic of monolithic ceramics. This behavior is distinct from the behavior of ceramic fibers in polymer matrix composites (PMC) and metal matrix composites (MMC), where the fibers typically fracture before the matrix due to the higher failure strain capabilities of these matrices.

Generally, CMC names include a combination of type of fiber/type of matrix. For example, C/C stands for carbon-fiber-reinforced carbon (carbon/carbon), or C/SiC for carbon fiber-reinforced silicon carbide. Sometimes the manufacturing process is included, and a C/SiC composite manufactured with the liquid polymer infiltration (LPI) process (see below) is abbreviated as LPI-C/SiC.

The important commercially available CMCs are C/C, C/SiC, SiC/SiC and Al₂O₃/Al₂O₃. They differ from conventional ceramics in the following properties, presented in more detail below:

- Elongation to rupture up to 1%
- Strongly increased fracture toughness
- Extreme thermal shock resistance
- Improved dynamical load capability
- Anisotropic properties following the orientation of fibers

1.6 Type of reinforcement:

Whisker:

Whisker is a single crystal in the form of a fiber. Whiskers can be considered as a sub-group of fibers possessing shorter lengths compared to conventional fibers. They are among the strongest materials that we know of. Whiskers can be produced from materials like graphite, silicon

carbide, aluminum oxide, iron, and alike as well as hydroxyapatite, dicalcium phosphate anhydrous, cellulose whiskers and other biomaterials.

Whiskers are a generic class of materials having mechanical strengths equivalent to the binding forces of adjacent atoms. For example, SiC whiskers have tensile strength greater than 27 GPa and a Young's modulus greater than 500 GPa. Thus, in contrast to conventional materials— which contain a multiplicity of grain boundaries, voids, dislocations and imperfections—the single-crystal whisker approaches structural perfection and has eliminated almost all defects. Because of this internal perfection, the strength of whiskers is not strictly limited by their surface perfection. This is very significant in that it gives whiskers an unusual toughness and nonfriability in handling as compared with polycrystalline fibers and fiberglass.

If the strength of the whisker is plotted against its diameter, it is found that as the whisker becomes smaller (and therefore more nearly perfect), its strength increases rapidly. The tensile strength, elongation and modulus of whiskers compare favorably with those of other reinforcing fibers such as glass, high-modulus graphite, Kevlar and boron. Whiskers have a fivefold to six fold greater basic fiber strength, a high elongation equivalent to that of Kevlar (about 3%) and a modulus greater than that of boron. The disadvantage of whiskers is that an improved technology for preparing discontinuous fiber composites must be developed in order to utilize all their reinforcing potentials.

They are easily damaged, i.e. break to shorter lengths, during processing. They also tend to get oriented leading to unwanted anisotropy in composites. It is also very difficult to carry out largescale manufacturing of whiskers that are defect-free. Thus, they are very expensive. Whiskers also pose difficulty in packing compared to particulates; hence, it is not possible to achieve high reinforcement-to-matrix ratios.

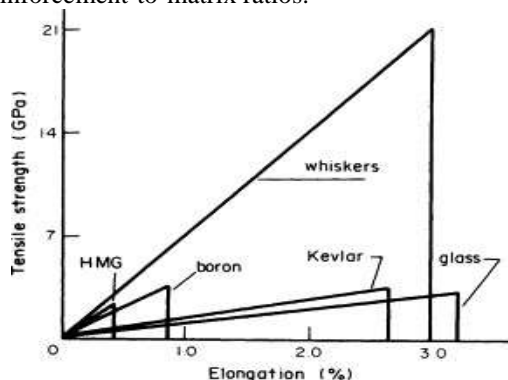


Fig 2 tensile v/s elongation of different type reinforcement

Particulate.

A particulate composite is characterized as being composed of particles suspended in a matrix. Particles can have virtually any shape, size or configuration. Examples of well-known particulate composites are concrete and particle board. There are two subclasses of particulates: flake and filled/skeletal:

Flake. A flake composite is generally composed of flakes with large ratios of platform area to thickness, suspended in a matrix material (particle board, for example). **Filled/Skeletal.** A filled/skeletal composite is composed of a continuous skeletal matrix filled by a second material: for example, a honeycomb core filled with an insulating material.

The response of a particulate composite can be either anisotropic or orthotropic. Such composites are used for many applications in which strength is not a significant component of the design. A schematic of several types of particulate composites is shown in fig

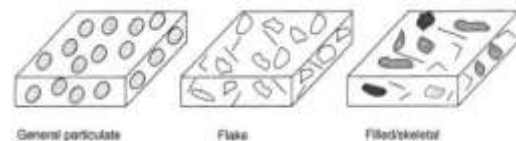


Fig 3: Types of particulate composite

Types of fiber reinforced materials:

1. Carbon fiber -reinforced polymer:

Carbon fiber-reinforced polymers (carbon-fiber-reinforced polymers), carbon-fiber-reinforced plastics, carbon-fiber reinforced-thermoplastic (CFRP, CRP, CFRTTP), also known as carbon fiber, carbon composite, or just carbon, are extremely strong and light fiber-reinforced plastics that contain carbon fibers. CFRPs can be expensive to produce, but are commonly used wherever high strength-to-weight ratio and stiffness (rigidity) are required, such as aerospace, superstructures of ships, automotive, civil engineering, sports equipment, and an increasing number of consumer and technical applications.^[1]

The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester, or nylon, are sometimes used. The properties of the final CFRP product can be affected by the type of additives introduced to the binding matrix (resin). The most common additive is silica, but other additives such as rubber and carbon nanotubes can be used.

