# LOW COST FIBREGLASS GO-KART

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# DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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# APPROVAL FOR SUBMISSION

I certify that this project report entitled **"LOW COST FIBREGLASS GO-KART"** was prepared by **LIEW YI HUI** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Mechanical Engineering at Universiti Tunku Abdul Rahman.

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# LOW COST FIBREGLASS GO-KART

## ABSTRACT

The purpose of this project was to develop a go-kart chassis by using the fibreglass composites material. Prior to that, studies and researches have been done with the purpose to understand the properties of the fibreglass composites material. Different types of fibreglass material would have different properties and usages. Different designs of the fibreglass-made go-kart chassis were developed and each of the designs was simulated to find out the relevant information regarding the design. The variations of the designs include the different in wall thickness of the chassis, different type of reinforcements used and the vary design considerations as well. It is known that when a go-kart chassis is loaded with a load of 70 kg or approximately 687 N, the bending deflection should be around a value of 5.229 mm. A suitable design was selected by comparing the simulation data with the targeted value. The selection was not only based on the results but the considerations such as the ease of installation of components, ease of fabrication and the comfort level as well. Finally, the prototype model was fabricated and experiment was carried out to verify the design is complied with what has been simulated. It can be concluded that a fibreglass-made go-kart chassis is feasible with the conditions of proper design and appropriate selection of the fibreglass material used.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Motor racing is one of the most adventurous sports activities in the world. It began to gain its attraction after the development of gasoline-fuelled engines. Motor racing can be defined as the involvement of motorized vehicles in any kind of racing or competition. Worldwide, there are plenty of motor sports such as rallying, car racing and etc. Often, professional skills and technical knowledge are needed as the requirements to be involved in these activities. However, there are also motor sports which are lower in cost and do not require skilled or well-trained drivers. Kart racing could be one of them.

Kart racing or karting is an open-wheel motor sport with the use of small-framed and four wheeled vehicles called kart. Basically, the kart racing is held on a scaled down racing circuit and guided by adequate trained personnel. Due to the nature of karting, it is suitable to be a leisure activity for everyone; even children can be involved in this kind of activity. The increasing popularity of kart racing has provided a rigid evidence to show the acceptance of karting among the people in this country.

## 1.2 Problem Statement

In the karting industry in Malaysia, there are still some obstructions to the growth of karting. Mainly, the cost of a kart could be the major subject in this issue. According to the survey, there are no local manufacturers of karts in Malaysia. Statistically, a kart in Malaysia could simply ramped up to ten thousands of ringgit depends on the specifications. Directly, the increasing cost would be absorbed by the consumers.

## 1.3 Aims and Objectives

The objectives of this project are:

i. To develop a low cost go-kart using fibreglass composite materials.
ii. To achieve a design of fibreglass-made go-kart without compromising the basic performance of a kart.

## 1.4 Schedule

Schedule is a list of project's terminal elements with the intended start and end dates. It provides the basis for monitoring and controlling the project activities. Gantt chart is a useful scheduling tool that can be used to represent the timing of tasks required to complete a project. A Gantt chart of this project is attached at the following page.

Following is the Gantt chart of this final year project;

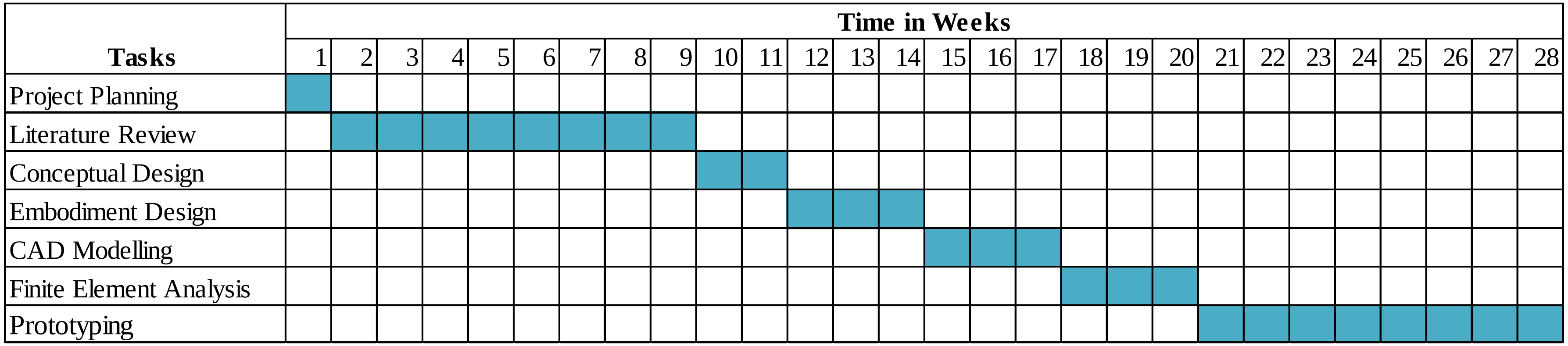


Figure 1-1: Gantt chart of the project

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 History of Go-Kart

Larry (2006) claimed that karting started off as a leisure activity for airmen during 1950s in America after the World War II. It gained its popularity when the activity is spread among the commons. The first go-kart was created by Art Ingels who was also known as father of karting in 1956 at California, America.

The kart invented was in the simplest form which made up from the basic components that could provide the fundamental needs for a miniature racing car. These components include the frame, engine and tyres. According to the study on the history of go-kart by International Recreational Go-Kart Association$_a$ (1991), there was no suspension proposed for that go-kart due to the economic and weight factors. The figure 2.1 below shows the go-kart invented by Art Ingels.

Figure 2-1: The first go-kart invented by Art Ingels. (IRGA, 1991)

According to International Recreational Go-Kart Association$_b$ (1991), an American company, Go Kart Manufacturing Co. became the first go-kart manufacturer in the year 1958 and McCulloch became the first company to produce go-kart engines at the following year. In the 1960s, the kart racing was spread widely in Europe. The design of karts were evolved and developed rapidly during the period.

The establishment of several governing and regulatory bodies in the 1980s strengthened the development of go-kart. Nowadays, the International Automobile Federation or Federation Internationale de I'Automobile (FIA) is the most renowned organisation for motor sport worldwide. It set the rules and regulations for all international four-wheeled motor sport. The Commission Internationale de Karting (CIK) is a karting commission under FIA. Besides, as stated by John$_a$ (2000), the World Karting Association (WKA) and International Karting Federation (IKF) are the other regulatory bodies that administered the kart racing. Refer to Appendix A for more information on the history of karts.

## 2.2 Components of Go-kart

Normally, a go-kart is in single seated form while twin seated karts can be found at some countries. Go-kart can be manufactured in different varieties such as size, weight, design, speed limit and etc according to the requirements of the racing style. Some karts can have a maximum speed of 260 km/hr while the normal karts have a maximum speed up to 80 km/hr.

Basically, a go-kart consists of four main components which include a chassis, engine, transmission system and tyres. Other than these main components, there are some other parts such as brakes and steering that contribute to the completeness of a go-kart. Nevertheless, a go-kart does not utilize any suspension system, seat belts and roll bars. As the rear axle is stiff, a kart has no differential and both rear wheels always turn at the same speed. For the current design, the engine is usually placed at the side of the driver seat and the power is transmitted by a chain.

### 2.2.1 Chassis

As stated by Walker (2005), chassis is the most important part of a go-kart. As there is no suspension system provided in a go-kart, the chassis built has to be flexible enough to absorb the shocks and works as a replacement for suspension. The figure 2.2 and 2.3 show an example of standard chassis used in the industry.

The weight of the chassis should be maintained at an optimum level where it is light enough to provide a fine handling while the solidness is not compromised in this matter. Often, a chassis with superior-quality could provide an excellent performance in terms of cornering, accelerating and stopping. The ability to withstand the high tensile, compressive and torsion force define the fineness of the chassis for a go-kart.

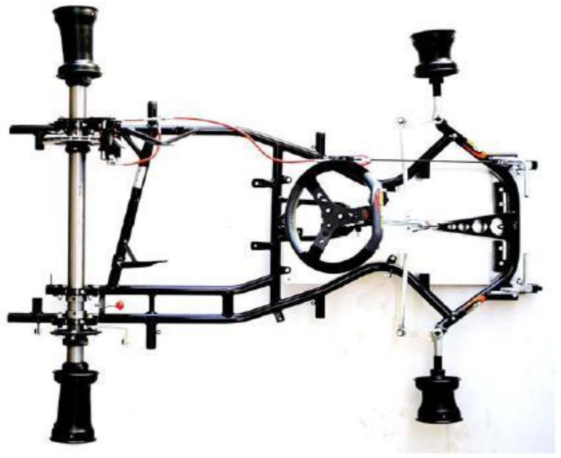

Figure 2-2: Chassis of a go-kart (CIK-FIA, 2010)

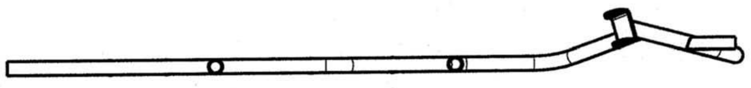

Figure 2-3: Side view of a go-kart chassis (CIK-FIA, 2010)

The designs of the chassis determine its performance on track. According to $John_b$ (2000), a chassis with wider rear rails tends to have a more stable turn at the corner as the "side bite" could be maintained in this subject. The side bite is referred to the capability to keep the go-kart on track without sliding or skidding. Nevertheless, the chances of a go-kart to flip over would reduce with the design of wider rear rails. In simple words, wider rails provide stability while turning and cornering. For further reading on the chassis, refer to Appendix B as attached.

### 2.2.2 Engine

There are two types of engines which are two-stroke engine and four-stroke engine that are commonly being utilized in a go-kart. Both of the engines are petrol-fuelled. Basically, most of the go-karts are using the two-stroke engine as the engine is small but powerful enough to satisfy the desired performance requirements. However, due to the efficiency in the environmental factor, the application of four-stroke engine in the go-kart is developed rapidly in last few years.

According to Tsavo Media Canada (2008), the two-stroke engine is originated from motorcycles. The common engine types are 100cc and 250cc engines. A single cylinder 100cc engine can produce up to 40 horsepower while the maximum power produced by a twin cylinder 250cc engine is up to 90 horsepower. However, some exhaust gases are generated due to mixture of oil and gasoline to drive the engine. This has caused some negative effects to the environment.

The four-stroke engine is a newly developed engine in karting industry. It is modified from the lawnmower engine. As stated in Tsavo Media Canada (2008), the power generated is ranged from 3 to 5 horsepower. The most essential advantage of this engine is that it has the minimal effects on the environment as compared to the two-stroke engine. It does not require the mixture of oil and gasoline to drive the engine and the noise generated is much lower.

### 2.2.3 Transmission System

Transmission system in automotive is a mechanism that involve the transmission of the power generated by engine to the wheels. In a go-kart, the power generated by the engine is transmitted to the rear two wheels by using the chain.

In a conventional go-kart, as claimed by $John_c$ (2000), there is no differential used and it can be considered as a non-shifting direct drive kart. This means that the rear axle is driven directly by the engine through the chain. In fact, the direct drive kart is still the most common kart used in the industry as the mechanical structure is much simpler and the cost is lower as compared to the shifter kart.

According to Tsavo Media Canada (2008), a shifter kart is the kart that employed the centrifugal clutch as its transmission system. The kart is operated on a manual transmission system that allowed the drivers to change the gears according to the speed. Shifter karts are costly and more complex in structure. Usually, the shifter kart is used at higher level of racing class as it required professional skills and technique.

### 2.2.4 Tyres

The tyres used for a go-kart are often depends on the conditions of the tracks. A wet weather condition would require the use of wet tyres and the slick tyres are used when the weather is dry. While some of the karts would use an intermediate tyres that have a moderate level of grooves on the tyres to counter with the weather that are in between the wet and dry. Both the wet and intermediate tyres have a full tread patterns which are functioned to expel the water trapped in between the road surface and tyres.

A slick tyre does not have grooves on the tyre. The tyres are designed to provide an excellent grip for the go-kart during the dry condition as the contact between the tyres and the track is optimum. Besides, the amount of traction is decreased due to the tread-less design of the slick tyres. The figure 2.4 below shows a slick tyre used in go-kart.

Figure 2-4: Example of a slick tyre (Partsquip, 2010)

Nevertheless, a wet tyre is grooved and it provides much more traction in the wet as compared to the slick tyres. The grooves can reduce the slipping or skidding in the wet condition. The figure 2.5 shows a wet tyre used in go-kart.

Figure 2-5: Example of a wet tyre (Sapiensman, 2010)

### 2.2.5 Brakes

Brakes are one of the important components in a go-kart. It helps to reduce the speed and stop the go-kart. There are few types of brakes system used in the current design of go-kart. However, the hydraulic braking system and the mechanical braking system are still the most common brake system being employed in a go-kart. The way the force from the brake pedal transferred to the calliper of the brake differentiates these two systems. The hydraulic braking system uses the hydraulic fluid through the pipe to transfer the force. While in the mechanical braking system, the force is being transferred by a cable.

### 2.2.6 Steering

According to Go-Kart Guru (2008), the steering systems used in a go-kart include the wagon style steering system and steering knuckle system. The wagon style system is applied in some of the karts, but it is not popular due to its poor performance and impractical to use for high level of competition. Both of the wheels are mounted on an axle and the axle is pivoted in the middle. The whole system will turn together as the wheels are turned. While for the steering knuckle system, the axle is mounted with the knuckles and the wheels rotate at the pivots of these knuckles. The turning direction of the wheels can be control by the use of tie rod which acts as a moving joint that transferred the load from the steering to steering knuckles. A better turning and cornering can be achieved through this application.

Figure 2-6: Simple steering knuckle system in go-kart (Go-Kart Guru, 2008)

## 2.3 Applications of Fibreglass in Go-kart

According to Tony Borroz (2009), the fibreglass has been used in automotive applications for more than 50 years. The most remarkable example would be the Chevrolet Corvette body which was completely made by the fibreglass composite materials since 1953. The continuous improvement on the applications of fibreglass in automotive has make the fibreglass one of the most extensive materials used in this industry especially in term of racing. The high performance properties provided by the fibreglass materials are the main reason for its popularity.

In the kart racing, the application of fibreglass is growing rapidly as well. In the current applications, the fibreglass-made parts could include the body components such as the seats and the chassis components which are the frames or the kart chassis. The engine is rarely built by the fibreglass as in the formula one racing due to the cost implied.

The high strength to weight ratio is the main reason for the fibreglass composite materials to become the material of choice in the kart racing. A fibreglass-made go kart body could provide a decent reduction in weight and help to achieve higher speed on the track.

In addition, the fibreglass-made go kart seat is becoming common due to the high internal damping of the material. The faster damping of the vibrations reduces the shocks transmitted to the driver and this help to have a better control over the driving and minimize the potential injuries.

## 2.4 Fibreglass

Generally, fibreglass is a glass fibre-reinforced polymer composite. Cardarelli (2008) stated that the term reinforced composites can be defined as the combination of at least two physically distinct materials acting together in the mean of the interfacial bond between them. A composite material could be isotropic or anisotropic. Isotropic means that the material has the equal properties in all directions. While the anisotropic can be defined as the properties of a material is directionally dependent.

According to Lubin (1975), a glass is a non-crystalline silicate containing different oxides such as calcium oxide, sodium oxide, aluminium oxide, silicon dioxide or silica and etc, which melt to form the eutectics. It is an inorganic material in which when cooled, it becomes rigid without crystallizing. The crystallizing can be explained as the atoms never arrange themselves into an orderly crystalline pattern. Furthermore, glass is often chosen as a fibre reinforcement material as it is easily drawn into high-strength fibres from the molten state. As stated in Mallick (2008), a three-dimensional and long network of silicon, oxygen and other atoms which arranged randomly formed the internal structure for a glass fibre. Thus, as mentioned above, glass fibre is a non-crystalline and isotropic material.

According to Callister (2006), fibreglass is simply a composite formed by the glass fibres contained within a polymer matrix. The thermoset polymers and thermoplastic polymers are the most commonly used polymer matrix in the fabrication of fibreglass. In simple words, fibreglass is a material made by the fine fibres of glass.

### 2.4.1 Advantages and Disadvantages of Fibreglass

The advantages and disadvantages of fibreglass composite materials are shown in the table 2.1 below. For more information, refer Appendix C for further explanation.

