Design Report for Team SPCE Racing

Team Number: 29

Abstract: *Team SPCE RACING aims at designing an efficient Go-Kart in compliance with the rule book of the second edition of Indian Karting Championship. The main objective of the team includes designing a light weight kart that provides for driver safety and cost effectiveness. Various aspects like driver ergonomics, endurance, speed and maneuverability have been taken into account. We have aimed to improve performance of each component without compromising on the set parameters.*

Introduction

The Go-Kart has been designed by Team SPCE Racing consisting of undergraduates from Sardar Patel College of Engineering affiliated to the University of Mumbai. Dr. Kiran Bhole sir served as the faculty advisor. The Team has undertaken extensive research to find better suited alternatives, increase endurance and make a race-ready kart. We have selected a simple design to enhance performance.

Results of analysis were carefully examined and necessary corrections were made. Analysis was done on ANSYS 16.0 to improve strength and rigidity, reduce wastage and to optimize overall performance. The kart design was modelled using CATIA V5 R21 and AutoCAD 15 and rendered in CATIA V5 R21.

1. Technical Specifications

1.1 Engine

Top Speed	115 km/hr
Displacement	124.7 cc
Power	11.2 Hp
Torque	11 Nm

Table 1.1

1.2 Chassis

Weight	15.74 kg
Wheelbase	47 inches
Track width	Front: 40 inches Rear: 38 inches
Centre of Gravity	8.5 inches from the ground

Table 1.2

1.3 Kart Performance Targets

Transmission System	
Maximum Acceleration	0.88 g
Top Speed	80 km/hr at the rate of 9000 rpm in the fifth gear
Maximum Torque at the wheels	194.28 Nm at the rate of 6500 rpm in the first gear
Engine	Highest carburettor torqued engine in the range of 125 cc
Chassis	
Wheelbase	47 inches
Track-width	Front: 40 inches Rear: 38 inches
Braking System	
a. To achieve locking of rear wheels b. To achieve balance between pedal effort and travel c. Better wet grip due to use of disc brakes d. No yawing on hard braking	
Steering System	
a. Minimum steering effort and better steering feedback b. Shortest possible turning radius is 1.66 m c. Aims for agility d. Compact wheel assembly	

Table 1.3

1.4 Kart Dimensions

Length	1730 mm
Breadth	1136 mm
Height (from ground to highest point of chassis)	819 mm
Ground Clearance	1.5 inches

Table 1.4

1.5 Steering (Steering Column)

Outer diameter	25.4 mm
Inner diameter	21.4 mm
Inclination with respect to ground	50
Material	Mild steel

Table 1.5

1.6 Transmission

We have used manual transmission using a push-pull rod.

1.7 Brakes

Master Cylinder (76 series Tilton)	5/8 inch bore diameter, Tandem
Brake caliper (Bajaj Pulsar)	28mm diameter Dual piston
Brake disc	190mm diameter (self- manufactured)
Brake pedal	Pedal ratio - 4
Maximum braking torque generated	35000 Ncm

Table 1.6

2. 3D view of the Kart

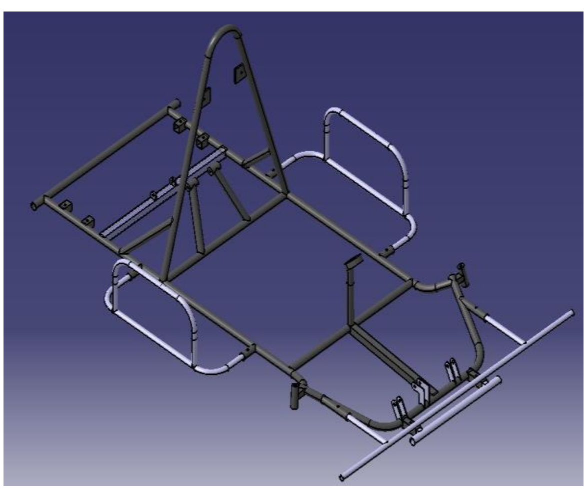

Figure 2.1: Isometric View

3. Design Methodology

3.1 Designing the frame

The primary objective was to ensure maximum safety of the driver and the secondary objectives included providing reliable mounts for components, reduction of weight, and economize on the overall cost.

