Design & Manufacturing of Racing Go-Kart

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FINAL YEAR PROJECT REPORT

We hereby recommend that the dissertation prepared under our supervision by: Usama Nayab (01244), Abdullah Ismail (01921), Hassan Liaqat Gondal (00131) Titled: Design & Manufacturing of Racing Go-Kart be accepted in partial fulfillment of the requirements for the award of Bachelors of Engineering in Mechanical Engineering degree with (____ grade)

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Declaration

I/We certify that this research work titled "*Design & Manufacturing of Racing Go-Kart"* is my/our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Copyright Statement

Dedicated to our parents

Acknowledgments

First of all, we would thank ALLAH Almighty, who gave us knowledge and dedication to be able to complete this research.

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Abstract

The aim of our project was to make a fully functioning Racing Go-Kart to cater to the growing needs of local market with the advent of new Go-Kart tracks in Pakistan. The project scope included design of chassis according to CIK-FIA regulations and manufacturing of a fully functioning Go-Kart.

Keywords: Go-Kart, Chassis, CIK-FIA, Manufacturing, Design, Solidworks

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Chapter 1
Introduction

1.1 Background

Go-karts are small four wheeled, suspension less vehicle. Although they are commonly associated with children, especially in Pakistan, people of all ages race on go-karts. It is perceived as stepping stone to higher ranks of motor sports. It started in North America and now has a huge following in Europe, with a number of different leagues and national championships. Recently in Pakistan Go-Kart tracks have been increasing in number to cater to the growing desire of racing in the middle class. And as these tracks increase in number, so does the requirement of actual Go-Karts and their gear, which all have to be imported as none of the required equipment is manufactured in Pakistan. A fully functional Go-Kart costs around PKR 700,000 to import from abroad. Us three friends being huge fans of Go-Karting and automobiles in general saw this opportunity and decided to manufacture a Go-Kart locally with the least number of parts imported from outside the country. Thus this project aimed to address the local needs of the market by manufacturing Go-Karts locally and doing so within PKR 150,000.

1.2 Aims and Objectives

The aim of this project was not just to design but also to manufacture a Go-Kart. As we believed that there's a huge gap between academia and local manufacturing in Pakistan. Our objectives were to:

- Design a chassis in Solidworks that fulfills the requirements set by CIK-FIA
- Perform analysis on the chassis in Solidworks
- Manufacture chassis and few other parts
- Source local materials as much as we can and import the necessary parts
- Assemble all the parts into a fully functioning Go-Kart

1.3 Methodology

To achieve our goal, we divided the project into several parts. Some parts were needed to be done sequentially whereas others in parallel.

- Design of chassis
- Analysis of design
- Taking completed design to market
- Making modifications to the design according to local market realities
- Sourcing parts locally
- Ordering parts from abroad
- Manufacturing of chassis and other parts
- Final Assembly

Chapter 2
Literature Review

The Fédération Internationale de l'Automobile (FIA), which is a governing body for many auto racing events including Formula One and World Rally Championship, is also responsible for regulating international go-kart competitions. Commission Internationale de Karting (CIK-FIA) is the appointed body of FIA which handles and regulates Go-Karting competitions.

In general Go-Karts have no differential gear and suspension system. This causes the inner wheels of the kart to rise during cornering. For this reason chassis of the Go-Kart must be able to handle bending rigidity and torsional stiffness so that the handling stability can be improved and vibrations absorbed which are produced during driving. There is limited literature of research work on Go-Karts available as racing engineering is an absolute secret and tunings of Go-Kart are mainly experienced based.

As our aim was to design a chassis as per the requirements of CIK-FIA, we reviewed their technical regulations. The chassis frame is the central and supporting part of the whole kart. It must be sufficiently resistant to be able to absorb the charges produced when the kart is in motion. Following were the regulations given by CIK-FIA in their "Karting Technical Regulations 2016" manual:

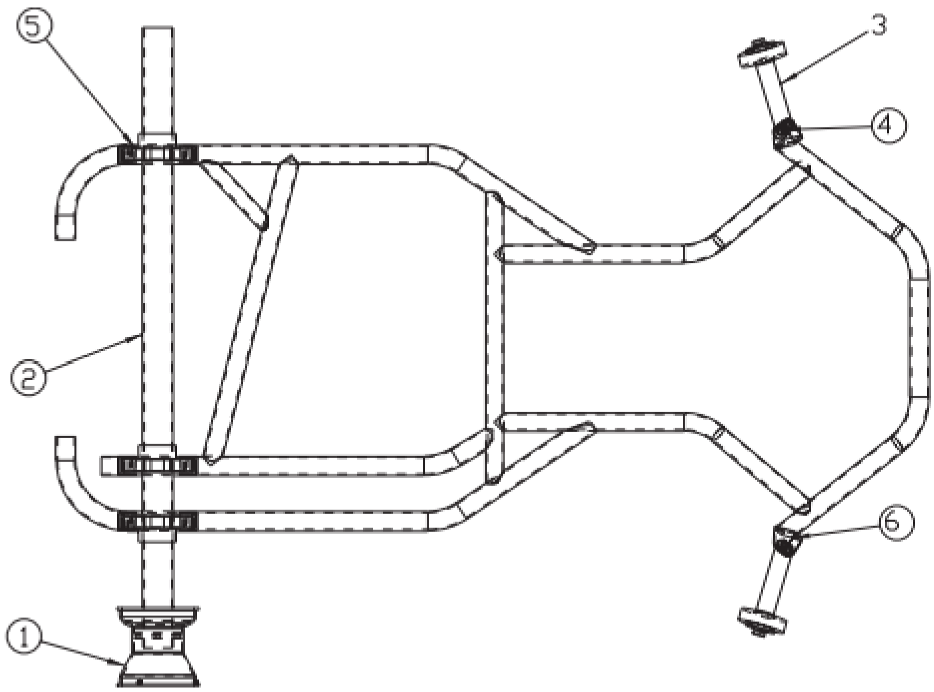
- Tubular construction with a cylindrical section. One piece with welded parts that cannot be dismounted.
- Structural steel or structural steel alloy meeting the ISO 4948 classifications and the ISO 4949 designations. Alloy steels having at least one alloy element the mass content of which is ≥ 5 % are forbidden.
- Any hydraulic or pneumatic absorbing device against oscillations is forbidden.
- All the chassis main parts must be solidly attached to one another or to the chassis frame. A rigid construction is necessary, no articulations.
- Wheelbase: Minimum 106 cm & Maximum: 127 cm.
- Track: At least 2/3 of the wheelbase used.
- Overall length: 182 cm maximum without a front and/or rear fairing.
- Overall width: 140 cm maximum.

- Height: 65 cm maximum from the ground, seat excluded.
- No part may project beyond the quadrilateral formed by the front fairing, the rear wheel protection (rear bumper) and the wheels.
- A sketch of the chassis frame and of the chassis main parts is also given in this manual and is shown in fig 1.1

DESSINS TECHNIQUES
TECHNICAL DRAWINGS

DESSIN TECHNIQUE N°1
Châssis cadre et pièces principales du châssis

TECHNICAL DRAWING No. 1
Chassis frame and chassis main parts



Légende

1	Jante
2	Arbre arrière
3	Fusée d'essieu
4	Axes-pivots
5	Supports de l'arbre arrière
6	Pièces de connexion avant

Caption

1	*Rim*
2	*Rear axle*
3	*Steering knuckle*
4	*King pins*
5	*Rear axle supports*
6	*Front connecting ports*

Figure 2.1 Sketch of Chassis

Chapter 3

Design

Using the regulations as guidelines, we made several designs on Solidworks so that we could perform analysis on them and therefore choose the best design possible.

Following designs were made on Solidworks with varying diameters and thickness:

Design # 1:

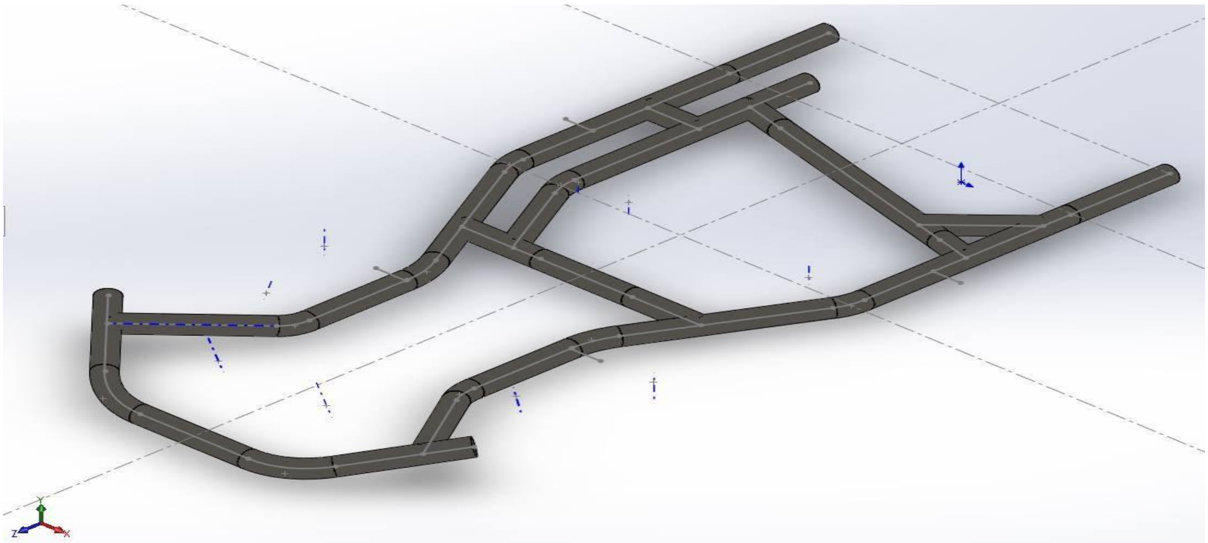


Figure 3.1

Design # 2:

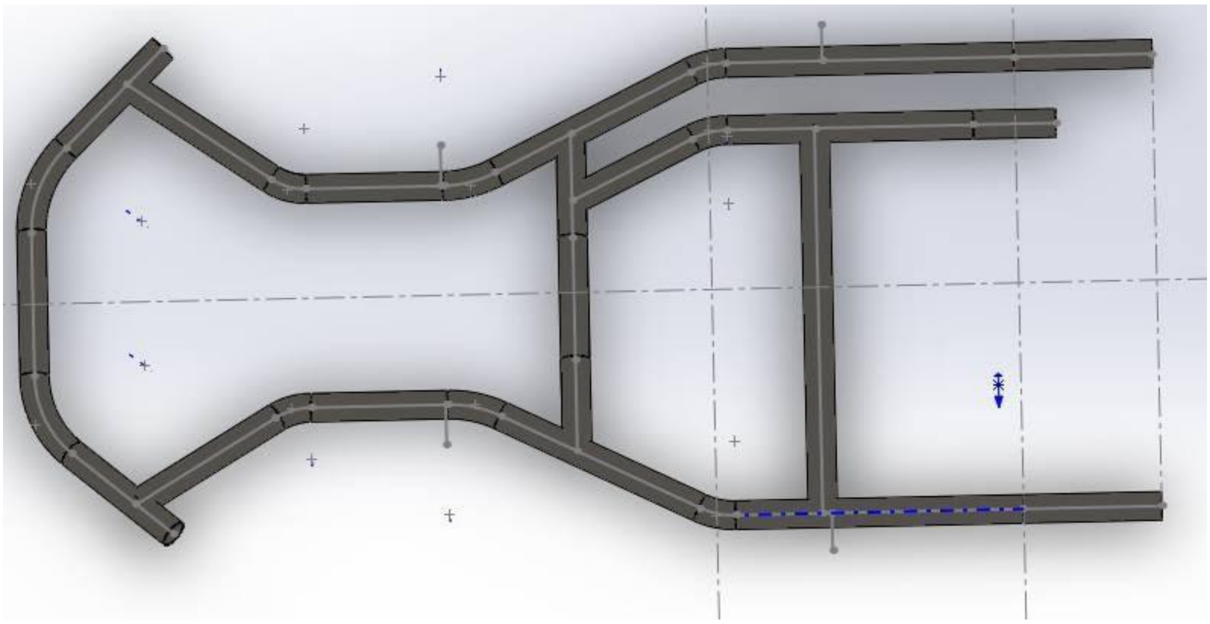


Figure 3.2

Design # 3:

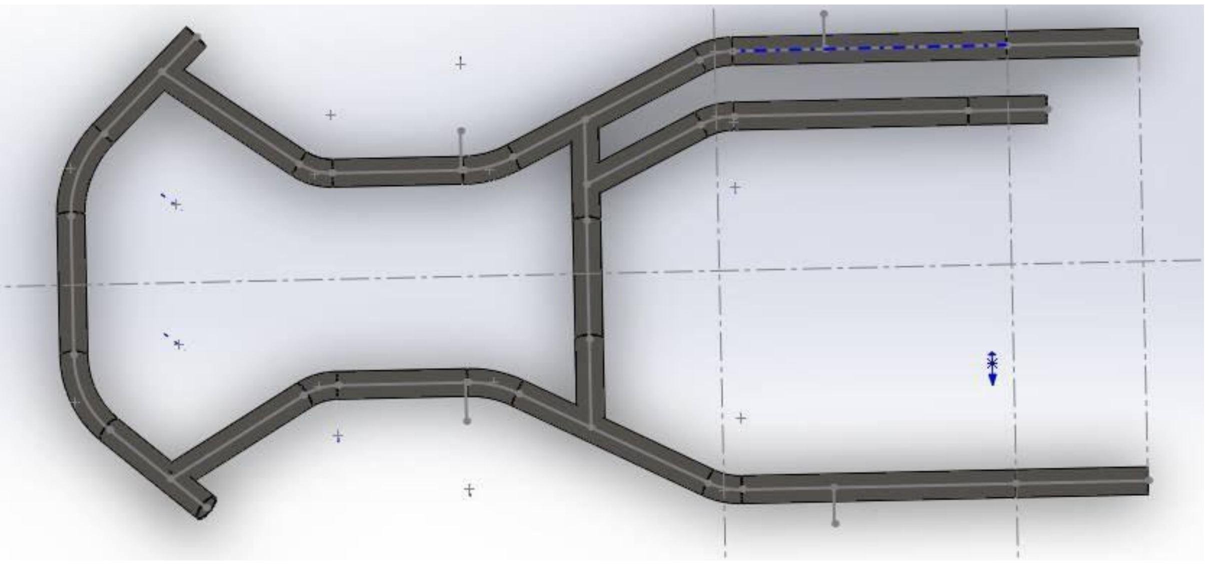


Figure 3.3

Design # 1 was selected as the final design after performing the analysis on all three designs on Solidworks. A detail of the analysis is given in the next chapter.

Chapter 4
Analysis

Analysis of two types was done on all three designs, static loading and torsional rigidity analysis. Also load calculations on rear axle were done to see if it would fail or not. But before we could do the analysis we had to select the material first and calculate the weight distribution for the main chassis.

4.1 Weight Distribution:

Before the analysis could be carried out on Solidworks it was necessary that we knew the weight distribution of the Go-Karts of our proposed designs. As the weight distribution would determine the forces acting on each tyre. And as the overall dimensions of all three designs were same the weight distribution calculated was also approximately same. Following weight distribution calculation was carried for Design # 1. Weight distribution was calculated with some approximations on the four tyres due to frame, seat, driver, engine, brakes, sprocket & tyres themselves.

1.5 Frame, Seat & Driver:

- Center of mass of frame was found to be acting at approximately the same point where the driver and seat was situated. Combined weight of 110kg was taken.
- Distance from load to rear wheels: 25 in & distance from load to front wheels: 22 in
- Distance of load from front left wheel : 10 in & distance from rear left wheel : 15.5 in

2.5 Engine & Clutch:

- Total weight of engine including clutch and transmission was found to be 30 kg.
- Distance from load to rear wheels: 22 in & distance from load to front wheels : 25 in
- Distance of load from front right wheel : 2.5 in & distance from rear right wheel : 6 in

3.5 Wheels, Brake & Sprocket:

- Front tyres with wheels weigh 3 kg each
- Rear tyres with wheels and sprocket and brake weigh 6 kg each

After calculations, weight distribution was found as follows:

	Front Right Tyre	Front Left Tyre	Rear Right Tyre	Rear Left Tyre
Frame, Seat & Driver	216.5	357.3	186.3	318.4
Engine, Clutch & Transmission	124.9	31.9	134.4	22.4
Wheels, Brake & Sprocket	29.4	29.4	58.8	58.8
Total	370.8	418.6	379.5	399.6

Table 4.1 Weight Distribution

Front to Rear weight distribution was found to be in ratio 50.3:49.7

Left to Right weight distribution was found to be in ratio 52.0:48.0

4.2 Material Selection:

According to CIK-FIA regulation the material should be structural steel or structural steel alloy meeting the ISO 4948 classifications and the ISO 4949 designations. Alloy steels having at least one alloy element the mass content of which is ≥ 5 % are forbidden.

AISI 4340 and AISI 1020 steel were considered for use. AISI 4340 was selected as the desired material due to its high yield strength and the fact that it is widely used in construction of professional Go-Kart frames. Its material properties are:

Mechanical Properties

The mechanical properties of annealed AISI 4340 alloy steel are displayed in the following table.

Properties	Metric	Imperial
Tensile strength	745 MPa	108000 psi
Yield strength	470 MPa	68200 psi
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Elastic modulus	190-210 GPa	27557-30458 ksi
Poisson's ratio	0.27-0.30	0.27-0.30

Table 4.2 AISI 4340 Material Properties

4.3 Torsional Rigidity Analysis:

Herb Adams (author of Chassis Engineering) defined torsional rigidity (actually “stiffness” in his 1993 publication) as it applies to a vehicle’s chassis as “how much a frame will flex as it’s loaded when one front wheel is up and the other front wheel is down while the rear of the car is held level”. This condition occurs at cornering. So it is important that the chassis doesn’t fail in cornering. To model this, points of rear wheels were fixed and opposite forces applied on the front wheels according to weight distribution to see the resulting effects.