Carbon fiber is sometimes referred to as graphite-reinforced polymer or graphite fiber-reinforced polymer (GFRP)

2. Glass fiber-reinforced polymer:

Glass (fiber) Reinforced Plastic (GRP) is a composite material that consists of a polymer matrix and glass fibers. The polymer matrix is usually an epoxy, vinyl ester, or polyester thermosetting resin. The resin brings the environmental and chemical resistance to the product, is the binder for the fibers in the structural laminate and defines the form of a GRP part. The glass fibers add strength to the composite. They may be randomly arranged, or conveniently oriented. The most common type of glass fiber used for GRP is E-glass, which is alumina-borosilicate glass. E-CR-glass (Electrical/Chemical Resistance) is also commonly used in applications that require particularly high protection against acidic corrosion.

As with many other composite materials, the two materials supplement each other to form a stronger compound. Plastic resins are strong in compressive loading; the glass fibers are very strong in tension. By combining the two materials, **GRP** becomes a material that **resists both compressive and tensile forces very well**. Production methods of GRP include filament winding, centrifugal casting, hand lay-up and spray lay-up, and pultrusion.

GRP features many beneficial characteristics. It comes with **low weight at high mechanical strength, resistance against chemicals and corrosion** (thanks to its non-conductive properties also electrolytic corrosion), **UV radiation and temperature stability**, and **environmental friendliness**. GRP is **waterproof**, making it ideal for all outdoor applications. It can be customized to be **fire-retardant** by using non-flammable resins. GRP is a **highly durable material** with very **long lifetime expectancy**, ideally suited for a wide range of applications in various industries.

3. Basalt fiber- reinforced polymer:

Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. Basalt fiber is made from a single material, crushed basalt, from a carefully chosen quarry source. Basalt of high acidity (over 46% silica content) and low iron content is considered desirable for fiber production. Unlike with other composites, such as glass fiber, essentially no materials are added during its production. The basalt is simply washed and then melted.

The manufacture of basalt fiber requires the melting of the crushed and washed basalt rock at

about 1,500 °C (2,730 °F). The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber.

The basalt fibers typically have a filament diameter of between 10 and 20 μm which is far enough above the respiratory limit of 5 μm to make basalt fiber a suitable replacement for asbestos.^[5] They also have a high elastic modulus, resulting in high specific strength—three times that of steel.^{[6][7]} Thin fiber is usually used for textile applications mainly for production of woven fabric. Thicker fiber is used in filament winding, for example, for production of compressed natural gas (CNG) cylinders or pipes. The thickest fiber is used for pultrusion, geogrid, unidirectional fabric, multiaxial fabric production and in form of chopped strand for concrete reinforcement

It is similar to fiberglass, having better physicomechanical properties than fiberglass, but being significantly cheaper than carbon fiber. It is used as a fireproof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods.

1.7 Why choose FRP over traditional materials?

Traditional materials have higher maintenance costs, less flexibility, and are more susceptible to corrosion when exposed to extreme elements. While the advantages of FRP are quite obvious, it may be helpful to see the characteristics stacked up against those of other building materials.

FRP vs Carbon Fiber: While carbon fiber's tensile strength is unmatched, it is much more rigid, costly, and not as durable as FRP. In addition, FRP is non-conductive and corrosion resistant

FRP vs Aluminum: It goes without saying, but aluminum is very low strength and is vulnerable to impact, it's also highly conductive and can break or deform. When comparing FRP and aluminum, FRP will offer more reliable flex and strength needed for similar applications.

FRP vs Steel: Steel is also highly conductive and susceptible to corrosion when exposed to the elements, making FRP a much better choice for challenging applications and impact.

FRP vs Acrylic: While acrylic is the obvious choice for applications that are less likely to suffer dynamic stress, FRP is stronger and built to thrive in harsh conditions.

FRP vs Wood: When weighing the benefits of these two materials, wood only wins in the category of upfront costs. However, while it is not a conductive material, it is nowhere near as strong as FRP, nor can it last in harsh environments or offer the safety features that fiberglass can.

1.8 What are the benefits of FRP?

Thanks to their make-up, these fiberglass products offer many advantages over traditional building materials, like corrosion resistance, low weight, high strength, they are versatile and customizable, as well as have the ability to withstand extreme temperatures.

Fiberglass products are the most cost-effective material over a lifetime of various applications.

- They are extremely customizable and versatile, allowing you to use them in multiple applications that a traditional building material would not allow for.
- FRP products need little time for production and installation, without compromising durability or function.
- Highly impact resistant and won't break under impact as traditional materials might. You can get better performance with fewer materials.
- Save money and time on maintenance thanks to the strength, durability, and corrosion resistance. FRP products generally need less maintenance.
- Can better meet your structural needs due to the flexible nature of its design.

While many of the benefits of FRP may be dependent upon your industry's needs, some of the top reasons why companies choose FRP over other materials are its production and installation time, lightweight, and corrosion-resistant, and maintenance qualities.