We began the process of designing the frame by making multiple sketches of the outer frame. The dimensions and the measurements were fixed keeping driver ergonomics in mind.

We built the chassis around the driver. We made a diagram on the ground with 1:1 ratio and checked the approximate value of the wheelbase. We fixed the value of wheelbase at 47 inches.

The track width was selected to be 0.8 times the wheelbase according to the rulebook guidelines. We tested the designs on ANSYS for durability of chassis.

After deciding the final design of the chassis, we made a prototype in order to prevent wastage of material.

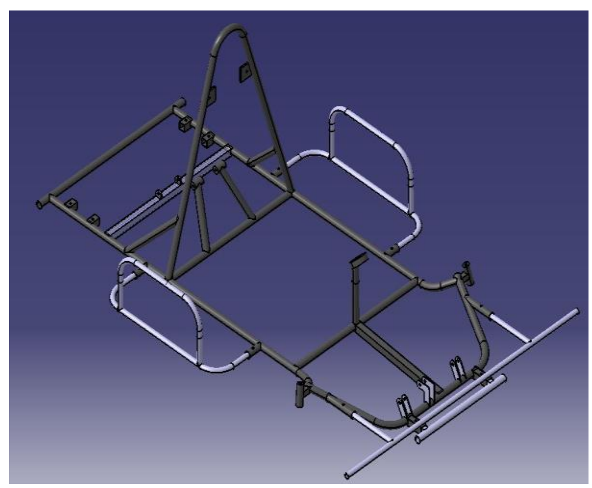

Figure 3.1: CAD Model of Frame

Figure 3.2: Frame Prototype

Figure 3.3: Frame

3.2 Driver Ergonomics

In order to extract optimum performance from the Go-Kart, it is essential to keep in mind driver ergonomics as well.
The following points were considered by seating the driver in the best possible driving position in the prototype.

i. Chassis

With the 3D designed chassis, the depression at the front of the kart created more leg room which resulted in a relaxed driving position. This arrangement also helped us in achieving a shorter effective wheelbase.

ii. Steering Column Inclination and position of Steering Wheel

The inclination of the steering column was finalized after considering the 'driving triangle' i.e. the extension of the steering column that must be extended to reach the top of the helmet. At the same time, the distance between the steering wheel and driver's torso was finalized after achieving an angle of 90° at the elbow. This driving position gives the driver maximum control over handling of the car.

iii. Gear Shifter

The gear shifter was placed towards the left with respect to the driver and the height of the knob was adjusted in such a way that it was in level with the steering wheel within the reach of the driver. This was done in order to minimize shift timings while driving.

3.3 Floor Planning

We made a diagram of the chassis on the ground using chalk with 1:1 ratio. We simulated the elevation and tested the dimensions with the driver.

3.4 Material Selection

Mild Steel AISI 1018	Mild Steel AISI 4130
Economical	Costly
No pre- processing required for welding.	Requires pre-heating for welding and post welding processes have to be employed
Heavier	Light-weight

Table 3.1

Thus, we decided to go with AISI 1018 as it gave satisfactory ANSYS results and was better suited for achieving our aim of making a sturdy kart.

3.5 Design Decisions

i. Selection of 3D chassis:

We tested both 2D and 3D chassis with similar dimensions and geometry;
The 3D chassis had:

- Less deformation
- Less stress
- Higher factor of safety,

this is because the force is distributed in such a manner that only a small part of it propagates beyond the bend.
The 3D chassis was able to provide a better seating position with a smaller wheelbase.

ii. Chassis rods:

We used pipes of the following cross section:

- Round Pipes

Outer Diameter	Thickness
25.4 mm	1.65 mm
19 mm	2 mm

Table 3.2

- Square pipes were used due their high torsional rigidity.

Cross Section	Wall thickness
25.4 mm	1.65 mm

Table 3.3

iii. Precision Techniques:

We have used cutting edge techniques like Laser Cutting in order to make high precision mounts and fixtures.

iv. Weight optimization:

- Weight of chassis along with the mounts = 15.6kg
- We have tried to decrease the track width and wheelbase in order to reduce the amount of material to be used while making the chassis.

We have selected pipes with minimum possible outer diameter and minimum possible thickness in accordance with rulebook parameters.