Following figures show the test results:

<u>Design # 1:</u>

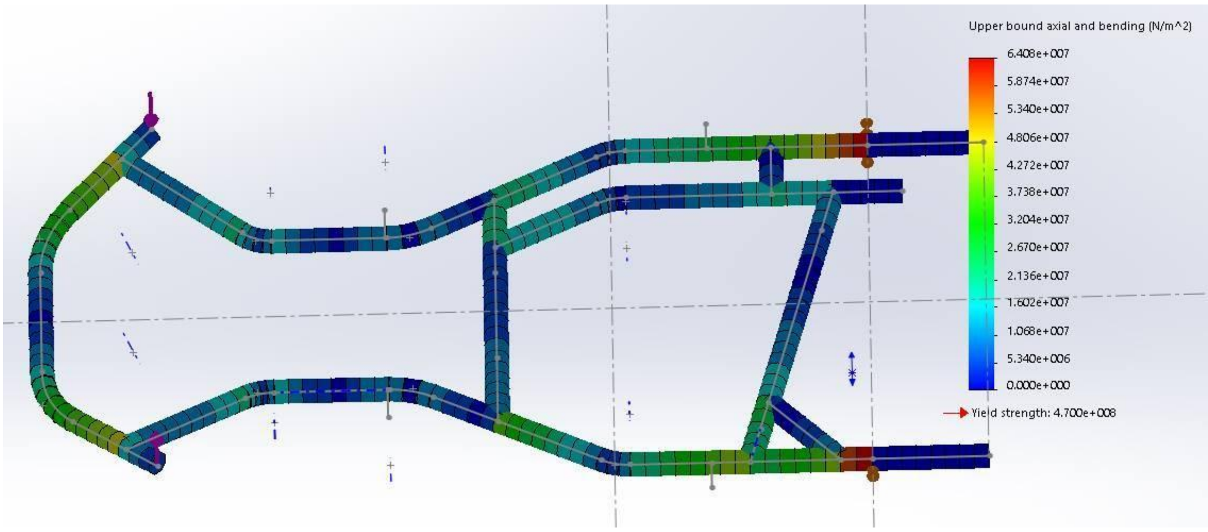


Figure 4.1 Torsional Rigidity Analysis on Design # 1

Design # 2:

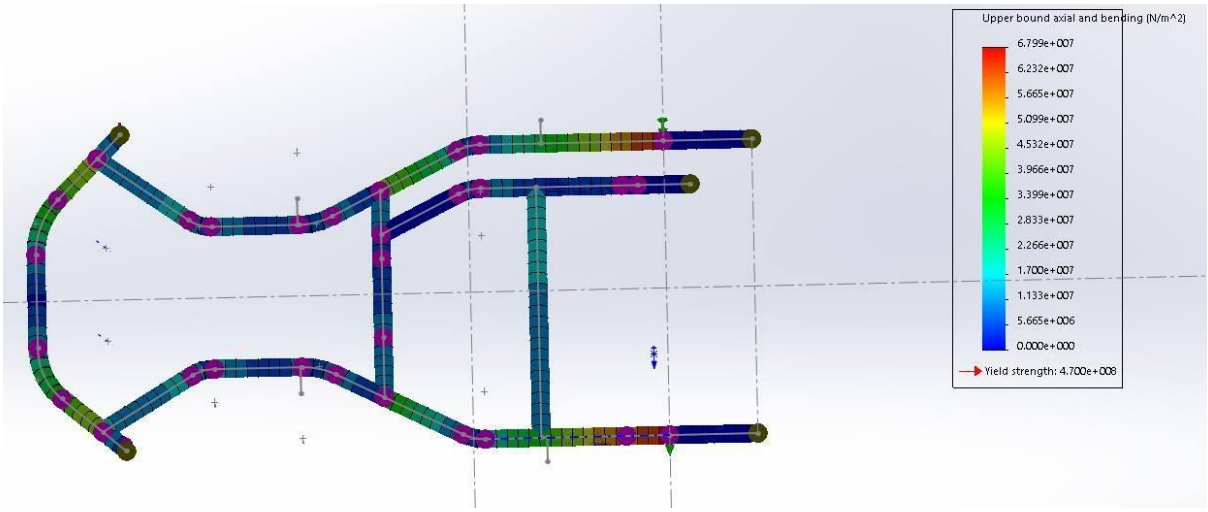


Figure 4.2 Torsional Rigidity Analysis on Design # 2

Design # 3:

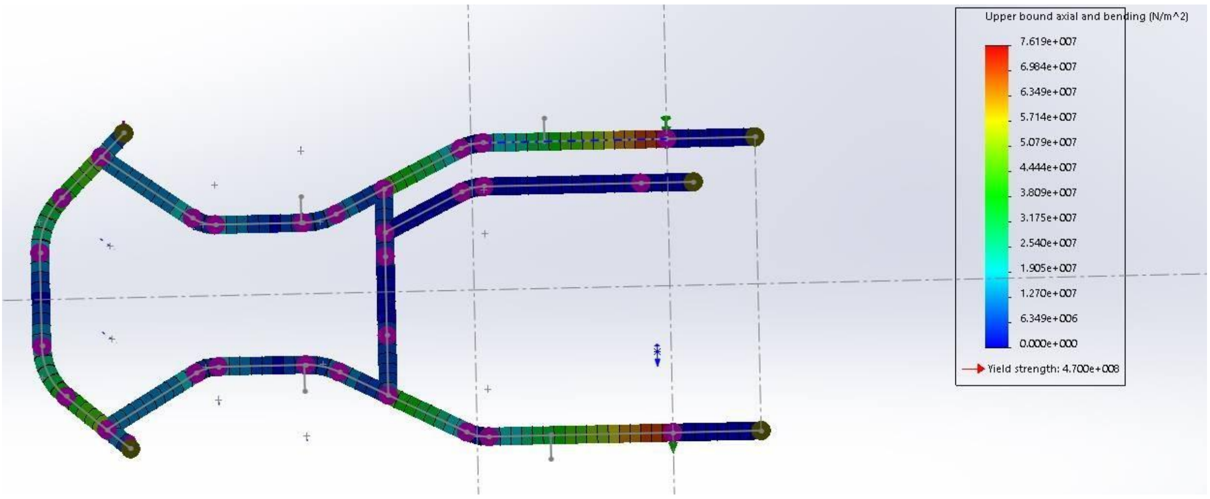


Figure 4.3 Torsional Rigidity Analysis on Design # 3

After the analysis, following factors of safety (F.S) were computed:

- Design # 1 had a F.S of 7.33
- Design # 2 had a F.S of 6.91
- Design # 3 had a F.S of 6.18

4.4 Static Loading Analysis:

In this analysis forces were applied at specific points to model weight of different components and points where tyres will be attached were fixed. This way we were able to see that if the frame would fail under static load and could find factor of safety for each design. Following figure shows the analysis result for Design # 1

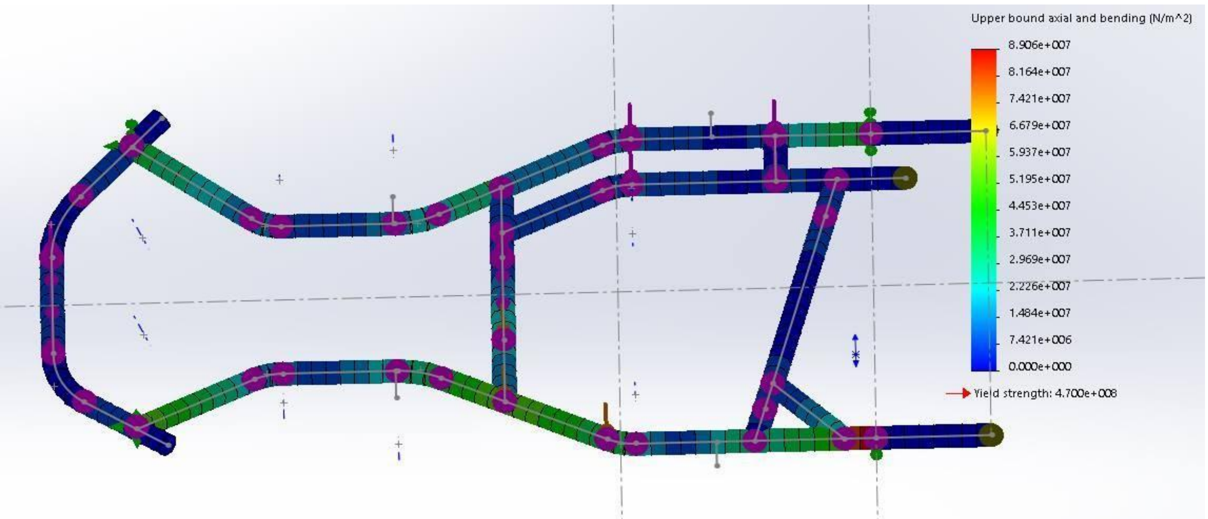


Figure 4.4 Static Loading Analysis on Design # 1

This analysis resulted in a factor of safety of 5.28 which was approximately same for all three designs. Therefore this design was selected for manufacturing.