1.9 Advantages and limitations of FRP:

FRP allows the alignment of the glass fibers of thermoplastics to suit specific design programs. Specifying the orientation of reinforcing fibers can increase the strength and resistance to deformation of the polymer. Glass reinforced polymers are strongest and most resistive to deforming forces when the polymers fibers are parallel to the force being exerted, and are weakest when the fibers are perpendicular. Thus, this ability is at once both an advantage and a limitation depending on the context of use. Weak spots of perpendicular fibers can be used for natural hinges and connections, but can also lead to material failure when production processes fail to properly orient the fibers parallel to expected forces. When forces are exerted perpendicular to the orientation of fibers, the strength and elasticity of the polymer is less than the matrix alone. In cast resin components made of glass reinforced polymers such as UP and EP, the orientation of fibers can be oriented in two-dimensional and three-dimensional weaves. This

means that when forces are possibly perpendicular to one orientation, they are parallel to another orientation; this eliminates the potential for weak spots in the polymer.

Failure modes

Structural failure can occur in FRP materials when:

- Tensile forces stretch the matrix more than the fibers, causing the material to shear at the interface between matrix and fibers.
- Tensile forces near the end of the fibers exceed the tolerances of the matrix, separating the fibers from the matrix.
- Tensile forces can also exceed the tolerances of the fibers causing the fibers themselves to fracture leading to material failure.

1.10 TYPES OF RESINS:

Synthetic Resin:

Synthetic resin is a chemical organic compound mainly composed of atoms such as carbon, hydrogen and a little oxygen, nitrogen and sulfur etc. combined together with certain chemical bond. Synthetic resin, as a bonding agent, is the main component in plastic. It not only bonds together its own structure, but also bonds other materials together tightly and firmly.

Plastics is made by adding to resin with fillers and additives that play apparent function of modification to plastic, but resin is still the most primary factor that determines the features and main applications of plastic. The content of resin in plastic is around 30%-60%. According to different chemical reactions in production, synthetic resin is classified to polymer (poly-addition) resin (such as polyvinyl chloride and polystyrene) and condensation (poly-condensation) resin (such as asphenolicaldehyde, epoxy and polyester etc.); according to the change in performances when heated, classified to thermoplastic resin and thermosetting resin.

Plastic made of thermoplastic resin is thermoplastic plastic. It becomes soft when heated, then melted at even higher temperature, whereas it is hardened again when temperature goes down. This procedure goes repeatedly without considerate affect to its performances and appearance. Polymer resin is thermoplastic resin with low heat resistance and low stiffness but with good performance of impact toughness. Plastic made of thermosetting resin is thermosetting plastic. During processing, thermosetting resin becomes soft when heated, but after setting and molding, it no long changes its form even when heated again, namely, it is available for plastic molding, setting and hardening only once.

Condensation resin is hard and brittle thermosetting resin with better heat-resistance and higher stiffness

Resin casting:

It is a method of plastic casting where a mold is filled with a liquid synthetic resin, which then hardens. It is primarily used for small-scale production like industrial prototypes and dentistry. It can be done by amateur hobbyists with little initial investment, and is used in the production of collectible toys, models and figures, as well as small-scale jewellery production.

The synthetic resin for such processes is a monomer for making a plastic thermosetting polymer. During the setting process, the liquid monomer polymerizes into the polymer, thereby hardening into a solid.

Single-monomer resins may be used in the process, which form homopolymers (polymers containing only one type of polymer). In such uses, the "curing agent" mixed with the resin contains what is loosely referred to as a "catalyst," but which is more technically an initial source of free radicals (such as MEKP) to act as an initiator in a free-radical chemical chain reaction polymerization. Alternately, resin casting may be accomplished with a resin plus a nearly equal amount of a "hardener" liquid (as in many epoxy resin or polyester resin systems), which functionally contains a second polymer, for use in forming a final product plastic which is a copolymer. Copolymers contain two different alternating chemical entities in the final polymer molecule.

Polyester Resin

Polyester resin is an excellent matrix material in the creation of fiberglass (GRP) in the presence of a catalyst and combined with glass fiber chopped strand matting (CSM). It has many applications and is notable cheaper and easier to use than other resin systems.

Polyester resins are unsaturated synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Maleic Anhydride is a commonly used raw material with diacid functionality. Polyester resins are used in sheet moulding compound, bulk moulding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass—so-called fiberglass reinforced plastic (FRP)—are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls. The material is composed of pigments that are very similar to those used in other pavement markings. The pigments are used to impart color, hiding and other desirable properties,

like all other markings. However, these pigments are pre-ground prior to being blended into the resin. The marking has polyester resin that is mixed with a reactive solvent, a styrene compound. Normally, solvents are expected to evaporate and not participate in the setting up process. In addition to acting as a solvent, the styrene participates in the polymerization process. In order for this material to begin to react, a catalyst must be added to initiate the reaction.