Table 2-1: Advantages and disadvantages of fibreglass

| Advantages | Disadvantages |
|---|---|
| • Superior tensile strength<br>• High strength to weight ratio<br>• High chemical resistance<br>• Corrosion resistance<br>• High durability<br>• Non-conductive material<br>• Good thermal properties<br>• Design flexibility<br>• Affordable and cost effective<br>• High internal damping<br>• Dimensional stability<br>• Excellence surface finish | • High sensitivity to abrasion<br>• Wear and tear of the tools due to the high hardness of fibreglass |

### 2.4.2 Types of Fibreglass

The characteristics and categories of a glass are determined by its compositions. Different compositions would result in various properties of glass, namely E-glass for electrical insulation, S-glass for high tensile strength and C-glass for chemical resistance. These three types of fibreglass are the most common used fibreglass in the industry. The attributes of fibreglass composite materials are largely depend on the category of the glass composited.

#### 2.4.2.1 E-glass

According to van der Woude and Lawton (2010), E-glass is the most common used glass fibres in the industry due to the lower cost among the groups. Basically, E-glass is an Alumina-Borosilicate glass designed primarily for electrical insulation purposes. The designation “E” means electrical which represented its speciality in electrical properties. Other than its electrical properties, E-glass is effectively being applied in the composite reinforcement as its balanced characteristics in terms of strength, stiffness, corrosion resistance and essentially isotropic properties. The table 2.2 below shows the compositions of E-glass.

Table 2-2: Typical composition of E-glass

| **Type** | **Range (in wt %)** |
|---|---|
| Silicon dioxide, $SiO_2$ | 52-62 |
| Aluminium oxide, $Al_2O_3$ | 12-16 |
| Calcium oxide, CaO | 16-25 |
| Magnesium oxide, MgO | 0-5 |
| Boron oxide, $B_2O_3$ | 0-10 |
| Sodium oxide, $Na_2O$ | 0-2 |
| Potassium oxide, $K_2O$ | 0-2 |

As shown in the table above, the main composition in the E-glass is silica or silicon dioxide. It is an oxide of silicon and it is very hard. Besides, the content of sodium oxide and potassium oxide are very low as compared to the other substances. This provides the E-glass a better corrosion resistance and higher surface resistivity.

Besides the silicon dioxide, other oxides such as aluminium oxide, calcium oxide, magnesium oxide, boron oxide, sodium oxide and potassium oxide are found in the composition of E-glass. These oxides are normally added to modify the network structure of the E-glass to have a wide range of properties. The E-glass would be more comprehensive in term of its physical and chemical properties through the combination of different oxides.

#### 2.4.2.2 S-glass

Other than E-glass, S-glass is another common glass fibre used in the current industry. The complexity and high manufacturing cost have make it much expensive than E-glass. Thus, the application of S-glass is restricted to the products with greater requirements due to the higher cost.

According to Potter (1997), the S-glass is a high tensile strength glass and its tensile strength is approximately 33 percent higher than E-glass. Nevertheless, S-glass has the highest tensile strength among all the fibres in use. The designation “S” simply represents the word “strength”. The applications of S-glass are mainly practiced in the aircraft industry, missile manufacturing, aerospace components and other high performance applications. The significant properties of S-glass include high strength to weight ratio, excellent strength retention at high temperature and high fatigue limit. The table 2.3 below shows the typical composition of S-glass.

Table 2-3: Typical composition of S-glass

| **Type** | **Range (in wt %)** |
|---|---|
| Silicon dioxide, $SiO_2$ | 64-66 |
| Aluminium oxide, $Al_2O_3$ | 24-25 |
| Magnesium oxide, MgO | 9.5-10 |

#### 2.4.2.3 C-glass

As stated by Potter (1997), C-glass is another glass fibre that mainly used in the applications that required better resistance to chemicals. The designation “C” represents the term “chemical”. Accordingly, the key characteristic of C-glass is corrosion or chemical resistance.  The C-glass fibres are usually employed in the applications such as chemical storage tanks, pipes and etc. Basically, the application of C-glass could provide a protection to permeation and degradation. The table 2.4 shows the typical composition of C-glass.

Table 2-4: Typical composition of C-glass

| Type | Range (in wt %) |
|---|---|
| Silicon dioxide, $SiO_2$ | 64-68 |
| Aluminium oxide, $Al_2O_3$ | 3-5 |
| Calcium oxide, CaO | 11-15 |
| Magnesium oxide, MgO | 2-4 |
| Boron oxide, $B_2O_3$ | 4-6 |
| Sodium oxide, $Na_2O$ | 7-10 |
| Potassium oxide, $K_2O$ | 7-10 |

### 2.4.3 Forms of Fibreglass

Fibreglass is produced in a variety of forms. These forms include the roving, chopped strands, mats and woven. Strand is most the basic form of continuous fibreglass and it is formed through a group of parallel filaments.

Roving is the most common form of fibreglass. According to Mallick (2008), roving is simply a group of parallel strands which gathered and wound on a cylindrical tube. Generally, roving is used in continuous moulding operations such as filament winding and pultrusion. The figure 2.7 below shows an example of continuous strand roving.

Figure 2-7: An example of continuous strand roving (GP Impex, 2010)

Based on van der Woude and Lawton (2010), the continuous strands can be cut into shorter lengths to produce another form which is chopped strands. The chopped lengths are usually in the range of 3 mm to 50 mm. The chopped strands are usually used to reinforce the thermosetting and thermoplastic resins. Besides, the chopped strands are often applied in the injection moulding. The figure 2.8 below shows an example of chopped strand.

Figure 2-8: An example of chopped strands (LBIE, 2009)

Chopped strands mat (CSM) is another popular form of fibreglass. CSM is produced by spreading the longer chopped strands evenly in a random pattern and mixing the chopped strands with the resinous binders. The CSM is usually used in hand lay-up moulding, press moulding, autoclave moulding and various continuous impregnating processes. Besides, CSM provides isotropic properties which mean the product has the equal properties in all directions. The figure 2.9 below shows an example of chopped strands mat.

Figure 2-9: An example of chopped strands mat (QDC, S.L., 2010)

Other than the forms mentioned above, fibreglass can be found in the woven form as well. Woven roving is another common type of fibreglass used in the current industry. According to Lubin (1975), it is produced by weaving the continuous strands in two mutually perpendicular directions and the properties of the woven roving are largely depend on the style of weaving. Woven roving is often used as reinforcement of thermosetting polymers in a variety of applications. The figure 2.10 below shows an example of woven roving.

Figure 2-10: An example of woven roving (DIYTrade, 2007)

## 2.5 Polymer Matrix

Generally, fibreglass composite materials consist of fibreglasses bonded to a matrix with different interfaces between them. In another word, matrix acts as an intermediate between the fibreglass to adhere and keep the fibreglass in a fix location and orientation. Most of the fibreglass composite materials in the industry are in the form of laminate which means that the materials are made by depositing several layers of fibreglass and matrix and consolidating them to a certain thickness.

According to Tucker and Lindsey (2002), besides keeping the fibreglass in place, matrix is used as a medium to transfer the stresses or loads between the fibreglass as well. Nevertheless, matrix provides protection for the fibreglass from the environmental damage and the surface degradation caused by the abrasion. Thus, the configuration of the fibreglass and matrix is always a crucial step in fabricating a fibreglass composite material.

There are various matrix materials which include the polymer matrix, ceramic matrix and metallic matrix. Among these materials, the polymer matrix is the most common used matrix in the industry. While the ceramic and metallic matrixes are used mainly for high temperature applications.

As stated in Callister (2006), a polymeric material is formed by a group of polymer molecules with similar chemical structure and connected together by strong covalent bonds. For the applications of polymer matrix, the thermoset polymers and thermoplastic polymers are the most widely used matrix materials largely due to its simplicity of processing.

According to Biron (2007), in a thermoset matrix, the molecules are chemically bonded together by cross-links and form a three-dimensional network through the covalent bonding. Often, the term, resin, is applied in the industry to describe the resulting polymer. The thermoset polymer could not be melted by the heat once the cross-links are formed. However, if the number of cross-links between the molecules is less, the polymer could still be softened at elevated temperature. There are few types of resins which are commonly being used such as the polyester, epoxy, vinyl ester and etc.

While for the thermoplastic matrix, as claimed by Tucker and Lindsey (2002), there are no chemical linkages between the individual molecules. The molecules are not chemically bonded, but held by weak bonds or intermolecular forces such as the van der Waals bonds and hydrogen bonds. Thus, the thermoplastic polymer could be melted and softened by the heat and reshaped accordingly as desired. The examples of thermoplastic matrix resins include the polyamide, polysulfone, polyphenylene sulfide, polyether ether ketone and etc.

As mentioned above, there are plenty of polymer matrixes available in the industry. However, due to the market constraints, the thermoset matrixes are applied at most of the time. Nevertheless, the thermoplastic matrixes are seldom applied in the application of go-kart too. Thus, the reviews will be focused more on the thermoset matrix. For further information on thermoplastic matrix, refer to the Appendix D as attached.

### 2.5.1 Polyester Resin

As stated by Mallick (2008), polyester resin is an unsaturated resin formed by the reaction of dibasic acids with polyhydric alcohols. The polymeric resin is obtained by dissolving the mixture in a reactive monomer such as styrene. By dissolving in styrene, the viscosity would be reduced and make the resin easier to handle. The solution could be cured or polymerized through the heating process to provide a strong cross-linked structure. The curing process is often carried out with the use of catalyst or accelerator. The properties of polyester resin are often depends on the density of the cross-links.

The polyester resin is the most popular resin used in fibreglass products. The combination of polyester resins and fibreglass composite materials offer a wide range of properties to a certain product. Polyester resin is much cheaper as compared to the other resins. Besides, the ease of handling the resin is another attractive point of using polyester resin. The hand lay-up method is usually employed with the application of polyester resin.

Other than that, the polyester resin has a good resistance to corrosion and degradation caused by the chemical attacks. Excellent electrical properties could be provided by the polyester resin as well. Nevertheless, other composite properties such as lower viscosity and fast curing time are the advantages of using polyester resin.

According to van der Woude and Lawton (2010), the principal disadvantage of polyester resin over the other resins is the high volumetric shrinkage. The shrinkage would results in uneven depression on the surfaces and affects the appearance of the product. This issue is strictly not allowed in the applications where Class A surface quality is important such as automotive industry. However, some finishing process can be carried out to minimize the poor surface finish.

### 2.5.2 Epoxy Resin

According to Shenoi and Wellicome (1993), epoxy resin is formed by the reaction of three members' rings which is known as epoxy. An epoxy resin could contain few epoxy groups. The epoxy groups are referred to the chemical groups containing of an oxygen atom bonded with two carbon atoms, which is the three members ring. Similar to the polyester resin, curing is needed to produce an insoluble cross-linked structure. However, instead of catalyst, the curing agent used by epoxy resin is hardener. Often, amines are used to cure the epoxy resin where both the epoxy and amide take place in a chemical reaction to create the molecular structure.

Epoxy resin has the excellent mechanical properties and good resistance to the chemicals which are much better than the polyester resin. Due to these advantages, it is the most common used resin in the high performance industry such as aircraft manufacturing. Besides, epoxy resin offers a wide variety of properties through the selection of curing agents, hardening method and modification.

Nevertheless, the epoxy resin has the first rate adhesion ability and the strong adhesion is available to a variety of materials. The low shrinkage during the curing process is further enhanced the adhesion as a rigid and unstrained adhesive bond could be formed. Other than that, the attributes such as good electrical properties, better water resistance and thermal stability are the attractive points of epoxy resin.

On the contrary, the higher cost than polyester resin and longer curing time are the main disadvantages of the epoxy resin. Often, an epoxy resin takes few days to be cured instead of few hours of curing in polyester resin. Thus, the applications of epoxy resin are limited to the products where the requirements are high. Besides, the possible hazards in handling the resins and hardener are another obstruction in applying the epoxy resin.

### 2.5.3 Vinyl Ester Resin

As similar to polyester resin, vinyl ester resin is an unsaturated resin formed by dissolving in the styrene monomer which can reduce the viscosity of the mixture. As stated by Shenoi and Wellicome (1993), the vinyl ester resin will reacts with the styrene to form the rigid cross-links between the molecules. The curing process is similar to the polyester resin as well. A unique point of vinyl ester resin that differentiates it from the other resins is that it contains a number of hydroxyl groups which will form the hydrogen bonds with the similar groups on a fibreglass surface. This would results in better wet-out and creates a good adhesion with the fibreglass.

While for the properties of the vinyl ester resin, it is analogous to the polyester resin in certain points too. The curing time is fast and the viscosity is lower due to the styrene monomer. Besides, vinyl ester resin has an excellent chemical resistance and tensile strength which are on par with the epoxy resin. On the other hand, the cost for a vinyl ester resin is higher than polyester resin but lower than epoxy resin. Nevertheless, vinyl ester resin provides a moderate adhesion power which is slightly higher than the polyester resin. As similar to the polyester resin, the high volumetric shrinkage happened in vinyl ester resin as well.

## 2.6 Fabrication Process by Using Fibreglass Materials

The fabrication process of fibreglass composite materials is rather simple and inexpensive among the available materials in the market. The materials needed for the fabrication of a fibreglass product could be as simple as the moulds, resins, fibreglass and finishing materials.

Moulding is always the first step to start the fabrication process. The moulds could be made by a variety of materials such as plywood, cardboard, Styrofoam, aluminium sheets and etc depend on the requirements or specifications of a particular product. Often, the surface of the mould is applied with a layer of release agents such as wax, oil or release coating like poly vinyl acetate (PVA) to ensure the mould can be released or unplugged smoothly in the end of the process. Nevertheless, a gel coat is always sprayed on the surface of the mould after the layering of release agents. A gel coat is a resin-based surface coating which can provide a better surface properties and achieve a desired appearance as the gel coat is available in a wide range of colours.

After the moulding process, the next step would be the layering of fibreglass and resins. As mentioned earlier, fibreglass is available in different forms such as roving, mats, chopped strands and etc. The selection of forms is always depends on the applications and the fabrication process. Normally, the catalyzed resin mixtures are applied on the mould followed by the layering of fibreglass. This step is repeated until the required coverage and thickness are achieved. The resins have to be mixed with the catalyst or hardener to start with the hardening process. Catalyst is a corrosive material, thus, the mixing ratio must be in accordance to the specified requirement and extra care is needed during the process.

In some of the applications where the surface properties are important, the gel coat would be applied again to enhance the smoothness of the surface. Once all the processes have been done, the product would be allowed to settle down for a period of time before removing the mould from the final product. Sanding or grinding could be carried out to eliminate the rough spots on the surface to have a better surface finishing.

### 2.6.1 Hand Lay-Up Method

Hand lay-up method is the first and most widely used technique for producing the fibreglass composite materials. The moulds can be made from various materials such as wood, steel, plaster and etc. Often, a gel coat is applied on the surface of the mould to obtain a better finishing and enhanced resistance to chemical attacks. The catalyzed resin mixtures are then brushed manually on the mould followed by the layering of fibreglass. Polyester and epoxy resins are the common resin used with this technique. Besides, hand lay-up method is always a good choice for small scale production as the cost is much lower and the fabrication process is simpler.

### 2.6.2 Spray Deposition Method

Spray deposition is a technique where the chopped fibreglass and resins are sprayed simultaneously onto the surface of the mould using the sprays. In another words, it is a mechanized version of hand lay-up method. Thus, the production rate is much higher than the manually controlled hand lay-up method. Nevertheless, the gel coat is applied on the surface of the mould to get the same effects as in hand lay-up method.

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### 2.6.3 Filament Winding Method

In the filament winding method, the fibreglass rovings are winded continuously over a rotating mandrel. The winding could consist of few layers of fibreglass in the same or different orientation. The fibreglass could be impregnated with the resins prior to winding. The common resins used are polyester resin and epoxy resin. The process is considered done after the curing is carried out and the mandrel is removed.

### 2.6.4 Injection Moulding Method

Injection moulding is a common technique used for producing fibreglass composite materials. The molten polymer matrixes which are often the thermoplastic polymers are mixed with the fibreglass in the mixing chamber and being forced into a mould cavity under the high pressure. The cost of the injection moulding method is much higher than the other techniques largely due to the complexity of the mould.

### 2.6.5 Pultrusion Method

Pultrusion is a continuous manufacturing process where the fibreglass in the form of mats or rovings is impregnated continuously in a resins bath and pulled through a heated die where the resins undergo the polymerization process. The pultrusion method could only produce the products with uniform cross sections such as rods, hollow tubes and squares. The pultruded fibreglass composite materials have the characteristics of high strength to weight ratio, excellent dimensional stability, good structural properties and etc.

## 2.7 Selection of the Types of Fibreglass and Resin

Since the fibreglass composite material is chosen as the main material of this project, the selection of material would be emphasised on the fibreglass material itself rather than the other materials in the market. The selection of fibreglass materials would be performed on the types of fibreglass used, the forms of the fibreglass materials, the types of resins used, moulding materials and the processing methods.