4.5 Rear Axle Calculation

Rear axle is an integral part of a go kart as it is directly linked to a sprocket which in turn is linked to the engine through a chain. It also doesn’t have a differential and will bear stresses due to static loading and torsion. According to CIK-FIA rear shaft should have a max external diameter of 50 mm with at least 1.9 mm thickness and for 31 mm external diameter, the thickness of the pipe should be at least 4.7 mm. We decided to use a solid 1.25 in (31.75 mm) rear axle made of AISI 1010 steel due to local market availability. Following are the calculations that were done on the rear shaft:

- Using the values obtained from weight distribution on rear wheels, we calculated maximum stress due to bending moment.
- Two bearings were used to support the rear axle. Left bearing was placed at a distance of 7 in from the left wheel and right bearing was placed at a distance of 7.5 in from the right wheel.
- Shear force and bending moment diagrams were drawn to find out the maximum bending moment acting on the rear axle. It was found to be 72.31 Nm.
- Using the equation: Maximum Bending Stress= My/I we found the bending stress to be 23 Mpa which is well below the ultimate tensile strength of AISI 1010 which is 365 Mpa.
- For shear stress on rear axle due to torque was calculated. A torque of 15 Nm was applied. Using the formula Maximum Shear Stress= Tr/J we found the shear stress to be 2.38 Mpa which is also well below the ultimate tensile strength of the material.

Chapter 5
Manufacturing & Assembly

5.1 Chassis:

After selecting a model with 1.25 inch diameter pipe and 1.35 mm wall thickness and material AISI 4340 steel, we went into the market to explore our options. After discovering the limited variety of material available, our design had to be remodeled countless times because exploring the local market, we found a lot of times that our required material dimensions, or manufacturing facilities were not available. We also faced difficulties in finding AISI 4340 material locally. There was abundance of stainless steel and AISI 1010 steel in the market. We couldn’t use stainless steel as it wasn’t permitted in regulation of CIK-FIA and AISI 1010 wasn’t an option due to its low yield strength. Finally we were able to source the material from Karachi after discovering that there is only 1 manufacturer of AISI 4340 pipes in Pakistan. After getting the material, we found out that the equipment needed to bend 1.25 inch diameter pipe was unavailable in the market, hence leading us to remodeling the design. These are just a few examples, amongst many more including during assembly, that we came across during our project. This meant that we had to alter our design and finally selected a design with 1.50 in diameter pipe with 2 mm wall thickness and AISI 4340 steel.

For welding we selected TIG welding for manufacturing of our chassis frame as it is neater and much stronger than electric arc welding. As welding directly affects the strength of the chassis, if the welds are weak we run a risk of structural failure and risk the safety of the driver. We frequented the welder almost daily during this whole process.

Figure 5.1 & Figure 5.2 Representing the making of Chassis in the welding shop

5.2 Imported Parts:

There were some required parts that were unavailable in Pakistan. These parts had to be sourced elsewhere. For this we got in touch with local Go Karting track facilities, and they gave us contacts of people who imported such parts. We sourced our rims and tires from China through an agent. The Body Kit was sourced directly from china through a supplier.

According to CIK-FIA rim of tyres should be 5 inch in diameter. The maximum exterior diameter of the front wheel: 280 mm and of the rear wheel: 300 mm. The maximum width of a rear wheel: 215 mm and the maximum width of a front wheel: 135 mm. Therefore front wheels with 45/100-5 (4.5" wide, 10" high) and rear wheels with dimensions 60/110-5 (6" wide, 11" high) were selected and imported from china through a local vendor in Lahore.

Figure 5.3 Tyre being installed on Rim

Figure 5.4 Body Kit imported from China

For Body Kit CIK-FIA regulations dictate that non-metallic, carbon fibre, Kevlar and glass fibre are forbidden. In all categories, if plastic is used, it must not be possible to splinter it and it shall not have any sharp angles as a result of a possible breakage. Therefore plastic Body Kit was selected and imported from China directly.

5.3 Suspension:

Regarding suspension, according to CIK-FIA All suspension devices, either elastic or hinged, are prohibited. Hydraulic, pneumatic or mechanical suspension devices are forbidden on all karts.

Figure 5.5 & 5.6 clearly show that there is no suspension used in the Go-Kart

5.4 Braking System & Other Parts:

We sourced the brake from local used parts vendor. It was a twin piston hydraulic (which was a requirement of CIK-FIA) powered brake, which is usually used in All Terrain Vehicles (ATVs). We sourced a brake disk and sprocket, both off a motorcycle. The rear shaft had to be mounted on bearings, and these Journal bearings were easily available in the local market. When it came to the seat, we needed something that would hold the driver in place when taking turns, as Go Karts produce a lot of Lateral G's while cornering. We had to work with what we could find, so we got a plastic seat that matched our requirements.