3.6 Factor of Safety

Front impact	2.085
Rear Impact	6.4023
Side impact	4.0232
Roll over impact	No rollover (proof given in calculation report)

Table 3.4

5. Vehicle Dynamics

5.0 Material Selection

i. Steering Hub, Steering Column, Pitman Arm: Mild Steel 1018

As the Steering Hub and the Pitman arm are subjected to shearing forces, Mild Steel 1018 was safe to use. From manufacturing point of view, Mild Steel was found to be suitable as the Steering Hub and the Pitman arm were to be welded to the Steering Column which is also made up of Mild Steel.

ii. Knuckle, Steering Arm, Spindle: Aluminium 6082

Aluminium 6082 has higher weldability, higher strength as compared to Aluminium 6061. The above mentioned parts were not subjected to shearing forces and thus we decided to use Aluminium 6082 to save weight. The spindle, knuckle and the steering arm are to be welded together.

iii. Tierods: Aluminium 6061

Tierods are not subjected to any shear forces and they are not to be welded to the Pitman arm. Thus, we considered using Aluminium of grade 6061 as it was sufficiently safe to use. Mild steel inserts were provided for Rose Joints to avoid shearing of aluminium.

iv. Steering Wheel: Carbon Fibres

With an aim to reduce the overall weight of the kart, Carbon Fibre steering wheel was finalized after extensive research.

v. Aluminium 7-series over 6-series

Aluminium 7-series has no major advantage over 6-series apart from strength-to-weight ratio. Weldability of the two is the same. Also the analysis of 6-series was found to be safe on ANSYS. Economically, 7-series was too costly and hence was rejected.

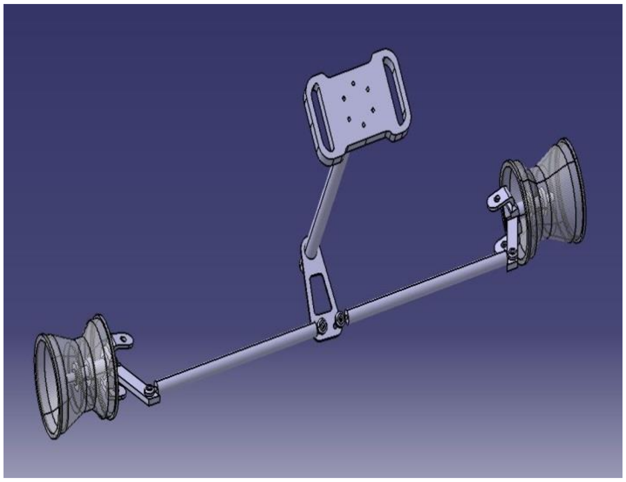

Figure 5.1: Steering System

5.1 Steering System

This system was selected based on its simplicity and direct actuation, i.e. no lag in turning of wheels with respect to turning of steering wheel. (The play in the system is negligible as no u-joint was used in the steering column setup)

- Lesser wear of tyres
- Shorter turning radius
- Easier maneuverability which in effect reduces steering effort.

i. Steering Wheel:

The wheel was made in more of a rectangular profile than a circular one to provide clearance between driver's knees without compromising on the acting diameter of the Steering Wheel. The Steering Wheel is bolted on the Steering Column using a using a mild steel disc.

ii. Steering Column:

Rod: outer diameter	1 inch
Wall thickness (Rulebook guidelines)	2 mm
Length (considering the forearm and the elbow to be at 90° for maximum control over the steering wheel and better handling)	45-50 cm
Rod: inclination (Considering driver ergonomics and driving triangle)	50°

Table 5.1

The steering column is mounted using a base plate and rose-joint arrangement. A solid MS shaft was inserted at the bottom of the steering column to provide threading for the nut to be fit into the rose joint.

iii. Bearing:

Thickness	0.025 inches
Outer diameter	2.25 inches
Inner diameter	2.25 inches

Table 5.2

The bearing used was RLS-8 (SKF standard). The bearing was press fit into the casing. Now, the casing was welded to the steering column and hence the steering column was free to rotate about the bearing axis.