Based on the reviews done, there are a range of materials available in the industry. However, in this country, the resources available are limited. For instant, the obtainable type of fibreglass in the market is mainly the E-glass fibreglass and the resins offered would be the polyester and epoxy resin. Nonetheless, the chopped strands mat (CSM) is the most common form of fibreglass available. Besides, the choice of processing methods is limited as well. For a small scale production, the use of epoxy resin is not practical as the cost implied is much higher and the hand lay-up technique is the most commonly used method.

As in this project, the aims are focused on the low cost and local sourced materials. Thus, the selection would largely depend on the availability of the materials in the market. Importing a material is impractical as it goes against with the objectives of the project.

## 2.8 Concept of Design

In this project, the design of the kart chassis is mainly based on the concept of monocoque design that applied in the racing cars or even some of the high end road cars. Basically, a monocoque design is the concept where the entire chassis is built in a single unit. A remarkable example would be the McLaren's MP4-12C. The chassis of the car was built in a one piece carbon-fibre tub. The figure 4-1 below shows the carbon-fibre monocoque design of the MP4-12C.

Figure 2-11: The carbon-fibre monocoque chassis of MP4-12C (McLaren Automotive, 2011)

As mentioned above, the MP4-12C's chassis was a carbon-fibre monocoque chassis. The properties of carbon-fibre are definitely more superior compared to the fibreglass. So, the questions arose when the design is to be done in the fibreglass material. The Lotus Elite built in 1957 would undoubtedly be the answer for this. The chassis of the car was entirely made of fibreglass. In another way of speaking, the car was structured on a fibreglass monocoque chassis. Since the fibreglass is chosen as the building material for the go-kart in this project, it is feasible to design as what have been done in the Lotus Elite.

Nevertheless, the design of the go-kart chassis in this project is largely inspired by the Formula 1's car body. The figure 4-2 below shows an example of the Formula 1's car.


Figure 2-12: An overhead view of the McLaren MP4-26 (McLaren F1, 2011)

## 2.9 Design Requirements

Maurizio, Giuseppe, and Gianpiero (2004) did a research in the vertical deflection of a go-kart chassis when it was loaded with the load until 30 kg. The displacement in the vertical direction was obtained as below.

Table 2-5: The displacement obtained under a given load

| Load (kg) | Displacement (mm) |
|---|---|
| 0 | 0 |
| 5 | 0.36 |
| 10 | 0.72 |
| 15 | 1.10 |
| 20 | 1.49 |
| 25 | 1.86 |
| 30 | 2.24 |

The relationship between the load and the displacement is shown in the figure 2-13 below.

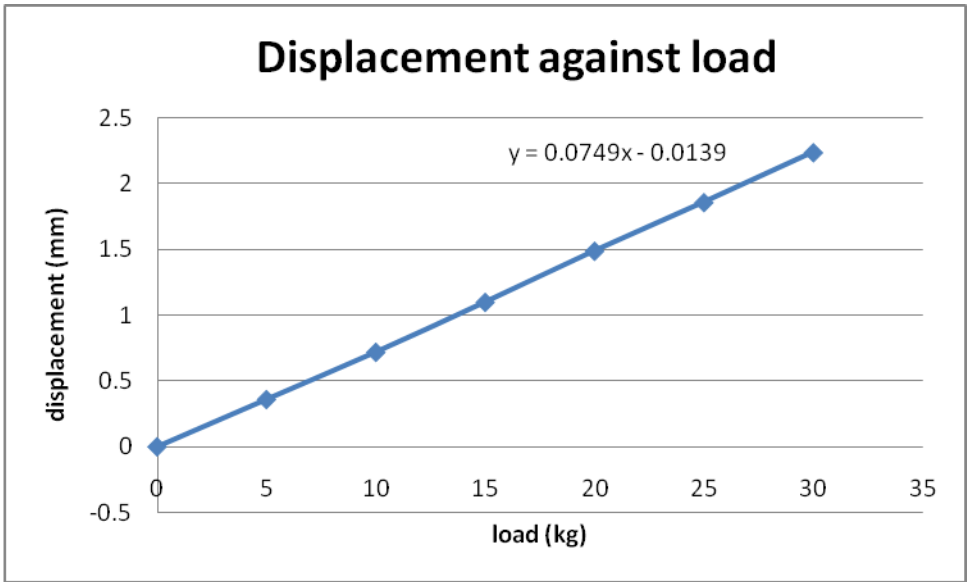


Figure 2-13: The relationship between displacement and given load

If a load with 70 kg (approximately a human weight) is loaded on the chassis, by using the equation obtained from the graph, the displacement achieved is 5.229 mm. Thus, it can be concluded that, for a go-kart chassis loaded with 70 kg of weight, the bending deflection of the chassis obtained is 5.229 mm. The research finding shown was carried out on a conventional tubular go-kart chassis. As in this project, the design of the chassis is different from the conventional chassis. Thus, the value needs not to be the exact displacement for a load of 70 kg but it acts as a reference point for displacement obtained.

Meanwhile, for the torsional stiffness of a go-kart, in Liang, Yu and Wu (2007), it is stated that a recommended torsional stiffness for a go-kart should be at least 165 Nm/deg. However, there is an unanswerable doubt in this value whereby the amount of force and moment exerted at the kart body to obtain the value is not known. Thus, if this value is to be the reference value for the project, certainly there would be some questions arise. Somehow, the figure 2-14 shows the force-deflection curve for a car chassis testing.

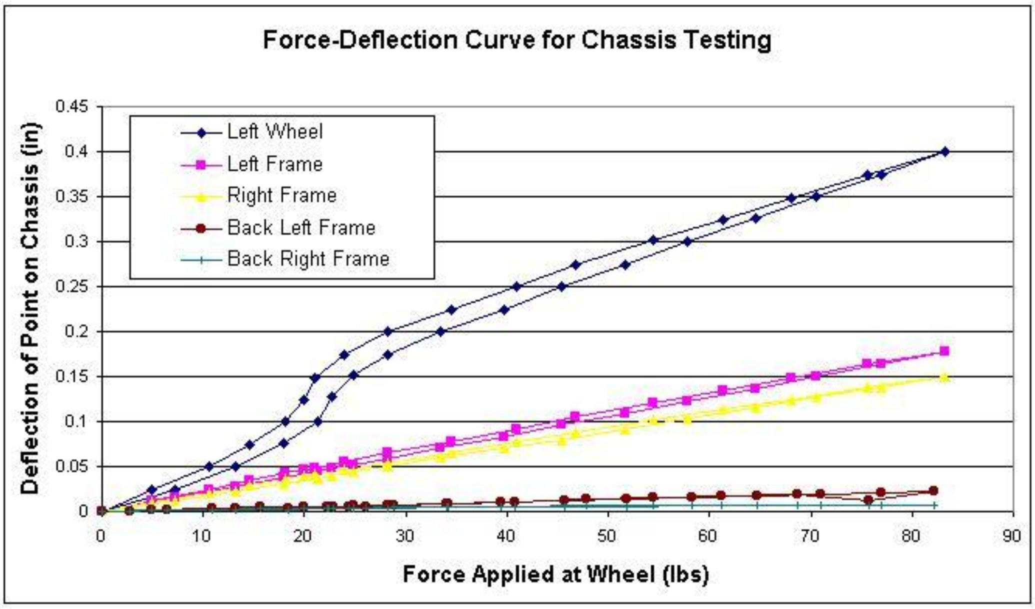


Figure 2-14: The force-deflection curve for a chassis testing (Rileydynamics, 2011)

# CHAPTER 3

# METHODOLOGY

## 3.1 Process Flow of the Project

Methodology could be explained as a description of the proceeding of a project. In another words, it is a set of methods or procedures of a project. Often, a flow chart is used as a tool to represent the procedures which show the steps from the start to the end of a project. A flow chart of this project is attached at the following page

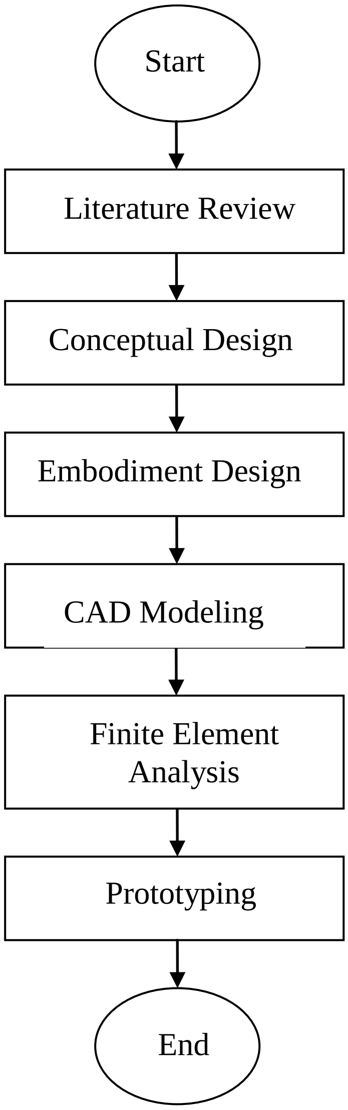


Figure 3-1: Flow chart of the project

## 3.2 Literature Review

Literature review is the process of obtaining and summarizing the related information through the reviews on the journals, books, internet resources, articles and etc. It provides the background knowledge of the studies and worked as a guide to the later part of a project. Similarly, in this project, the information of a go kart such as the history and the components are studied in the earlier part of this stage. Nevertheless, the research on the material is carried out as well. The information like the applications of fibreglass materials, the properties of fibreglass, the characteristics of different polymer matrixes and the fabrication process of fibreglass materials are obtained and studied through the literature review. An evaluation of materials is performed in this stage of process as well.

## 3.3 Conceptual Design

Conceptual design is the process where the conceptualization is performed. It is a stage where the ideas of the design are demonstrated through the drawings or sketching. The concepts of the design are generated based on the information obtained and brainstorming is always a good method to create an idea. Nevertheless, the conceptual design often involves the activities like description of overall concept and definition of the specifications. As in this project, the concept of how the fibreglass composite materials are applied to the structure of a go kart is determined in this stage.

### 3.4 Embodiment Design

Embodiment design is carried out after the concepts of the design are generated. In this process, the preliminary design layouts and configurations are developed from the selected concept. The technical criteria are identified in the embodiment design as well. In this stage of the project, the architecture, shape and general dimensions of the go kart are established.

Nevertheless, the materials are selected before proceed to the modelling of the design. As the fibreglass composite material is chosen as the principal material of this project, the material selection process will be focused on the selection of fibreglass rather than the other available materials in the market. The decision matrices such as Pugh selection method is used as a tool in the material selection process.

### 3.5 CAD Modelling

CAD modelling is a process to create computerized models for a product before it is physically produced. This process enables the visualization of a design and identification of potential design problems before the prototyping process. As in this project, the detail drawings and the final design specifications of the go kart are worked out. Then, the go kart with predetermined dimensions and patterns is drawn and modelled by the modelling software and a finite element analysis will be carried out on the completed model to determine the performance of the design.

## 3.6 Finite Element Analysis

Finite Element Analysis or FEA is a tool used to identify the performance of a model by stressing the model to obtain the specified results. The detailed visualization of where the parts would bend or twist and the distribution of stresses would be indicated through the simulation. Modifications could be done to improve the areas where the stress sustainability is weak. Finally, a final design review is performed to ensure the design is workable and ready for prototyping.

## 3.7 Prototyping

A prototype of the finalized design is built and the performance of the design is verified to comply with the design requirements.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Design of Go-kart

### 4.1.1 First Kart Chassis Design

As mentioned in the earlier section, the design of the chassis is inspired from the car body of a Formula 1’s car. The concept of having a cockpit is implemented. Nonetheless, in the Formula 1’s car, the car body can be considered as a full covered body with an opening for the driver to enter into the driving cockpit. However, in our go-kart design, the chassis is built in an open chassis style while maintaining the driving cockpit design. The opening area of the chassis is designed with the purpose to ease the installation of the engine and any other relevant mechanisms. Nonetheless, the ease of maintenance is another consideration for an open chassis. The figure 4-1 and figure 4-2 shows the first design of the go-kart chassis in this project.

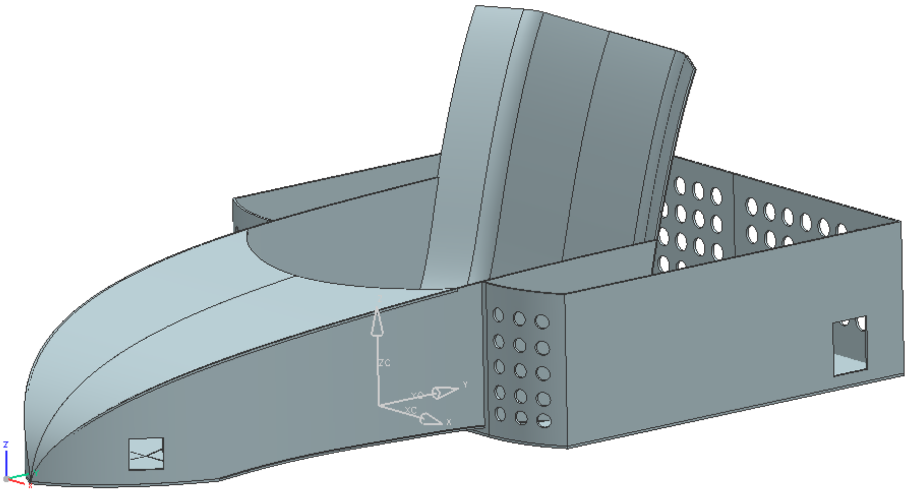

Figure 4-1: The first design of the go-kart chassis

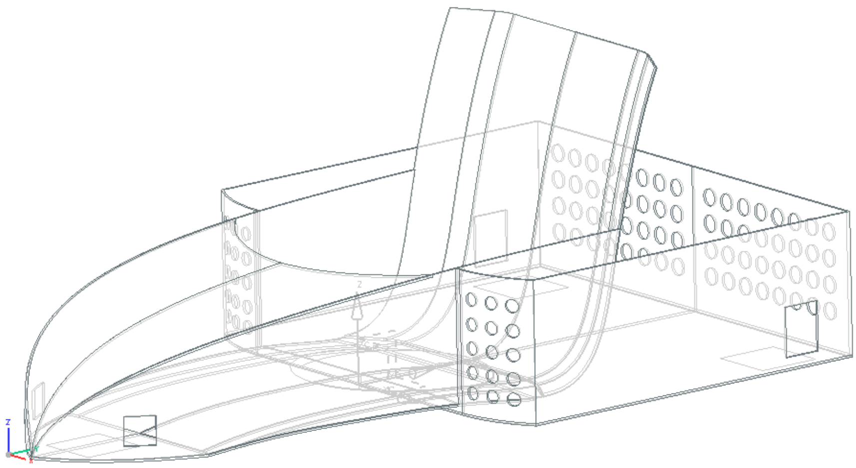

Figure 4-2: The wireframe model of the first go-kart chassis design

As shown in the figure 4-1, the seat is designed in a single unit together with the chassis. Nevertheless, there are some holes available at the both side of the kart body to allow the air flow into the engine compartment for cooling effect. Besides, the air resistance can be reduced as well.

Basically, after the consideration of the difficulties that would be faced during the fabrication process, the design is simplified. Instead of having a base that is in a curvature form, the base is modified to become a flat base design. Nevertheless, the design of the seat is simplified as well since the seat is not the focus in the project. The figure 4-3 and figure 4-4 shows the modified version for the first chassis design.