Figure 5.7 Twin Piston Hydraulic on Disc Brake

Figure 5.8 Master Cylinder of Brake mounted on the pedal

Figure 5.9 Rear Shaft with Journal Bearings mounted as well as Sprocket & Brake Disc

5.5 Steering System:

The steering system was a challenge. Designing and manufacturing the steering linkage was easy, which consisted of tie rods, and a metal plate welded to the steering shaft. The steering mounts were made of metal rods. The tricky part was the steering geometry, which was essential to make the Kart perform correctly in turns. We welded the wheel axle mounts at a 12 degree KPI angle. The axle stubs were welded at such an angle to keep the wheels at 0 camber. Coming to the steering wheel itself, we couldn’t find one of a small size which could be used on the Go-Kart. Therefore the steering wheel was made of steel sheet that was milled into shape and bent metal pipes were used as handles. To connect the steering wheel to the steering shaft, a hub was machined out of 1.5 in diameter solid steel rod that was used to connect the steering wheel to the steering shaft. A 12 degree kpi and 0 degree camber was achieved.

Figure 5.10 Chassis with Steering System mounted on

Figure 5.11 Steering System with wheel

5.6 Drive Pedals

CIK-FIA regulations regarding pedals were; whatever the position of the pedals, they must never protrude forward of the chassis including the bumper. Pedals must be placed in front of the master cylinder. And that the accelerator must be triggered off by a pedal equipped with a return spring. A mechanical link is compulsory between the pedal and the carburettor. Therefore Accelerator and brake pedals of a car were purchased from a local parts store and then were modified to suit our application. Pedal mounts and the mechanism to control the brake and throttle was a major challenge, and had to be designed from scratch. The pedals were shortened and re-welded, then custom mounts were fabricated with stops and hinges to keep them in the right motion range. The brake pedal was directly connected to the master cylinder which was mounted behind it. As for the accelerator pedal, this was connected to the accelerator wire. The wire had to be customized to fit our length requirements. For this, we took two cables and joined them together.

Figure 5.12 Brake Pedal

Figure 5.13 Accelerator Pedal

5.7 Engine

The engine used was a 250CC air-cooled motorcycle engine with a 4 speed transmission. This was sourced from Karachi, and single cylinder design was ideal for low to mid range torque that we required. The engine is rated 15 Nm torque and 12 hp. The engine was mounted onto the Chassis using custom fabricated mounts that were TIG welded to a thick steel plate, which was welded to the Chassis. Engine mounts had to be designed with great strength as they would need to bear a lot of fatigue stress, given the high vibrations of a single cylinder engine.

Figure 5.14 Engine when mounted on the bike

Figure 5.15 Engine after being mounted on the Go-Kart

5.8 Gear Shifting Mechanism

Our kart had a 4 speed transmission from a motorcycle, which is designed to be shifted by foot. We needed to design and fabricate a system that allowed us to operate it by hand. We designed a hand held shifter out of wood, which was attached to a metal bar directly connected to the gear shifter. This lever action allowed us to shift gears efficiently. The clutch lever was directly mounted onto the gear lever.

Figure 5.16 Metal bar connected to Gear Shifter

Figure 5.17 Clutch lever mounted on a Wooden Gear lever

5.9 Sprocket & Brake Disc Mounts

The sprocket and brake disk had to be mounted to the shaft, and for this, we fabricated hubs out of steel, which were designed to fit the disk and sprocket, and attach onto the shaft. The hubs were held in place on the shaft with the help of bolts that sat in drilled holes.

Figure 5.18 Sprocket mounted on Rear Shaft & Bearing

Figure 5.19 Grinding the Shaft for mountings

5.10 Body Kit Mounts

Body Kit mounts were fabricated out of angled Iron. They were arc welded to support the body panels, attached directly onto the chassis. The panels were then bolted to the mounts, and were removable for transportation.

Figure 5.20 Partially assembled Go-Kart

Figure 5.21 Fully assembled Go-Kart

Chapter 6
Cost Analysis

Following table represents the cost incurred during this project. We were successfully able to keep the cost within PKR 150,000.

Engine	PKR 40,000
Body Kit	PKR 25,000
Chassis Manufacturing	PKR 20,000
Kingpins	PKR 6,000
Wheels & Hubs	PKR 35,000
Brake & Shaft	PKR 5,000
Miscellaneous	PKR 12,500
Total Cost	PKR 143,500

Table 6.1 Cost Analysis

Chapter 7
Results and Future work

7.1 Results & Conclusion

In this project we were able to complete our Go-Kart starting from scratch. It was demoed in our university and we were also able to drive it on the main roads. It reached a maximum speed of 70 km/h in our road tests. It also has a road clearance of 2 inches which enables it to go over quite a few speed breakers. In the end we experienced both sides of our mechanical engineering, i.e. design and manufacturing. We successfully made a product by bridging the gap between these two, which was our main challenge.

7.2 Future Work

- More robust mounting for Body Kit
- Replacing the motorcycle engine with a specialized Go-Kart engine
- Sourcing better material for manufacturing chassis from abroad
- Making the Body Kit and seat from fiberglass to reduce cost further
- Integrating telemetry to record performance indicators

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