The figure below shows the idealized chemical structure of typical polyester

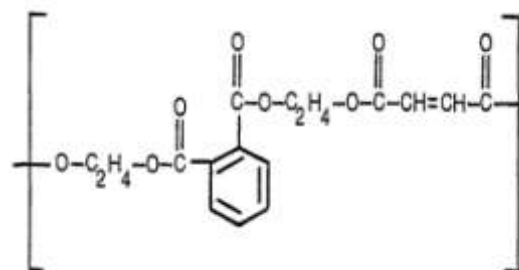


Fig4: Chemical structure of polyester resin

Phenolic Resin:

Phenolics are of particular interest in structural applications owing to their inherent fire-resistant properties yielding LOI values of 25 or so, although they tend to increase smoke generation. Their main disadvantages are low toughness and a curing reaction that involves the generation of water. This water can remain trapped within the composite and during a fire steam can be generated, which can damage the structure of the material.

Cured phenolic resins do not ignite easily because of their high thermal stability and high charring tendency on decomposition. The principal volatile decomposition products are methane, acetone, carbon monoxide, propanol and propane. In a few cases, where phenolic resins require flame-retardant treatment, additive and reactive flame retardants can be used.

Alkyd Resin:

Alkyd resins are vegetable oil or fatty acid-modified low molecular weight polyesters derived by the condensation reaction of polyhydric alcohols, monobasic and polybasic acids, vegetable oils, and fatty acids. These resins are polyesters, but polyesters are preserved for the word "oil-free polyesters" in the coating sector (i.e., those free of fatty acids or vegetable oils). Alkyd resins may be classified as drying (including semi drying) and non-drying. Both types are typically produced from dicarboxylic acids or anhydrides, such as phthalic anhydride or maleic anhydride, and polyols, such as trimethylolpropane, glycerine,

orpentaerythritol.^[5]Alkyds are a synthetic resin and used in items such as paints. They are not the same as resins derived from natural sources such as plants.

For the drying resins, triglycerides are derived from polyunsaturated fatty acids (often derived from plant and vegetable oils, e.g. linseed oil). These drying alkyds are cured by the oxygen in air. The drying speed and the nature of the coatings depends on the amount and type of drying oil employed (more polyunsaturated oil means faster reaction in air) and presence of catalysts, the so-

called oil drying agents. These catalysts are metal complexes that catalyze cross linking of the unsaturated sites. Cobalt salts are particularly effective and widely used. Alkyd resins are extensively used in the surface coating application because of their excellent mechanical properties, reliability, superior drying speed, high gloss, lower cost than the acrylic binders. Alkyd-based coatings are applied on metals, woods, concrete walls for their decoration and protection

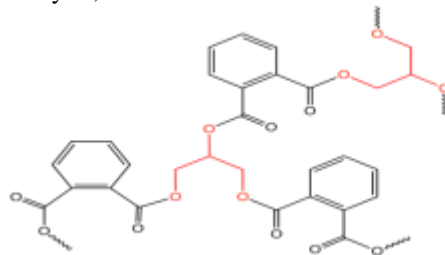


Fig 5: Structure of an idealized alkyd resin derived from glycerol and phthalic anhydride

II. DESIGN AND ANALYSIS OF BODY PARTS

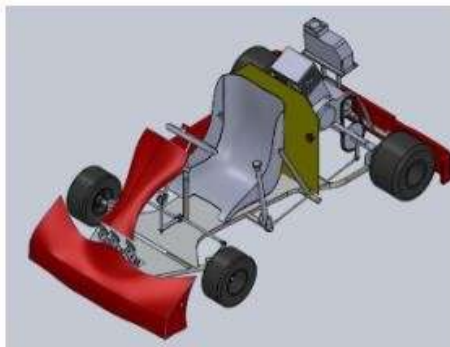


Fig : isometric view

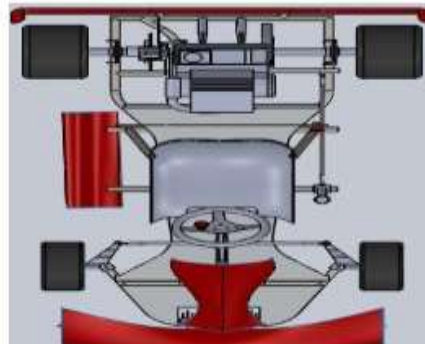
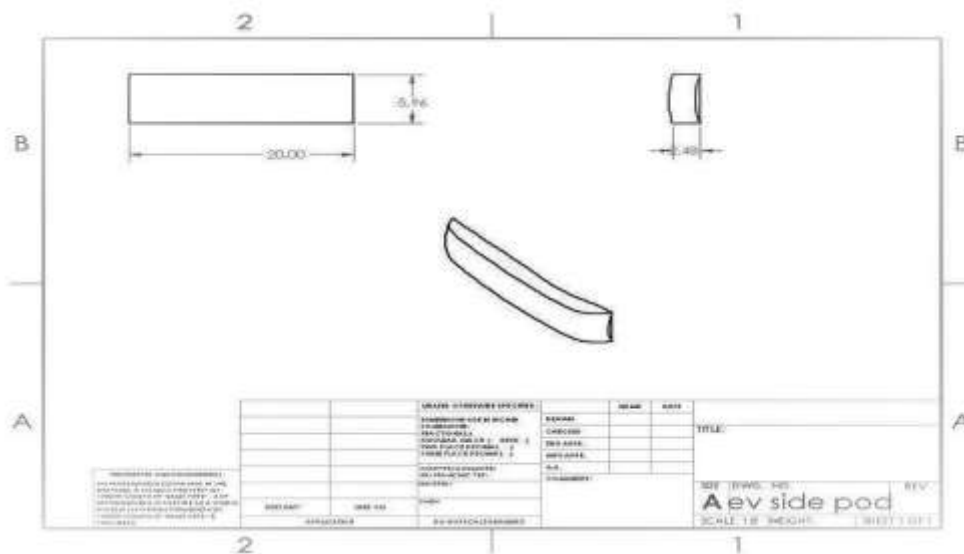