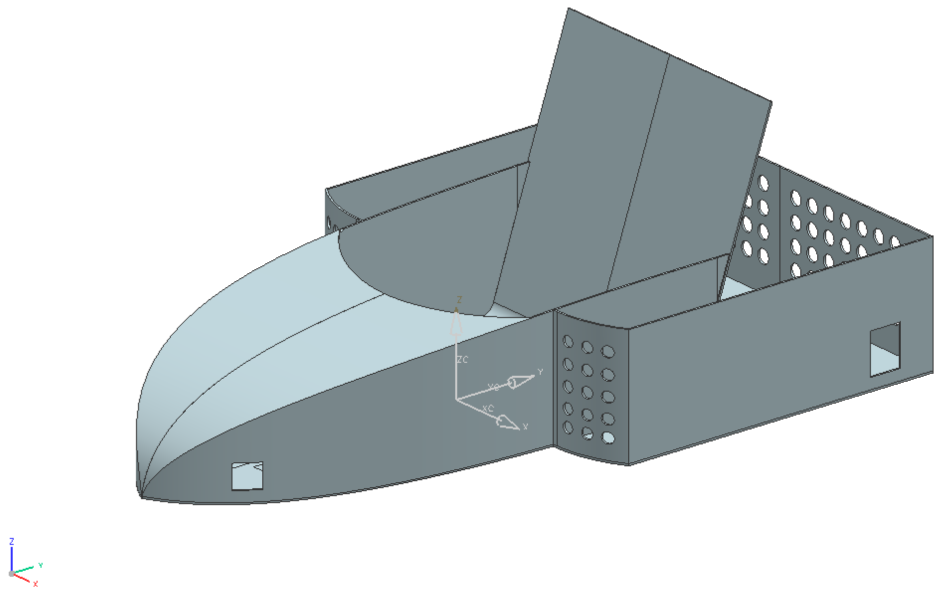

Figure 4-3: Modified version of first kart chassis design

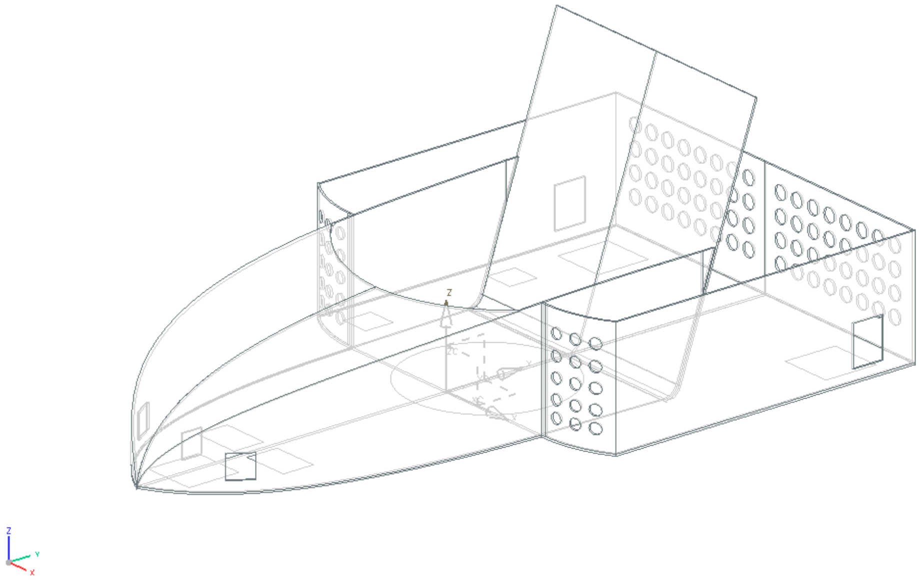

Figure 4-4: The wireframe model of the modified first go-kart chassis design

Table 4-1: Summary of the first design

| Pros | Cons |
|---|---|
| • Open chassis<br>• Ease of installation<br>• Ease of maintenance<br>• Opening of holes to reduce air resistance and help in ventilation | • Extra part such as seat<br>• Unnecessary curvature design<br>• Potentially limited space in the driving cockpit |

### 4.1.2 Second Kart Chassis Design

For the second design of the go-kart chassis, it is actually modelled based on the first design. The variations include the removal of the seat from the chassis design. As mentioned above, since the seat is not the focus, it would be reasonable to be removed from the design. Besides, the front cover on the top of the chassis is trimmed to a smaller size with the purpose to allow more rooms or space for the installation of steering system. Nonetheless, a smaller cover could provide a more comfortable driving condition. Moreover, the thickness of the chassis is set to be 3.5 mm. The figure 4-5 below shows the design of the modified go-kart.

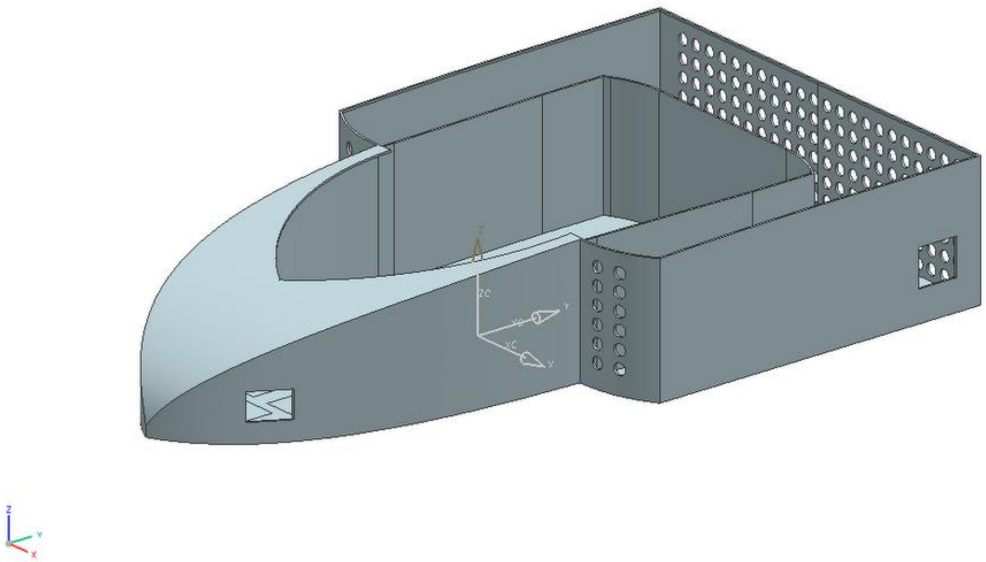

Figure 4-5: The second design of the kart chassis

Simulation on the displacement has been carried out in this design as well. The load assumed is 70 kg or approximately 687 N, which is similar to a human weight and it is applied on the sitting area of the chassis. The maximum displacement of the go-kart chassis could be obtained. The figure 4-6 below shows the simulation of displacement for this design.

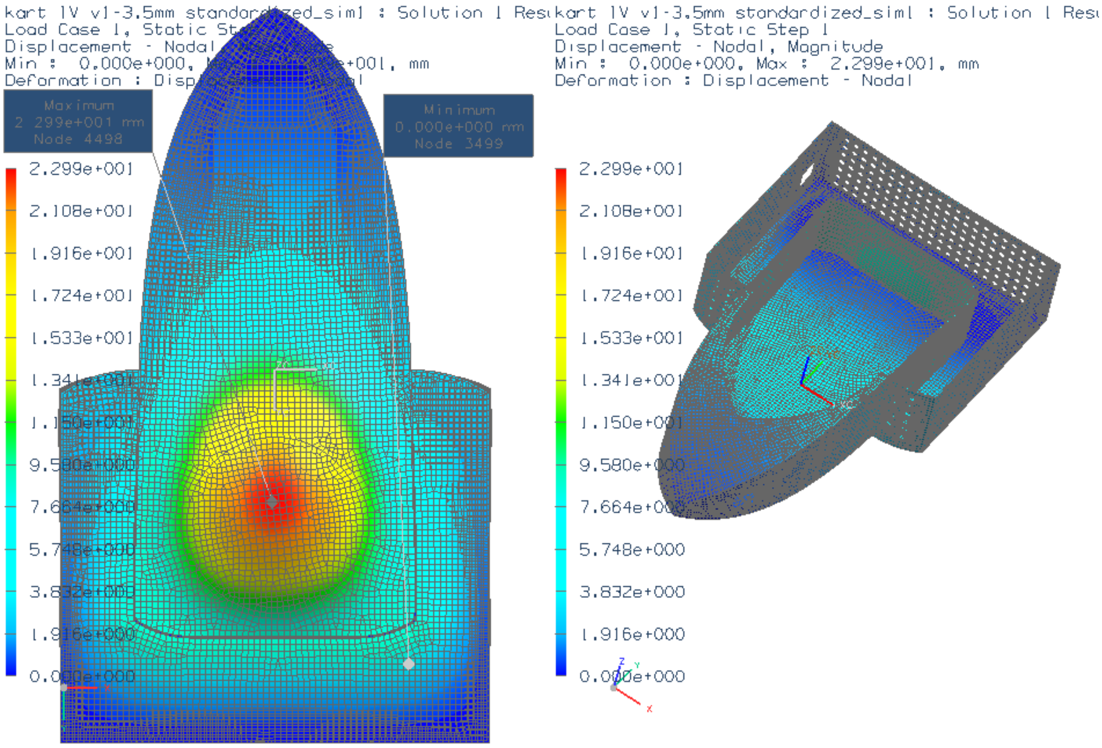


Figure 4-6: The simulation result for second design of kart chassis

The data obtained from the simulation showed that the maximum displacement achieved is 22.99 mm. The weakest area of the chassis is believed to be the sitting area. Obviously, the displacement of 22.99 mm is not a satisfied result as it is largely against the desired value of displacement. Modifications and improvements need to be done in order to achieve a better result.

Table 4-2: Summary of the second design

| **Pros** | **Cons** |
| --- | --- |
| • Removal of seat<br>• Smaller front cover<br>• Ease of installation<br>• More space in the driving cockpit | • Large displacement |

Thus, another variation based on the same design of chassis has been made to find out a feasible solution. Since the application of fibreglass allows the thickness of the chassis to be varied by adding or reducing the layers applied, the thickness of the chassis is decided to be increased to 15 mm which is considerably large to find out the effects on the displacement result. The figure 4-7 shows the simulation results for the chassis of improved thickness.

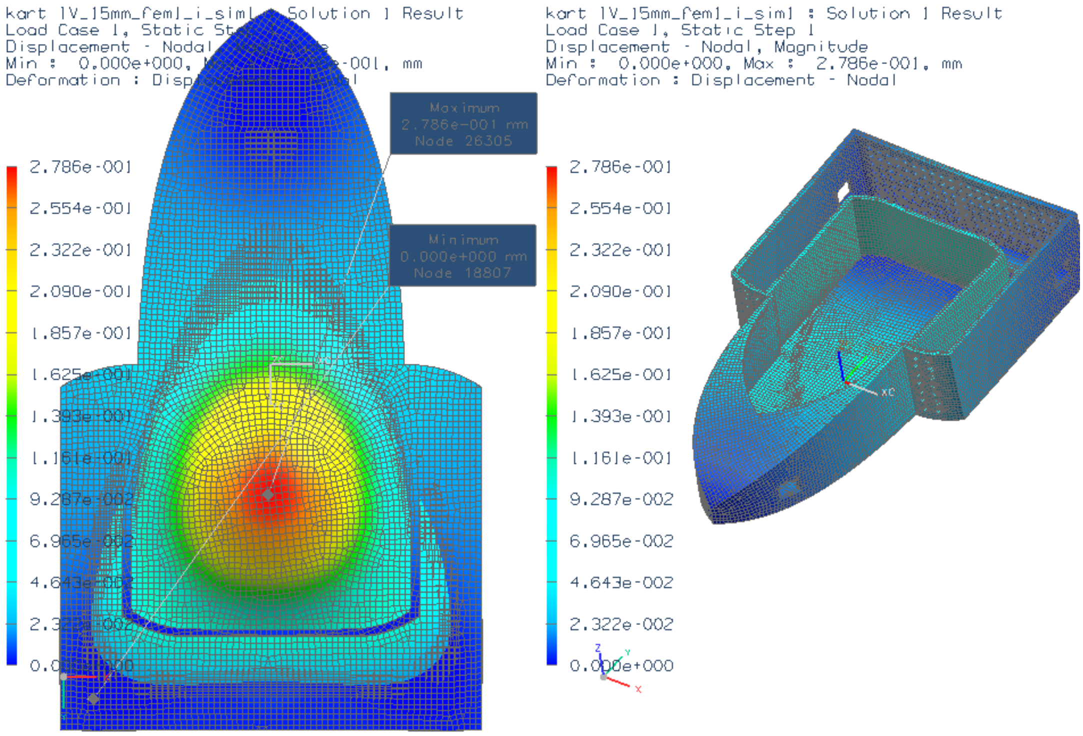


Figure 4-7: The kart chassis with 15 mm thickness

Dramatically, by applying the same amount of load, the maximum displacement obtained is about 0.2786 mm. The value obtained is much lower as compared to the previous simulation. Thus, it can be conclude that a chassis with thicker wall especially at the area where the load taking is largest could provide a better displacement result and thus higher stiffness.  However, thicker wall would contribute to the increment of chassis mass as compared to the others and the issue of over designed would arise.

Table 4-3: Summary of the improved second design

| Pros | Cons |
|---|---|
| • Small displacement<br>• Higher stiffness | • Thicker wall<br>• Heavy chassis<br>• Over designed |

### 4.1.3 Third Kart Chassis Design

From the simulation of thicker chassis wall, it is very obvious that the design of 15 mm is unnecessary. Thus, for the third design of the go-kart chassis, the thickness of wall is maintained at 3.5 mm. Nonetheless, since the second design with a 3.5 mm wall thickness does not give a convincing displacement result, a series of reinforcement methods is tried and tested in the third design of kart chassis with the purpose to reduce the displacement. The figure 4-8 below shows the third design of the go-kart chassis.

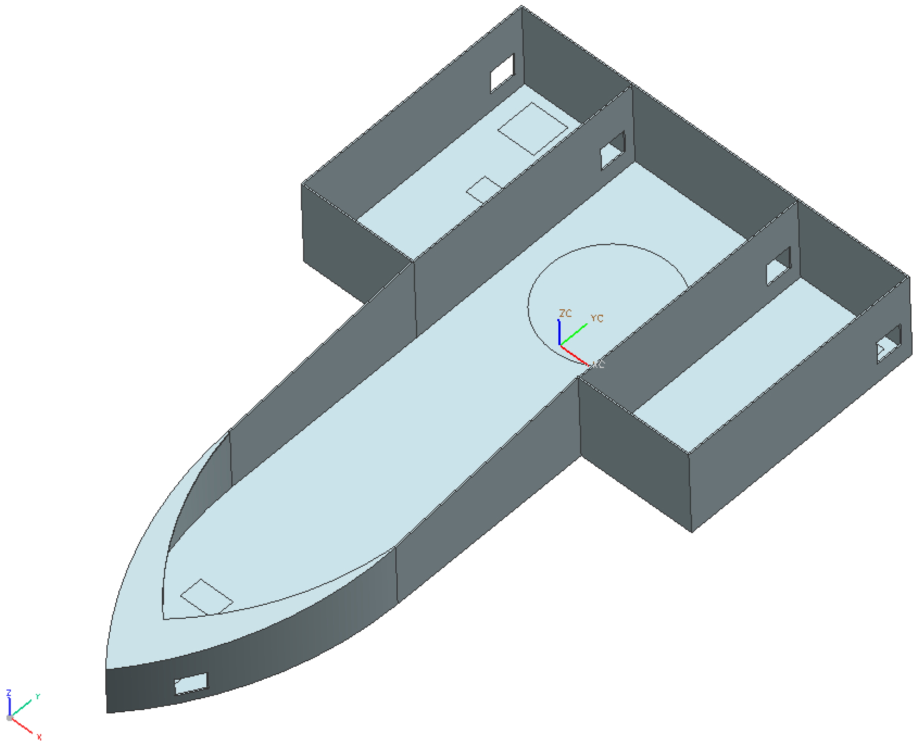


Figure 4-8: The third design of the go-kart chassis

Basically, as shown in the figure 4-8, some modifications have been done on the third kart chassis based on the model of second kart design. Thoroughly, the length of the driving cockpit is extended to provide a larger legroom to the driver and thus, a more comfortable driving condition. Besides, the front cover is further trimmed to a smaller size to ease the installation of driving mechanism such as petal, brake and etc.

Under the consideration of ease of fabrication, some curvature parts of the chassis are changed to a simple and squarish design. Nonetheless, the holes available at the both side of the kart body are removed as well. However, it is known that a sharp corner would give an increase in the stress concentration and this high stress concentration would lead to a design failure. Thus, the effect of these eliminations would be examined in the simulation of the design.

Table 4-4: Summary of the third kart chassis design

| **Pros** | **Cons** |
|---|---|
| • Extension of driving cockpit<br>• More legroom<br>• Ease of installation<br>• Ease of fabrication<br>• Simplicity of design<br>• Smaller displacement as compared to previous design | • Higher stress concentration at sharp corner |

#### 4.1.3.1 First Version of Third Kart Chassis Design

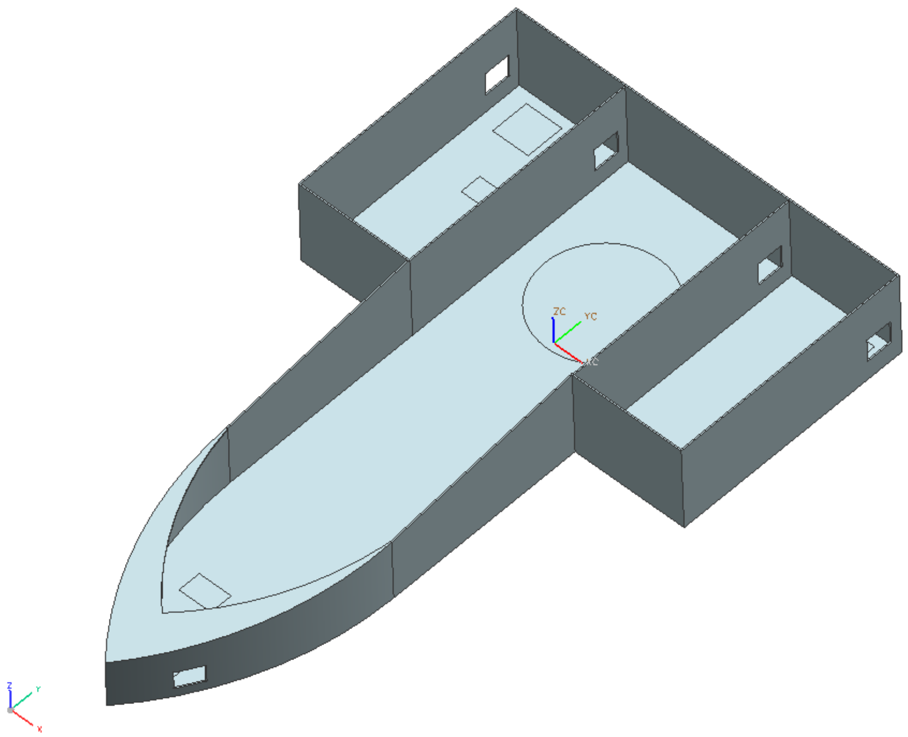

Figure 4-9: The first version of third kart chassis design

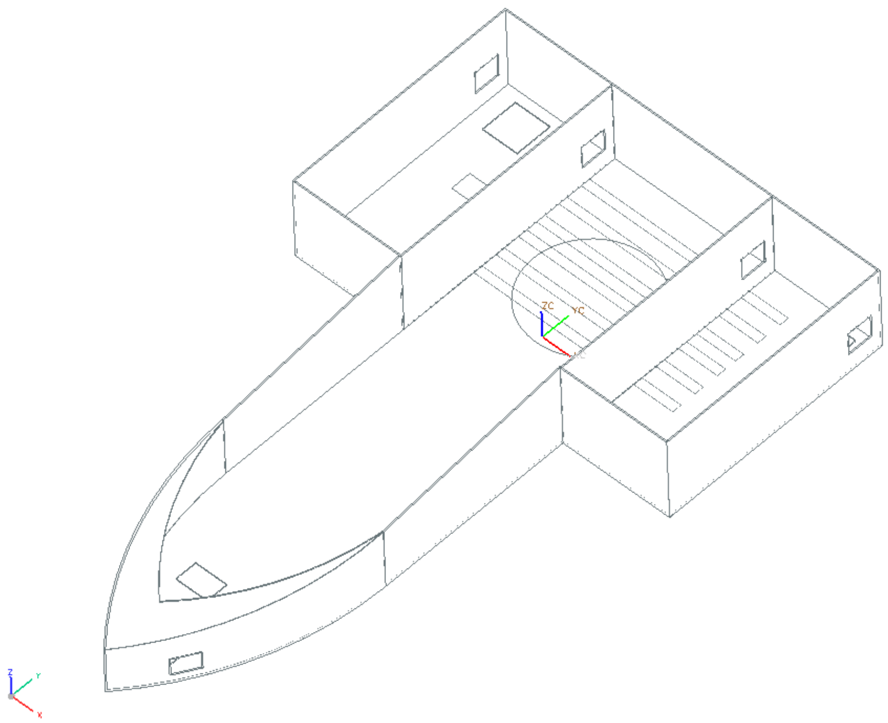

Figure 4-10: The wireframe model for the first version of third kart chassis design

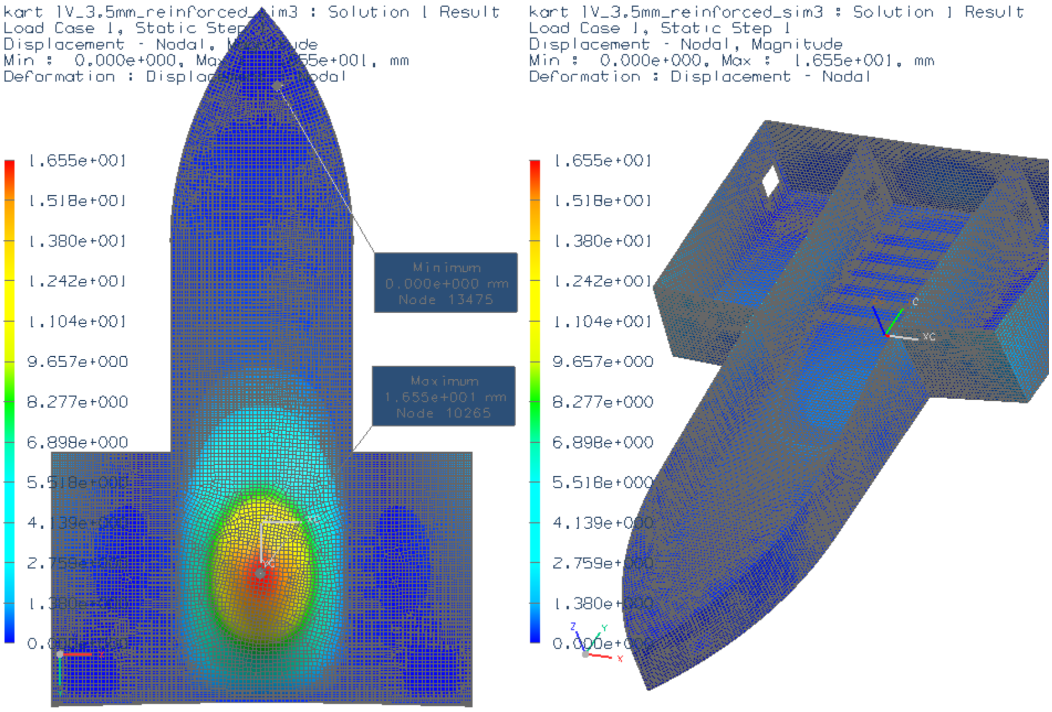


Figure 4-11: The simulation result for the first version of third kart chassis design

As shown in the figure 4-9, some fibreglass stripes have been added to the centre bottom of the chassis where the load taking is considerably the largest. This is done to strengthen the chassis by the mean of adding the thickness.

From the simulation results shown in the figure 4-11, the displacement obtained is 16.55 mm. The value is lowered as compared to the second chassis design but still higher than the desired displacement. Thus, it can be said that the addition of stripes help in the reduction of displacement and further reinforcements have to be done to improve the value. Besides, the effect of eliminations of the curvature design and removal of holes do not give a negative result in the simulation as shown. Hence, for the sake of fabrication, the eliminations are considered workable even though it might not be the same story in the practical.

#### 4.1.3.2 Second Version of Third Kart Chassis Design

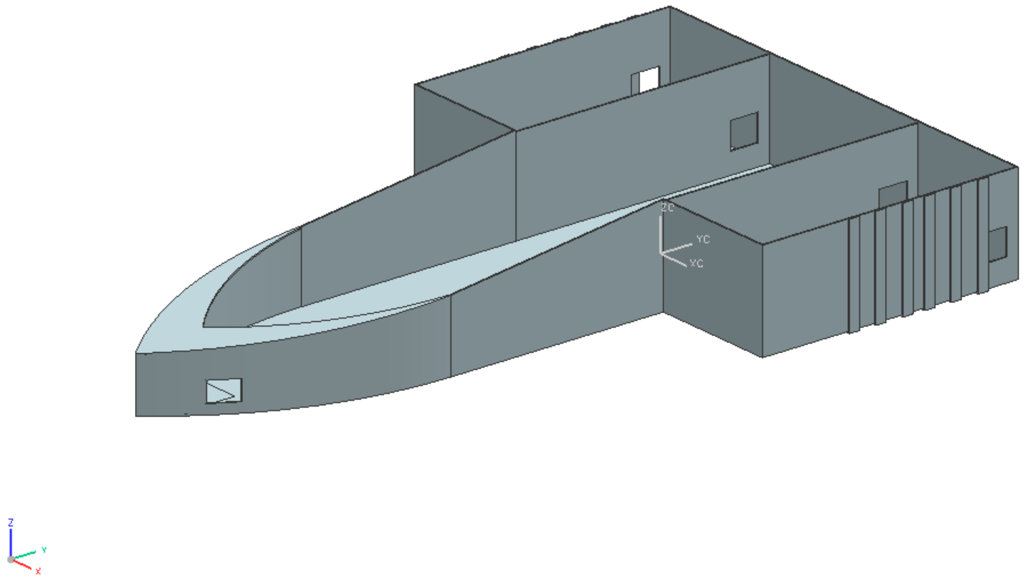

Figure 4-12: The second version of third kart chassis design

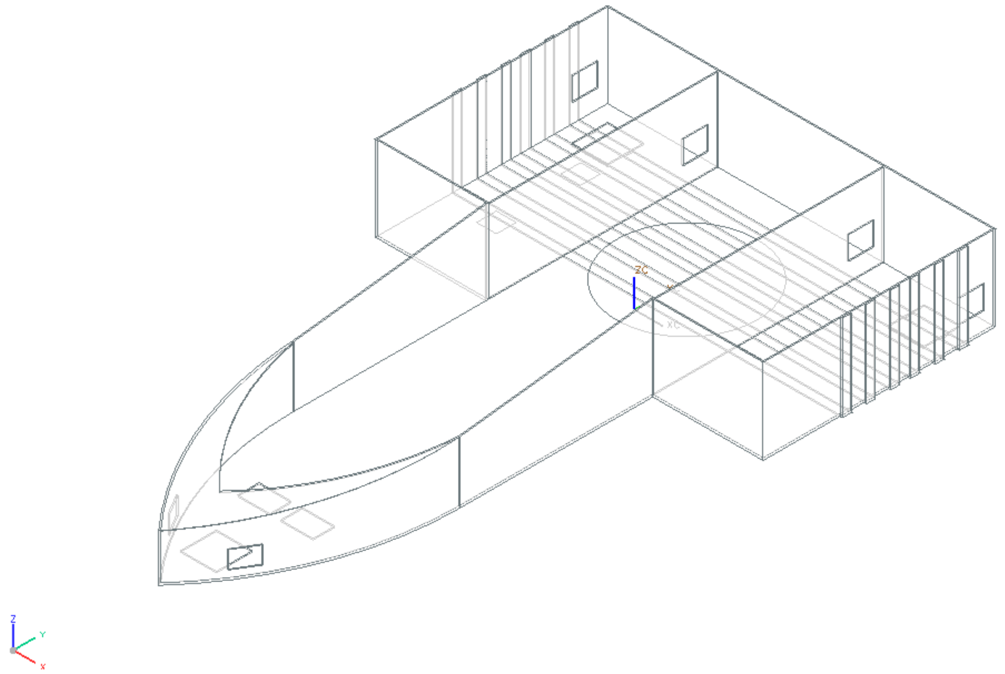

Figure 4-13: The wireframe model for the second version of third kart chassis design

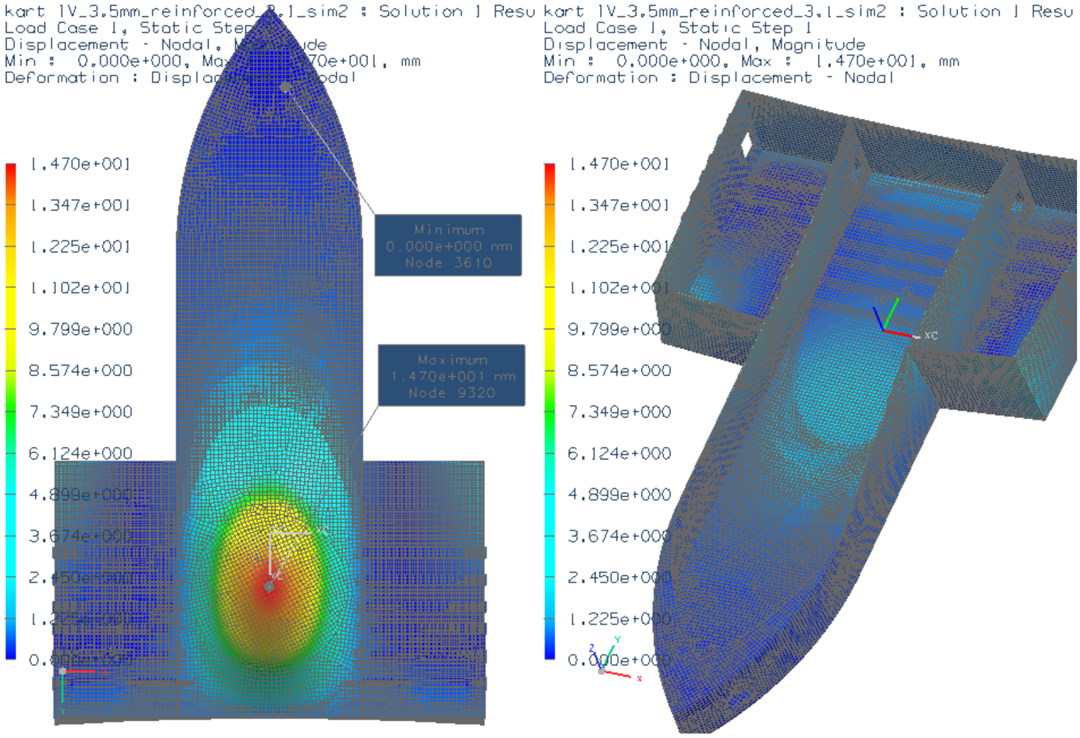


Figure 4-14: The simulation result for the second version of third kart chassis design

As shown in the figure 4-12, the length of the fibreglass stripes has been increase to the side wall of the chassis. From the simulation results shown in the figure 4-14, the displacement obtained is 14.70 mm. The value is lowered as compared to the first version of the design but still higher than the desired displacement. Thus, further reinforcements have to be done to improve the value.