Fig: top view

➤ GEOMETRIC DESIGNS OF BODY PANELS FOR GO KART:



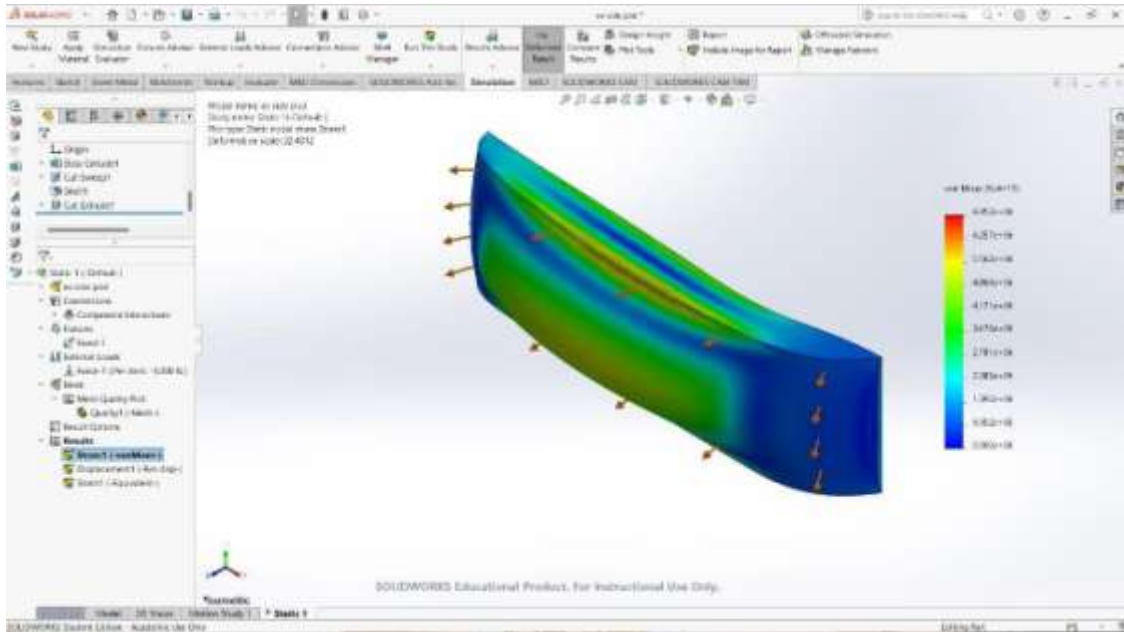


Fig 17: static nodal stress of side panel

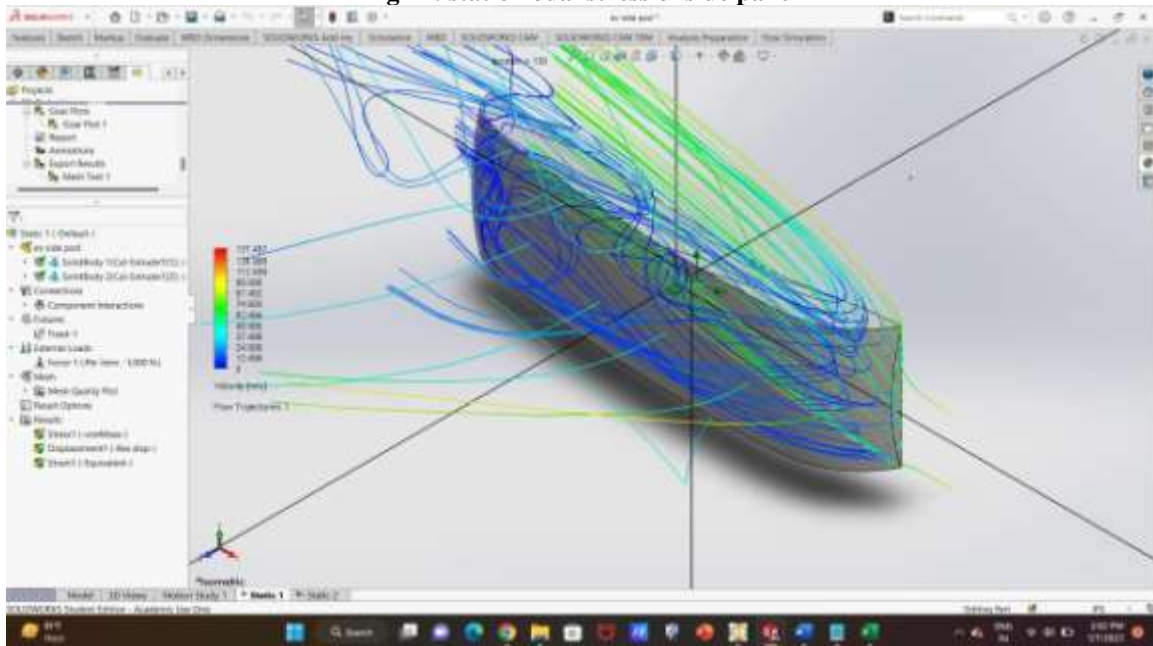


Fig: CFD analysis

III. EXPERIMENTATION

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. 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, E-glass and carbon fiber were discarded as the Carbon Fiber was very expensive and the other remaining alternative materials were comparatively thoroughly investigated as per Table 2. For

ABS Acrylonitrile Butadiene Styrene, 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 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.