#### 4.1.3.3 Third Version of Third Kart Chassis Design

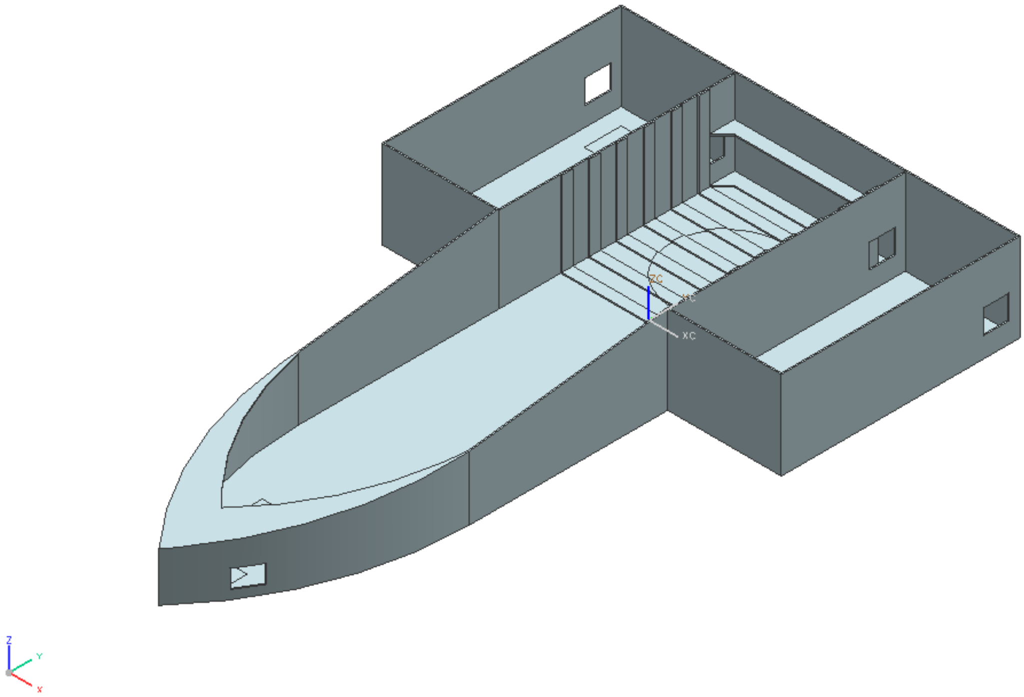

Figure 4-15: The third version of third kart chassis design

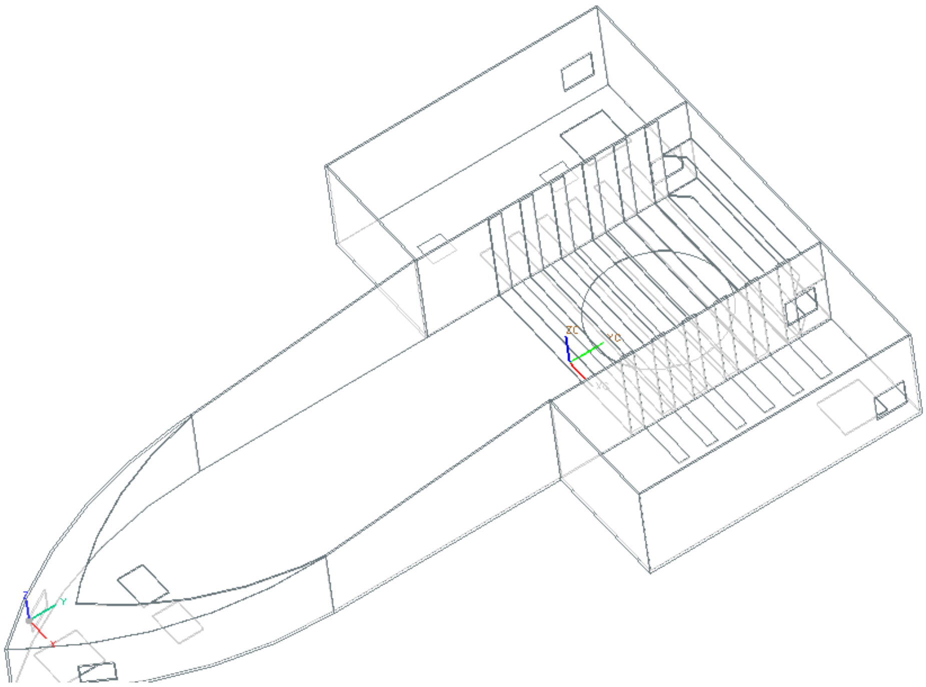

Figure 4-16: The wireframe model for the third version of third kart chassis design

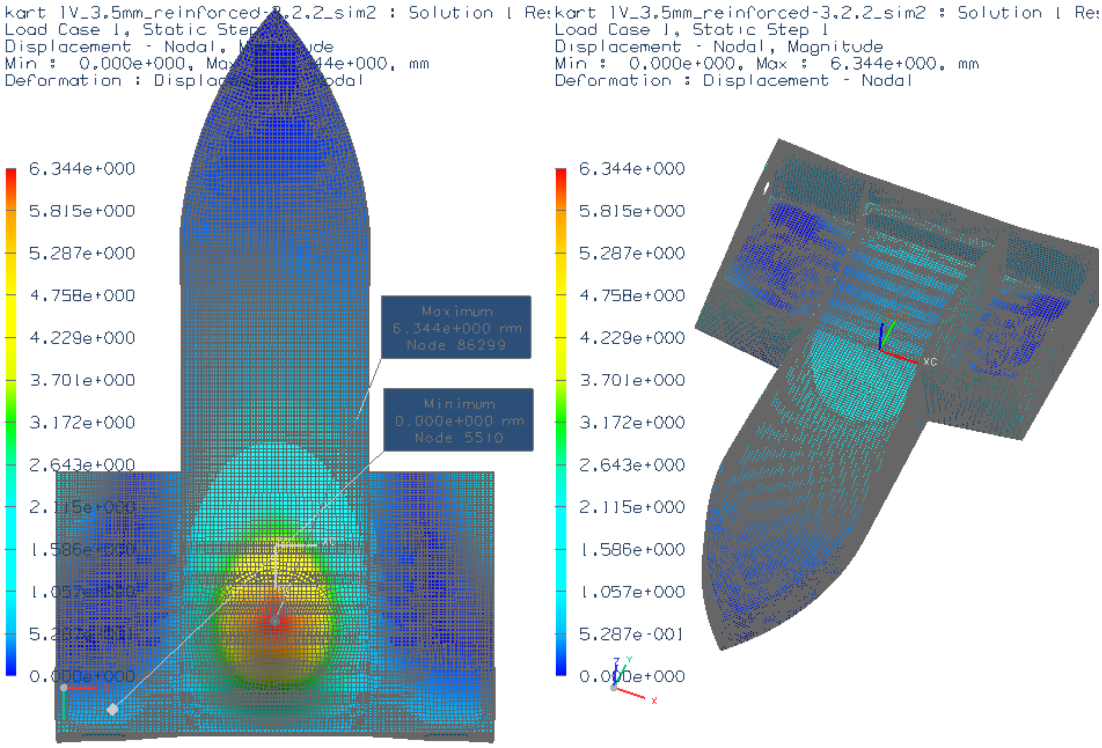


Figure 4-17: The simulation result for the third version of third kart chassis design

As shown in the figure 4-15, instead of increasing the length of the fibreglass stripes as what have been done in the second version, the stripes are added at the inner wall of the cockpit. Nonetheless, additional reinforcement stripes are added at the rear wall of the chassis as well. From the simulation results shown in the figure 4-17, the displacement obtained is reduced dramatically from the 14.70 mm in the second version of design to 6.344 mm. The value is much lowered as compared to the previous versions of the design and somehow it can be considered near to the desired value of 5.229 mm.

#### 4.1.3.4 Forth Version of Third Kart Chassis Design

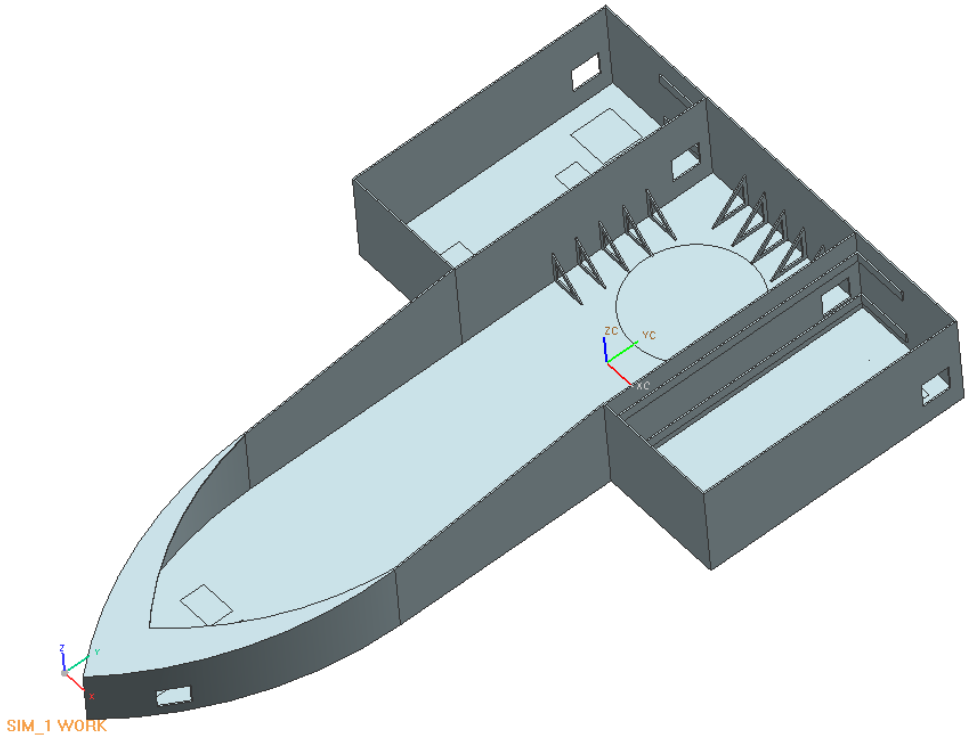


Figure 4-18: The forth version of third kart chassis design

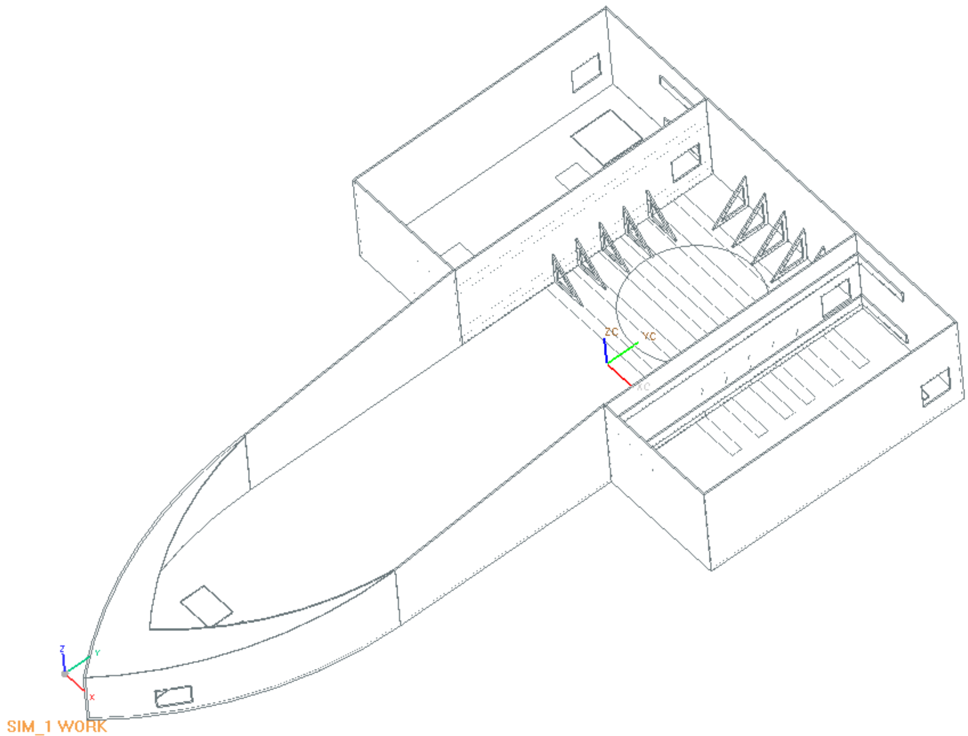


Figure 4-19: The wireframe model for the forth version of third kart chassis design

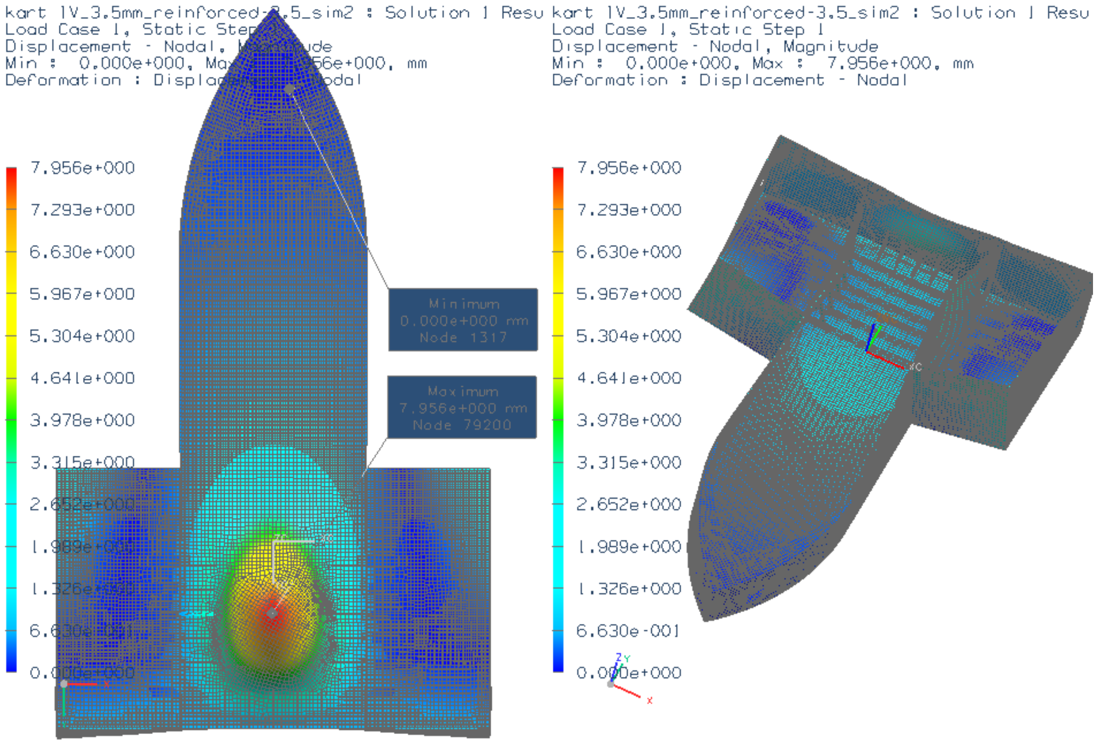


Figure 4-20: The simulation result for the forth version of third kart chassis design

As shown in the figure 4-18, a new type of reinforcement is introduced. The triangular type of reinforcements is implemented at the inner wall of the cockpit and two stripes are added at the outer wall of the driving cockpit. From the simulation results shown in the figure 4-20, the displacement obtained is 7.293 mm. The value obtained is lowered as compared to the previous version of the design except the third version. Regardless of this, the displacement obtained is still higher than the desired displacement. It is worth to mention that the structure of the triangular type of reinforcement might cause a potential issue to the placement of the other components in a kart such as the rear driving axle. Thus, further reinforcements have to be done to improve the design.

#### 4.1.3.5 Fifth Version of Third Kart Chassis Design

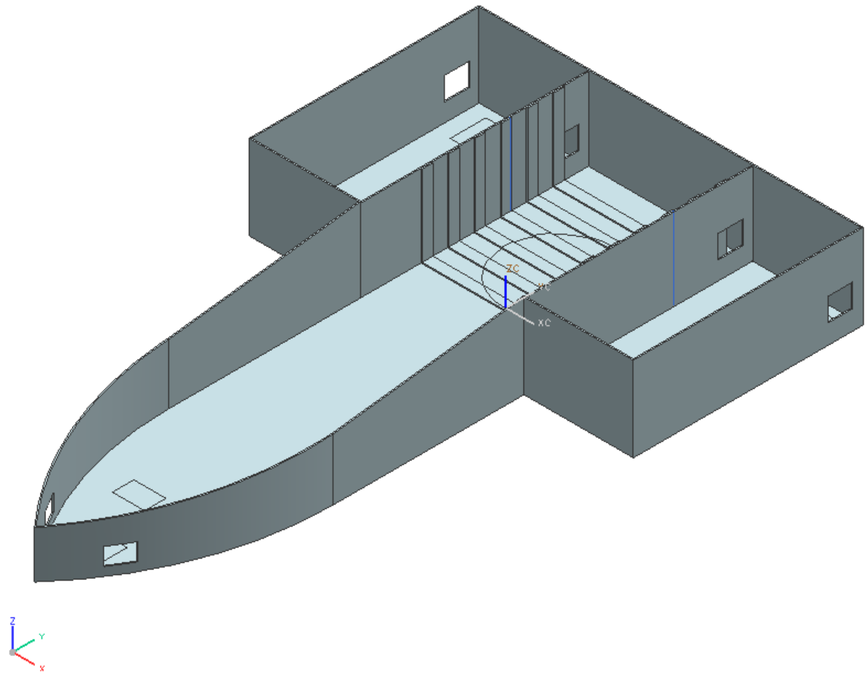

Figure 4-21: The fifth version of third kart chassis design

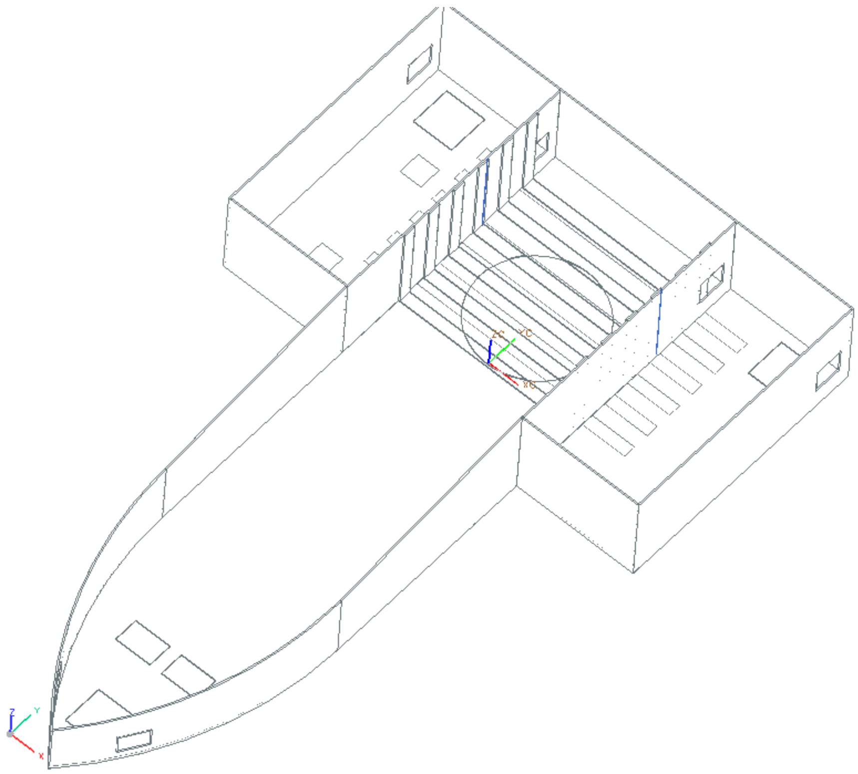

Figure 4-22: The wireframe model for the fifth version of third kart chassis design

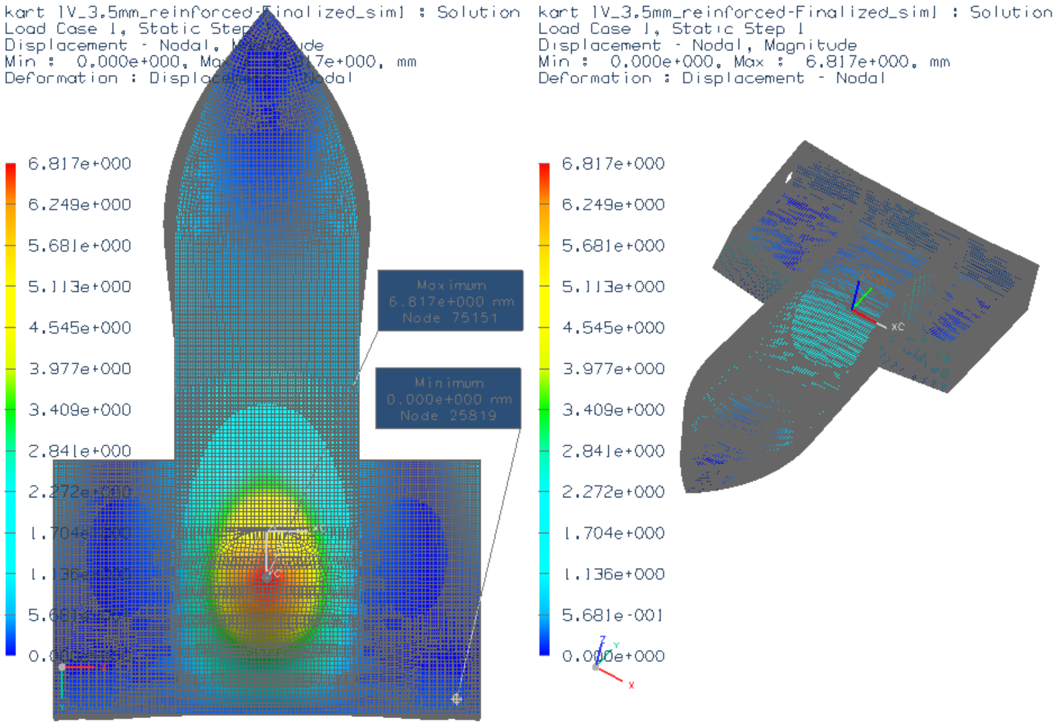


Figure 4-23: The simulation result for the fifth version of third kart chassis design

As shown in the figure 4-21, the stripes are added at the inner wall of the cockpit only. This version of design is actually a simplified design from the other versions. Besides, the front cover is removed to test the effect on the displacement value. From the simulation results shown in the figure 4-23, the displacement obtained is 6.817 mm. The value is lowered as compared to the previous versions of the design except the third version. However, the ease of fabrication on the reinforcement is the highlight point of this design. Nonetheless, a simulation has been carried out on this version of design to test its torsional stiffness and deflection when it is under loading.

Table 4-5: Table of force, displacement and torsional stiffness

| **Force (N)** | **Displacement (mm)** | **Torsional Stiffness (Nm/deg)** |
|---|---|---|
| 150 | 34.29 | 12.25 |
| 300 | 68.57 | 12.34 |
| 450 | 102.9 | 12.48 |
| 600 | 137.1 | 12.69 |
| 750 | 171.4 | 12.97 |

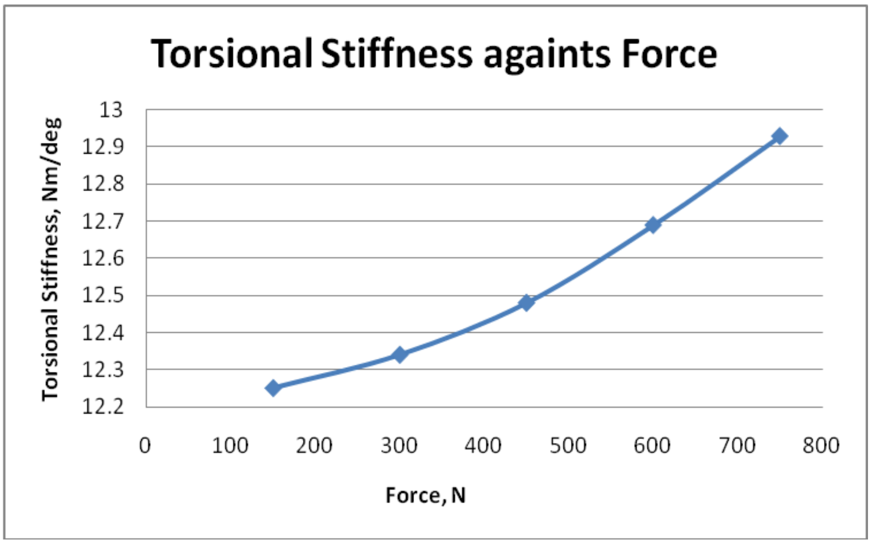


Figure 4-24: The graph of torsional stiffness against force

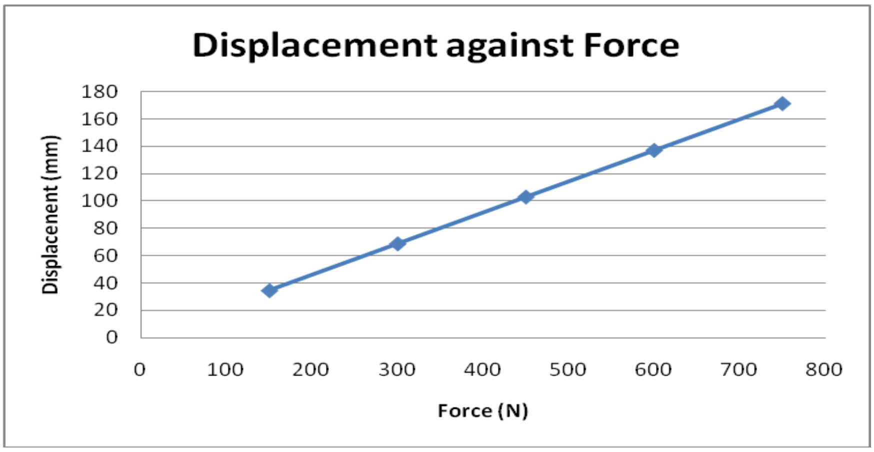


Figure 4-25: The graph of displacement against force

From the figures above, it is obvious that the torsional stiffness and the deflection on the chassis are increase when a greater force are exert. This matched the trend as shown in figure 2-14. For the torsional stiffness of the chassis, it shows an increasing trend. As stated by Liang, Yu and Wu (2007), in a real kart, the torsional stiffness of a go-kart can be controlled through the positioning of extra members and the adjusting of the width in between the two kingpins. Nevertheless, a torsional bar is always added to alter the torsional stiffness of a kart. Thus, it is believed that the torsional stiffness of kart, when comes to a point, can be altered accordingly to suit with the different driving condition.

#### 4.1.3.6 Summary of Third Kart Chassis Design

Basically, there are five different versions in the third design of the go-kart chassis. Each of them is different in the mean of reinforcement used. The table 4-6 below shows the displacement result obtained for each version of design.

Table 4-6: Summary of the displacement obtained for each version of design

| Design | Displacement (mm) |
|---|---|
| Version 1 | 16.55 |
| Version 2 | 14.70 |
| Version 3 | 6.344 |
| Version 4 | 7.293 |
| Version 5 | 6.817 |

Obviously, the third version of design has the lowest displacement when it is loaded with a load of 70 kg. The next would be the fifth version. As the ease of fabrication is one of the consideration when comes to a design, the fifth version of design would be the choice. Thoroughly, the reinforcement used in the fifth version can be considered as a simpler design yet do not sacrifice the bending rigidity of the chassis. The displacement obtained is slightly higher than the second version of design and of course the desired displacement of 5.229 mm. However, as for the go-kart, the chassis is actually acts as a suspension as well. Given a same loading, the lower bending deflection does not always represent a good design. A lower bending deflection could give a higher stiffness of the body. In the case of go-kart, high stiffness would result in a bumpy ride when it comes to an uneven road.

Thus, the fifth version of the third kart chassis design is chosen as the design to build out the prototype model. Refer to appendix E for the dimension of the design.

## 4.2 Fabrication of Go-kart Chassis

### 4.2.1 Fabrication Process of Go-kart Chassis

Prior to the discussion, it is worth to inform that the type of fibreglass used in this project is the E-glass chopped strands mat and the resin used is the polyester resin. The moulding materials used in this project is plywood and polystyrene foam. The polystyrene foam is used to form the curvature of the kart. The figure 4-26 and figure 4-27 below shows the moulding for the go-kart chassis prototype.

Figure 4-26: The plywood moulding of the go-kart

Figure 4-27: The polystyrene foam moulding that form the curvature part of the kart

Subsequently, a layer of release agents is supposed to be applied onto the surface of the mould to ease the removal process upon the completion. However, the adhesive tape which has a much lower cost is used to replace the release agent. The figure 4-28 below shows the complete mould for the outer part of the kart chassis before proceed to the layering of fibreglass.

Figure 4-28: Completed mould

The hand lay-up method is used in this project and the fibreglass together with the polyester resin was applied layer by layer until the targeted number of layers was achieved. The prototype was allowed to be cured before the removal of mould.

Figure 4-29: Layering of fibreglass

After the removal of the mould, the inner part of the chassis is fabricated. The processes mentioned above were repeated. The figure 4-30 shows the moulding of the inner part.

Figure 4-30: Moulding of the inner wall

Upon the completion of the basic structure, the reinforcement strips as shown in the figure 4-31 were layered to the centre area of the kart where the force is considered to be the largest as mentioned in the section 4.1.3 above.

Figure 4-31: The reinforcement stripes on the chassis of the go-kart

### 4.2.2 Highlighted Issues during the Fabrication Process

Throughout the fabrication process, some problems have been encountered. First would be the using of polystyrene foam as the moulding material. As the setting resin generates heat, the polystyrene foam would be damaged, hence, produced a poor surface finish. This is shown in the figure 4-32 in the Besides, even though a proper mixing ratio of resin to hardener has been set, the gel time are still not stable due to the surrounding temperature of the workplace. For example, in hot weather day, the resin could become very sticky after the hardener has been mixed into.

Figure 4-32: The damage caused on the polystyrene foam

Nevertheless, it is found out that the fibreglass mat used did not have the same thickness. This is shown in the figure 4-33 in the following page. Some areas of the fibreglass mat are thinner and contain lesser amount of chopped fibre strands. This could affect the strength of the structure if the area is considerably large.

Figure 4-33: Inconsistency in the thickness of the fibreglass mat

Besides, due to the hand lay-up method, air bubbles are formed easily when the layered fibreglass is brushed with the resin. The air bubbles that trapped inside tend to cause the porosity of the structure and hence, affect the strength of the structure. It is found out that the air bubbles are hard to be removed if the hand lay-up method was to be used. Besides, the design of sharp edges is believed to be the reason for this issue as well. The figure 4-34 shows the severity of the air bubbles.

Figure 4-34: The air bubbles trapped inside the body of the chassis

## 4.3 Comparison between Experimental and Simulation Data

An experiment has been carried out after the prototype of the go-kart chassis is built. The objective of the experiment is to verify the accuracy of the displacement obtained experimentally as compared to the simulation result. A set of dial gauges has been used to obtain the displacement of the chassis. The figure 4-35 below shows the configuration of the experiment.

Figure 4-35: The strain gauge used to obtain the displacement reading

The experiment is done on different points on the chassis and the percentage of difference between the simulation data and experimental results is calculated. The position of the points tested is measured during the experiment and subsequently the points are plotted in the CAD drawing to ensure the position is exactly the same with the experiment. The figure 4-36 in the following page shows the points tested during the experiment.

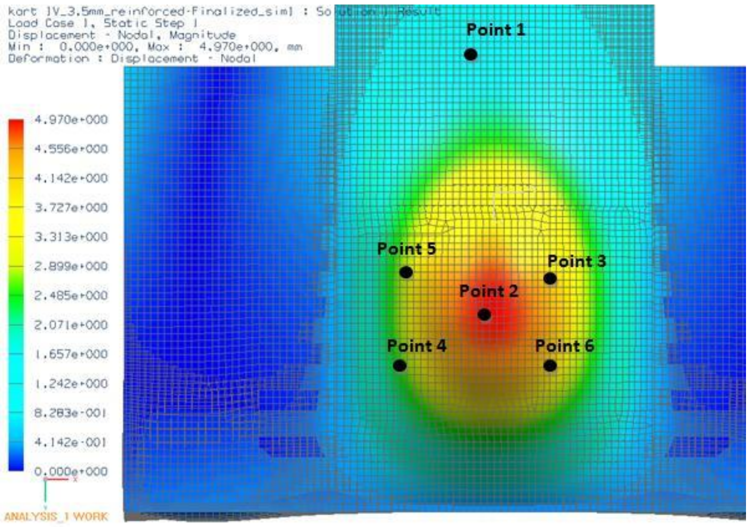


Figure 4-36: Points taken during the experiment

The results obtained are as shown below;

Table 4-7: Percentage difference between experimental displacement and simulation data

| | **Displacement (experimental), mm** | **Displacement (simulation), mm** | **Difference, mm** | **Percentage of Difference, %** |
|---|---|---|---|---|
| **Point 1** | 5.93 | 1.657 | 4.273 | 257.88 |
| **Point 2** | 6.21 | 4.970 | 1.240 | 24.95 |
| **Point 3** | 5.49 | 4.142 | 1.348 | 32.54 |
| **Point 4** | 3.97 | 2.899 | 1.071 | 36.94 |
| **Point 5** | 4.44 | 3.313 | 1.127 | 34.02 |
| **Point 6** | 4.66 | 3.727 | 0.933 | 25.03 |

Remarks: The percentage difference is obtained by dividing the difference in between the two results by the displacement as in simulation and multiplies by 100 %.

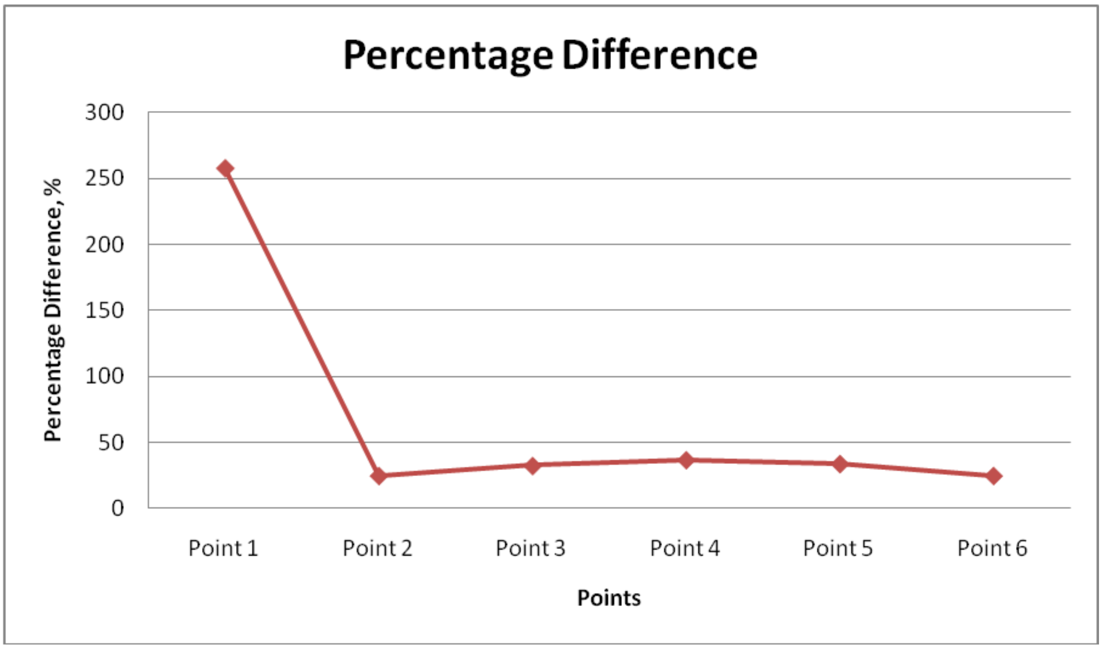


Figure 4-37: The graph of percentage difference for each of the points

As shown in the figure 4-37 above, the result for point 1 is obviously an outlier as the value is differed much from the other points. If the point 1 is taken into consideration, the average percentage difference obtained would be 68.56 % which is considerably large. However, if the point 1 is excluded from the calculation, the average percentage difference obtained is about 30.7 %.