Table . Initial evaluation of the suitable materials for panel manufacturing

Material	Density(gm/cm ³)	Feasible manufacturing process	Availability	Cost
E-Glass	2.55	Open moulding	High	Low
Carbon fiber	1.76	Open moulding	Very low	Very low
Acrylonitrile styrene (ABS)	1-1.05	Vacuum moulding	High	moderate

Table 6. Comparison between FRP and ABS for panel material.

Properties	FRP	ABS
Load bearing strength	High	Low
Impact strength	Low	High
Weight	Low	High
Brittleness	High	low

MATERIALS REQUIRED:

1 Fiber glass:

Types of Fiberglass:

Fiberglass can be broadly categorized into different forms, each of which is used for different applications:

A-glass: Also known as alkali glass. A-glass fiber is resistant to chemicals and has some similarities to window glass. Outside of the United States, it is used to make process equipment.

C-glass: Also known as chemical glass. C-glass offers great resistance to chemical impact.

E-Glass fiber in the form of chopped form mat (CSM) with different weight fractions such as 15%, 30% and 45% were used as reinforcement in CNSL- epoxy resin composites. Micro- hardness, tensile and flexural properties were investigated for all the composite panels of different compositions.

E-glass: Also called electrical glass. E-glass is an excellent insulator of electricity.

AE-glass: Alkali resistant glass.

S-glass: Also known as structural glass. S-glass is used for its mechanical properties.

E- Glass Chopped Strand Fibers:

E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiberglass.



Fig 19: E-Glass Fiber

Properties:

Properties that have made E-glass so popular in fiberglass and other glass fiber reinforced composite include:

- Low cost
- High production rates
- High strength
- High stiffness
- Relatively low density
- Non-flammable
- Resistant to heat
- Good chemical resistance
- Relatively insensitive to moisture

Specifications:

The specifications of the E-glass are mentioned below:

Type: Filaments

Tensile Strength: 1700MPa

Modulus of Elasticity: 72.5GPa

Density: 2.7

3.Catalyst- Nickel Phosphorous:

A new nickel-catalyst method is developed to activate the glass fiber surface. When the activation is completed, a layer of continuous and dense film is formed on the substrate. The activated film contains a great deal of nickel oxide particles which can become the active sites after they are deoxidized in the electro less bath. In the activated film on the glass fiber, the content of Ni element is 41.01 wt. %, the content of O element is 45.64 wt. % and the content of P element is 13.35 wt.%. Ni-P coatings obtained under the optimum pretreatment conditions are uniform, continuous and adhered to the glass fiber surface.

2. Polyester Resin:



Advantages:

Essentially two components in one container

- Long lasting and durable
- Does not discolor badly
- Relatively inexpensive
- Works well on concert

Disadvantages:

- Peroxide catalyst is a very reactive oxidizer
- Requires placarding as a hazardous material
- Requires commercial drivers license
- Flush solvent is flammable and a hazardous waste
- Moisture in surface a major factor and detriment
- HMA paving oils are a detriment
- Set up time depends on type of resin (usually 3-20 minutes)
- Difficult to determine whether mixed properly

4.Catalyst Costing:

Resin, Gel coat, Pool coat and Flow coat are some of the polyester resin products that use a minimum quantity of 1% catalyst (MEKP-NA2) and a maximum quantity of 3% catalyst (MEKP-NA2). For costing purposes 2.5% is the average amount of catalyst calculated per kg. Again for costing purposes 2.5% catalyst is used on resin, pool coat, gel coat and flow coat is the amount of catalyst used. Note: Most of all the products used in unsaturated polyester resin products, you will have to add a catalyst to it to get it to solidify. We recommend that you always make. Sure that you use the correct ratio's and quantities



Fig 21: Catalyst powder

How much catalyst should be added?

MEKP catalyst should be added at 1 – 4 % of the resin weight. Concentrations of catalyst outside of this range are not recommended; they

will lead to sub-optimal curing and premature laminate failure.

- Lower concentrations of catalyst (1 – 2 %) will deliver slower curing rates. A preference for a slower curing rate is desirable when temperatures are higher (e.g. summer). This is because the resin will harden quicker, so users have less time before the resin cures
- Higher concentrations of catalyst (3 – 4 %) will deliver faster curing rates. A preference for a faster cure rate is desirable for when temperatures are lower. This is because the resin will take more time to cure, meaning that users might want to speed things up a bit.

A more informative guide is outlined in Table below.