The reasons for the outlier point could be the human mistake when the reading of the gauge is taken. Moreover, the points 1, 3 and 5 are actually obtained from a same dial gauge and it can be seen that two out of three points obtained have a larger percentage difference as compared to the others. Thus, it is suspected that there is a possibility of dial gauge error.

## 4.4 Cost of Fabrication

Since the objective of this project is to develop a low cost fibreglass go-kart, the cost would definitely be a concern. The fibreglass composite material used is in the lowest price range. An example could be the polyester resin. It costs about RM10 to RM12 per kilogram which is considerably the lowest price as compared to the other resins such as the epoxy resin which could costs about RM40 per kilogram.

It is found that the overall cost to fabricate a fibreglass go kart chassis in this project is about RM500. The fabrication cost includes the cost of material and the tools and equipments as well. As mentioned in the section earlier, the cost to buy a kart in Malaysia could simply costs around ten thousands ringgit. Hence, it can be seen that the fabrication cost of this project is relatively cheap even though the cost involved is only for the chassis.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

Basically, the objectives of the project are achieved. A go-kart chassis is built by using the fibreglass composite material and this fibreglass made go-kart chassis has been simulated and tested by experiment in term of its bending deflection and torsional stiffness. The cost implied is adequately suits with the project's objective as the use of materials such as the polyester resin is at the lowest price range. Although the design of the go-kart chassis done in this project could not be considered fully utilized the properties or strength of the fibreglass composite material, it can be said that the performance in the mean of bending displacement gives a positive representation that the fibreglass composite material is suitable to be used as the building material of a go-kart chassis.

As for the design that has been prototyped in this project, there are actually a number of rooms for improvement that can be done. However, due to the timeframe provided, the improvements done are actually limited. Thus, further study would be required in order to maximize the design and the application of fibreglass materials. Nonetheless, from all the designs and studies that have been done, it can be concluded that a go-kart chassis need not to be in the conventional tubular form. One of the significant advantages of the application of fibreglass composite materials is the design flexibility. Thus, by continuingly carry out the testing and researching in the design of the go-kart chassis, an innovative and creative chassis can be developed while optimizing the performance of the go-kart at the same time.

## 5.2 Recommendations

From the very beginning of the process, the selection on the type of material used is very crucial to the entire project. As in this project, since the fibreglass composite material is chosen as the material used, the selection would be largely on the types of fibreglass used. Instead of the chopped strands mat that has a random pattern, it is recommended to use the unidirectional fibreglass such as the roving strands, woven roving and etc. By doing this, the orientation of the fibreglass can be manipulated with and thus, maximizing the properties of the fibreglass material. Nevertheless, epoxy resin is definitely at a higher rank than the polyester resin and it is applied in most of the automotive applications. If the cost is not the focus of a project, it is recommended to apply the epoxy resin.

Besides, moulding is the vital part when comes to the application of fibreglass composite materials. Thus, a more versatile moulding material should be used in order to have a more sophisticated design. As in this project, the design that involved curvature part is hard to be implemented as the fabrication of the part is definitely more difficult and the radius of the curvature is hard to be controlled by using the moulding material like plywood. Thus, by resolving the moulding issue, a design with sharp edges could be reduced which could in turn decreased the stress concentration of that area and reduced the possibility of air trapped.

Nevertheless, it is noticed that the hand lay-up method used in this project could invoke the issue of inconsistency while layering the fibreglass and this could lead to different thickness obtained in a body. Thus, it is recommended that a more machine dependant method should be used to replace the hand lay-up method.

In this project, the chassis is designed in an open chassis style. Since the application of full covered chassis is very common in the racing industry, it is recommended that a go-kart design with a fully covered chassis can be carried out. Besides, since a torsional stiffness for a go-kart is always not known or not revealed by the manufacturer, an onsite testing should be carried out in order to help in the verification of the design.

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# APPENDICES

## APPENDIX A: History of Go-Kart

The first go-kart was invented by Art Ingels in 1956. The kart was simply built by simple-structured frame, small engine and wheels. Thoroughly, the kart built by Art Ingels was framed by rugged tubular chassis with the West Bend 2-stroke engine mounted on a set of semi-pneumatic tyres. This combination was simple yet sustainable to the body weight of Art Ingels which was around 100 kg. Accordingly, this has provided a basis for the design of go-kart in the future invention.

The achievement of Art Ingels has drawn the attention on this miniature racing vehicle from the people around him. In the year of 1958, an American company, Go Kart Manufacturing Co. became the first go-kart manufacturer. Nevertheless, the involvement of McCulloch in the go-kart engine business in 1959 has made the McCulloch became the first company to produce engines for karts. The first engine created by McCulloch was the McCulloch MC-10. It was designed through the modification of a chainsaw 2-stroke engine produced by McCulloch.

In the 1960s, the kart racing has spread widely in Europe countries. As a result, more engine manufacturing companies were established in Europe rather than in America. The most significant evolution at this period was the application of motorcycle engine in go-kart. Furthermore, during the 1970s, the modern design of go-kart came into force. The engines were placed at the side of the seat instead of the position at the rear in the earlier design. Due to this change, the cooling of engines was more effective as the increase of air flow to the engines. Besides, more legroom was provided through this change.

# APPENDIX B: Chassis

In the earlier design of go-kart chassis, the stiff chassis with shorter bars that crossed over each other is always utilized by the manufacturers. This kind of chassis would experience break down easily as the go-kart is more likely to turn stiffly at the corners. As the time evolved, the longer bars are used for the chassis. This provides more flexibility for the go kart to deal with different kind of track surfaces.

According to Tsavo Media Canada (2008), the chassis of a go-kart can be categorized into open, caged, straight and offset. However, only the karts with open and straight chassis are approved by the CIK-FIA. An open kart is the most popular karts used and it does not have roll cage. For a caged kart, it comes with a roll cage that surrounds the drivers and it is always used on the dirt tracks. In the kart with straight chassis, drivers are sitting at the middle of the kart while the seat is located at the side for a kart with offset chassis.

The types of chassis for a go-kart used are often decided according to the requirements and condition of the track. Stiffer chassis is usually used in the dry condition while a more flexible chassis is preferable in the wet and poor traction condition. Nowadays, the application of stiffening bar has gained its popularity due to its ability to adjust the stiffness and flexibility of the chassis.

Generally, there is no differential for a go-kart. According to Nice (2000), the differential is a device made up of different gears and it allows each of the driving wheels to rotate at various speeds. The effects of differential are significantly shown in the turning or cornering.

As mentioned earlier, the rear axle of the go-kart is stiff and both rear wheels will always be forced to turn at the same speed. This would make turning more difficult to be done and increases the chance for the occurrence of slipping or skidding. In order to solve this issue, one of the rear wheels needs to be slide when going in the turn. Therefore, the chassis is designed in the way that the rear wheel can be lifted up slightly to ensure a smooth and safe cornering.

# APPENDIX C: Advantages and disadvantages of fibreglass

The versatility and cost-effectively are namely the most common used terms to describe the application of fibreglass in the industry. Nowadays, composite materials are largely being employed into many applications such as automotive, marine, construction, leisure and many others.

Due to the growing requirements on the specific performance and the cost consciousness, the flexibility of fibreglass composite as a reinforcement material has helped the industry in achieving the continuous improvement. There are many benefits of fibreglass is term of its mechanical and chemical properties, physical properties, durability and cost.

Fibreglass is a lightweight and strong material. It has a superior tensile strength as compared to other manufacturing materials such as steels, plastics, and etc. The high strength to weight ratio can be considered as the most attractive aspects of fibreglass. Besides, the high chemical resistance is another highlight for fibreglass. It will not react chemically with the other substances and the potential hazardous situations that arise with the other materials could be avoided.

Nevertheless, fibreglass has an excellent corrosion resistance as it will not deteriorate with the environmental extremes. This provides the fibreglass a longer life expectancy as compared to the other materials. In another word, the durability of the fibreglass is much higher and the cost for maintenance could be lowered.

Moreover, the high dielectric strength is another advantage of fibreglass. This characteristic means that the fibreglass is a non-conductive material and this makes the fibreglass an ideal insulating material. It suits the application where the metal housings or frames can effects the electronic performance. Besides, fibreglass has good thermal properties as well. Fibreglass is incombustible as the fibres retain nearly 50 percent of their strength at the temperature around 380 degrees Celsius.

Another advantage of fibreglass would be the design flexibility. Fibreglass can be tooled and fabricated into different shapes according to the design requirements. A complex shape of design could be achieved easily with the minimal effort. Besides, fibreglass is affordable and cost effective for many applications. As compared to the other reinforcements, fibreglass provides a high performance composite with the lower cost. Another unique attribute of the fibreglass is the high internal damping. This helps to reduce the transmission of vibration and noise by having a better absorption of vibration energy.

Nevertheless, dimensional stability is another attractive aspect of fibreglass. The possibility for the occurrence of contraction and expansion due to the heat or stress applied is low. Thus, the fibreglass-made products would maintain a better shape under severe mechanical and environmental stresses. In addition, the fibreglass-made products have an excellent surface finish for appearance. Nowadays, the fibreglass composites can be gel coated right inside the mould to provide the desired appearance.

While for the disadvantages of fibreglass, the main focus would be the sensitivity of the fibreglass to the abrasion during the handling process. The abrasion includes the action of rubbing the fibreglass products against each other, the contact of fibreglass with the processing equipments, and etc. These activities could create a surface damage to the fibreglass-made product and tends to reduce its tensile strength. As the surface damages or flaws undergo a cyclic stress, the strength would be further decreased. Besides, the hardness of the fibreglass would cause the excessive wear and tear to the tooling equipments.

# APPENDIX D: Thermoplastic Matrix

Polyamide is a semi-crystalline thermoplastic polymer and it is one of the most common thermoplastic resins used in the fibreglass composite materials. Amide group is part of the main polymer chain in polyamides.

According to Biron (2007), semi-crystalline polymers exist as viscous liquids at the temperature above the melting point of the crystalline polymer. Hence, the term semi-crystalline is referred to the polymers that remain uncrystallized during the crystallization process upon cooling.

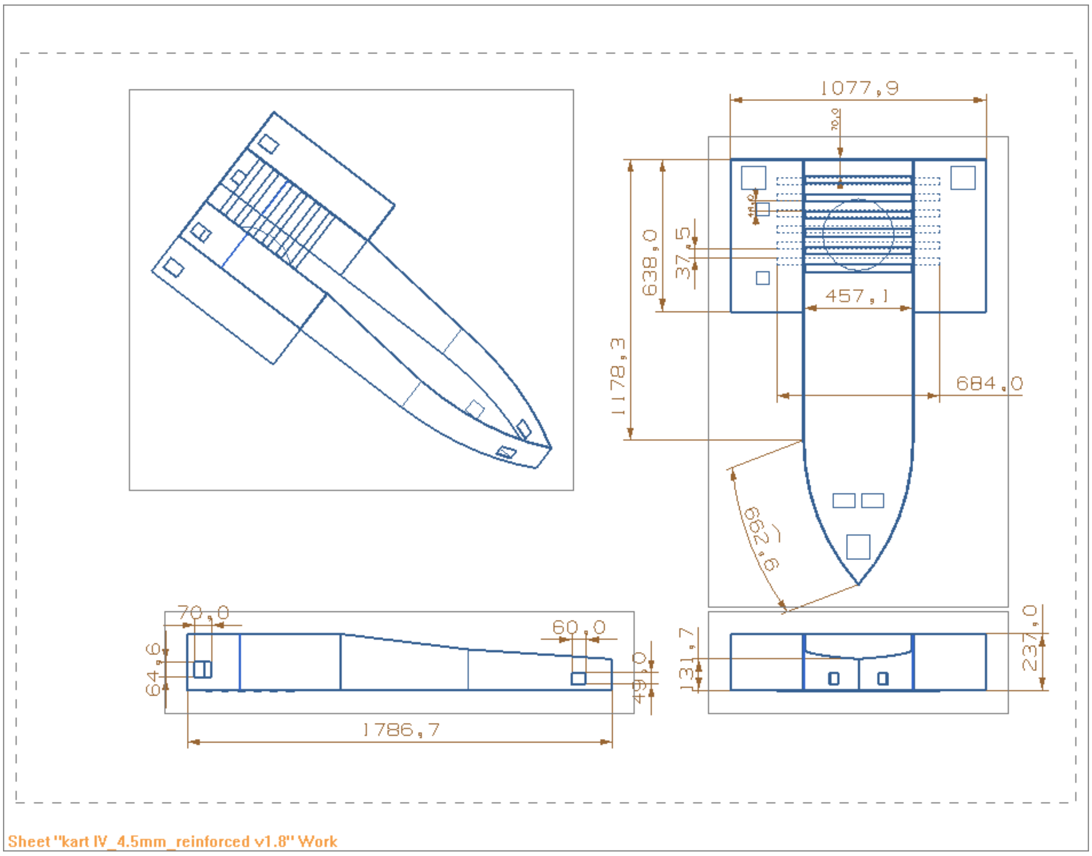
Generally, polyamide has the good mechanical properties where it is often characterized as a strong and tough polymer. Besides, polyamide has a good resistance to abrasion, fatigue and impart as well. It is always used in the application of automotive components as the performance of polyamide is still able to be maintained even at the elevated temperature. Injection moulding is the common fabrication technique used to produce fibreglass composite materials with polyamide resin.

As claimed by Tucker and Lindsey (2002), polyether ether ketone is a semi-crystalline thermoplastic polymer. It is formed by cooling the polymer slowly from its melt. If the quenching process is performed on the polymer, an amorphous polyether ether ketone is obtained. The term amorphous could be explained as formless or shapeless. Generally, polyether ether ketone offers higher fracture toughness as compared to the epoxy resin. Besides, due to the form of semi-crystalline, polyether ether ketone does not dissolve in the common solvent. Thus, it could be considered as a low water absorption polymer.

Similar to polyamide, polyphenylene sulfide is a semi-crystalline thermoplastic polymer as well. It has a wide variety of properties which consists of good mechanical strength, excellent thermal properties, good surface hardness and the lowest density among the other thermoplastic matrixes. On the other hand, some treatments and modifications of the polymer are needed to improve the poor adhesion of the polyphenylene sulfide with fibreglass materials.

According to Biron (2007), polysulfone is an amorphous resin formed by the linear condensation process from bisphenol-A and dichlorodiphenyl sulfone. It has a good mechanical strength and thermal stability. Besides, polysulfone could resist the degradation caused by the mineral acids, alkalis and salt solutions. However, the main disadvantage of polysulfone is that it required a high processing temperature which is not practical is small scale production.

APPENDIX E: Dimensions of the Fifth Version of Third Kart Chassis Design



# APPENDIX F: Ratio of Polyester Resin to Hardener

Prior to the fabrication of the go-kart, the mixing ratio of the polyester resin to hardener is determined. Few experiments have been carried out to determine the most suitable ratio that match with the fabrication conditions such as the surrounding temperature and humidity. It is known that higher ratio would results in a faster gel time. According to the definition by Net Composites (2008), the gel time is defined as the time required for the flow-able liquid resin to change to non flowing gel.

Basically, from the experiments done, the ratio is found out to be in the range of 100:1 to 100:3, which means that one to three percent of the hardener would work well with the fabrication conditions in this project. Thus, the ratio of polyester resin to hardener used was fixed at 100:1 throughout the whole fabrication process. For a clearer explanation, 1 ml of hardener is mixed with every 100 ml of polyester resin used. Besides, it is also discovered that the ratio of 100:1 would give a gel time of around 30 minutes at the room temperature.