Table 7. Recommended catalyst volumes (mL) per weight of resin (kg)

curing	Slower curing (suited to wamer weather)		Faster curing (suited to colder weather)	
	Catalyst(%)	1%	2%	3%
Note: relative quantities of MEKP catalyst to be added in mL per weight of resin (Kg)				
Resin amount (kg)	Hardener Usage (mL)			
1	10	20	30	40
2	20	40	60	80
3	30	60	90	120
4	40	80	120	160
5	50	100	150	200
6	60	120	180	240
7	70	140	210	280
8	80	160	240	320
9	90	180	270	360
10	100	200	300	400

11	110	220	330	440
12	120	240	360	480
13	130	260	390	520
14	140	280	420	560
15	150	300	450	600
16	160	320	480	640
17	170	340	510	680
18	180	360	540	720
19	190	380	570	760
20	200	400	600	800

Application:

Catalyst should be measured using a clean cylinder and added into dispensed polyester resin in a clean bucket. Mixing should be performed using a clean paddle or mixing instrument for around 2 minutes.

In the context of applying catalyzed polyester resin to glass fiber, users should ensure

sufficient tools are available in advance. These centre on:

- Wool roller – or a synthetic alternative. This roller should be used to disperse resin across a designated and workable area of glass fiber matting. Ensure the resin is applied in the correct amount per unit surface area of glass fiber CSM. For instance:

Table 8: Recommended quantity of resin for CSM

	Chopped strand matting (CSM)		
	300 g	450 g	600 g
Quantity of Polyester Resin	0.65 kg	1 kg	1.5 kg

- Paddle roller – this is critical in driving out excess air bubbles from the resin after a wool roller has been used to apply resin. Moderate pressure should be applied to drive out excess resin from the glass fiber creating a more consistent layer of laminate is created.

4.2.4 Hardener- MEKP (Methyl Ethyl Ketone Peroxide):

MEKP is a colorless to yellow liquid with mint like odor. It is used as a hardening agent for fiberglass-reinforced plastics and as a curing agent

for unsaturated polyester resins. It acts through the formation of free radicals that catalyze the polymerization of the plastic monomer. It has a low residual hydrogen peroxide content making it ideal for use in gel coats. The MEKP acts as a catalyst when mixed with the resin. The chemical reaction that follows causes heat to build up and cure or harden the resin.



Fig 22: MEKP Hardener

4.3 PREARATION OF THE MOULD:

Process of Modeling:

The process of molding is explained below in a step- by- step process:

Blocks of Styrofoam work best for preparing the required mould shapes have curves or other non-linear forms. Simply cut or shave the foam into desired shape. Use the sand paper for smoothing rough seams. Resin can be mixed in a clean plastic container, but because it generates heat when it sets, extreme care should be taken. Make sure that the hardener is being added according to the respective quantities. Right amount of hardener is to be measured. The quantities are mentioned in the below table

Table 9: Catalyst and Resin Measurement

Resin	Liquid Catalyst - MEKP NA2 (Ml)
50 g	1 ml at 2%
100 g	2 ml at 2%
250 g	5 ml at 2%
500 g	10 ml at 2%
1 kg	20 ml at 2%
1.5 kg	30 ml at 2%
2 kg	40 ml at 2%
5 kg	100 ml at 2%
10 kg	200 ml at 2%
25 kg	500 ml at 2%

The Styrofoam seem to melt into the resin as you spread it, and you can use the brush and additional coats of resin to build up the layer of fiberglass to a thickness of up to 1/4inch (0.6 cm). As we spread the resin over the Styrofoam, make sure to apply it over corners and weak spots with the same coverage that you would over flat, easy-to-reach surfaces. If you fail to get good coverage in corners, for example, your fiberglass will eventually develop weaknesses in those corners. Clean up any tools or spills with a solvent containing acetone before the material harden. Fiberglass is usually applied in layers until it is thick enough to give the required strength you desire to achieve. 2 layers were being made for the

body to be in the right shape. If possible, try laying down the fiberglass mat with the fibers oriented in different directions with each new layer. Fiberglass is strong across its axis but weak along its axis; if you can orient the strand mat so that its weak points are distributed along various axes instead of a single axis, you'll end up with much stronger fiberglass. If you have covered your form or mold with, you should be able to peel the form from inside the shape or peel the shape off of the form. The fiberglass will not stick to the Styrofoam. Repeat the steps of applying mat and resin until the finished the required thickness .i.e. 3mm

4.4 Effect of Temperature:

Temperature is a critical factor that affects curing and therefore the pot life of catalysed resin. An ideal range for curing is between 15 and 25°C.

Higher temperatures = faster curing and lower temperatures = slower curing.

In general, at a temperature of 20°, MEKP catalyst added to create a 2 % concentration will give a pot life of 15 – 20 minutes. As detailed in our MEKP catalyst manual, judgment is required when adding catalyst to resin to ensure appropriate curing.

IV. RESULTS AND DISCUSSION

The objective of the project is achieved and completed within the planned time .A low cost gokart chassis and the body parts has been

designed using SOLIDWORKS &CAD model a prototype has been developed using an fiber glass as per the rule book GKDC (Go-Kart design challenge)

However the advantages and application of fiber glass and resin are not fully maximized .This was due to lack of necessary understanding of the mixture of resin and hardener combination which has been throughout this project .beside their still lack of methodology and baseline data that can be used for the analysis of body part. The work done in this project is experimental study aimed to replace the traditional metals with the composite materials for the body parts of the go-kart vehicle

Table 10: properties of body panel

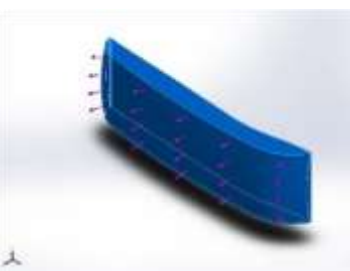
Model Reference	Properties
	Name: Epoxy, Unfilled
	Model type: Linear Elastic Isotropic
	Default failure criterion: Unknown
	Tensile strength: 2.8e+07 N/m²
	Compressive strength: 1.04e+08 N/m²
	Elastic modulus: 2.415e+09 N/m²
Poisson's ratio: 0.35	
Mass density: 1,100 kg/m³	

Table 11: CFD (Computational Fluid Dynamics) analysis velocity values :

X [m]	Y [m]	Z [m]	Pressure [Pa]	Temperature [K]	Velocity (X) [m/s]	Velocity (Y) [m/s]	Velocity (Z) [m/s]
-0.30728	0.29704	-0.2771	101334.736	293.176235	100.159276	2.39333616	2.39498788
-0.28865	0.29704	-0.2771	101335.301	293.179515	100.153844	2.33476339	2.33565429
-0.30728	0.27304	-0.2771	101336.066	293.152608	100.337673	-2.3164593	4.19483878
-0.28865	0.27304	-0.2771	101336.765	293.157483	100.330006	-2.2526319	4.09073437
-0.30728	0.29704	0.24966	101337.909	293.145248	100.364117	4.41618355	2.50718245

Force Results

Table 12: Force Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00N/m ² Node: 1	6.952e+06N/m ² Node: 32210
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	2.267e+00mm Node: 49073
Strain1	ESTRN: Equivalent Strain	0.000e+00 Element: 1	1.543e-03 Element: 1905

Table 13: Resultant Forces

Name	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction forces	N	-0.614922	-6.04585	-914.395	914.415
Free body forces	N	5.45827e-05	0.000114916	-0.00204653	0.00205048
Free body moments	N.m	0	0	0	1e-33

Pressure results:

Table 14: Resultant Forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Reaction forces	N	0.118775	2.08648	7.74331	8.02037
Free body forces	N	-8.00937e-08	-1.19209e-06	4.17233e-07	1.26554e-06
Free body moments	N.m	0	0	0	1e-33

Table 15: Pressure Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00N/m ² Node: 1	3.188e+04N/m ² Node: 641
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 1	1.349e-03mm Node: 742
Strain1	ESTRN: Equivalent Strain	0.000e+00 Element: 1	1.253e-05 Element: 180

V. 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. Al and Mg are used is much higher than the conventional materials. So it is essential for research and development in the field of lowering their cost, increasing their recyclability, enabling their integration and maximizing fuel economy benefits of automotive vehicles. By the use of composite materials instead of traditional heavy cast iron & steel we can reduce the weight by 10-60%

FUTURE SCOPE

There are scopes in order to achieve the project objective. In addition to being an engineering exercise, the Go-kart design challenge competition is about making an exhilarating formula style car that would entice a customer to purchase a ride. 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. 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. 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.

REFERENCES

- [1]. SAE Supra 2015 rule book
- [2]. Levon Minnetyan, Computational Simulation of Composite Structural Fatigue, NASA/CR— 2005- 213573, February 2005.
- [3]. Van Paepegem, W. and Degrieck, J. (2002). Coupled Residual Stiffness and Strength Model for Fatigue of Fiber-reinforced Composite Materials. *Composites Science and Technology*, 62(5), 687-696.
- [4]. Van Paepegem, W. and Degrieck, J. (2001), Experimental Setup for and Numerical Modelling of Bending Fatigue Experiments on Plain Woven Glass/epoxy Composites. *Composite Structures*, 51(1), 1-8.
- [5]. Van Paepegem, W., Dechaene, R. and Degrieck, J. (2005). Nonlinear correction to the bending stiffness of a damaged composite beam. *Composite Structures*, 67(3), 359-364.
- [6]. Van Paepegem, W., De Geyter, K., Vanhooymissen, P. and Degrieck, J. (2006). Effect Of friction on the hysteresis loops from three-point bending fatigue tests of fibre-reinforced composites. *Composite Structures*, 72(2), 212-217.
- [7]. Van Paepegem, W., Degrieck, J. and De Baets, P. (2001). Finite Element Approach for Modelling Fatigue Damage in Fibre-reinforced Composite Materials. *Composites Part B*, 32(7), 575-588.
- [8]. Van Paepegem, W. and Degrieck, J. (2001). Fatigue Degradation Modelling of Plain Woven Glass/epoxy Composites. *Composites Part A*, 32(10), 1433-1441.
- [9]. Van Paepegem, W. and Degrieck, J. (2002). Coupled Residual Stiffness and Strength Model for Fatigue of Fibre-reinforced Composite Materials. *Composites Science and Technology*, 62(5), 687-696.
- [10]. Piyanuch Luangtriratana, Baljinder K Kandola* and Peter Myler Institute for Materials Research and Innovation, University of Bolton, Deane Road, Bolton.