5.2 Pitman arm

Length	111.9 mm
Material	Mild steel
Thickness	3 mm
Shape (considering the stress distribution of forces applied through the tie rods and the steering column as well as considering the compact packaging of tierods and steering column)	Triangular

Table 5.3

Stress analysis on ANSYS revealed that major part of the arm experienced null force. Hence, we made slots to bring about weight reduction.

5.3 Tie Rods

Length	300 mm
Material (For weight reduction)	Aluminium alloy 6061

Table 5.4

Due to the shearing effect on aluminium, it was not possible to provide internal threading for rose joints. Hence, we press fitted a small mild steel hollow cylinder into the aluminium rod and made internal threading.
Tie rods are connected to the Steering arm and Pitman arm using M-8 Rose Joints.

5.4 Knuckle

Knuckle material	Aluminium alloy 6082
Spindle material	Aluminium alloy 6082
Bearing on spindle	6904 Z (SKF standard)

Table 5.5

The spindle is attached at the exact centre of the knuckle. This arrangement has helped us in reducing the spindle length, reduce the bending moment on it and have a compact wheel assembly.

The knuckle was mounted on the chassis using a kingpin bolt and post. The slots in the knuckle for kingpin post were fitted with brass bushings to prevent shearing of aluminium.
The steering arm was attached just above the centre line of the knuckle. Hence, the steering arm and the tie rods are parallel to the ground in the straight-ahead position of the kart. This arrangement helps reduce play in the system.
Material stopper was provided on the spindle on the inner side of the rim and circlip on the outer side of the rim to prevent the bearing from slipping out.

i. Ackerman Angle:

Ackerman angle	Turning radius
70°	2.077 m
65°	1.66 m

Table 5.6

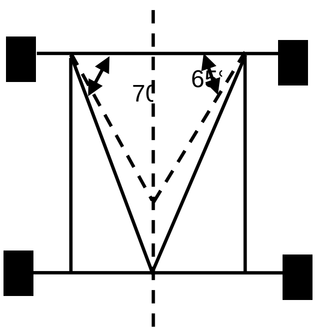

Figure 5.1

Ackerman angle was calculated using geometry.
At an angle of 70° between steering arms with respect to the horizontal 100% Ackerman principle was achieved. In order to reduce the turning radius, we have reduced the Ackerman angle to 65°, i.e. the extension of the steering arms intersect before the rear axle.

5.5 Rims

Anodized Aluminium alloy rims were used for weight reduction. The protrusion on the inside of the rim was machined by 30 mm to reduce the track width and achieve the required track width of 40 inches.

5.6 Tyres

	Slicks	Wets
	BKT	Supertrak
Front	10x4.5/5	10x4.5/5
Rear	11x7.0/5	11x6.0/5

Table 5.7

Considering the wet skid-pad event and possible wet conditions during the event, we have used a set of wet weather tyres along with slicks.
While selecting wet weather tyres, the thread pattern was finalized in such a way that it would displace maximum water during wet conditions.

5.7 Wheel Alignment

i. Camber:

Effects	Our selection
Negative camber is preferred for a race car since it increases tyre contact patch during cornering. On the other hand, it reduces the grip on straight line and creates losses in acceleration and straight line speed.	**0°** To ensure maximum straight-line acceleration. The tyres we have used are bias-ply tyres which provide maximum traction with 0° camber.

Table 5.8

ii. Castor:

Effects	Our selection
Positive castor has self-centering action which helps to maintain linear stability whereas excess castor increases understeer and reduces handling performance. Additionally, greater the castor angle more is the jacking effect.	**7°** Castor angle was varied between 6° and 12° for optimum self-centering action and straight-line stability.

Table 5.9

iii. Kingpin inclination:

Effects	Our selection
Greater the kpi more is the jacking effect but it also increases oversteer as the scrub radius is effectively reduced. Greater kpi results in lesser steering effort and excess oversteer.	**12°** Optimum value of kpi was finalized after varying it from 7° to 14° and selecting the appropriate scrub radius to minimize steering effort.

Table 5.10

iv. Toe:

Effects	Our selection
Toe-in or Toe-out factors are responsible for increase in wear and tear of tyres and increased power loss. • Toe-in increases straight line stability and	**No toe** Considering the disadvantages of power loss and the contradictions in the handling parameters

decreases cornering stability. • Toe-out decreases straight line stability and increases cornering stability.	of Toe-in and Toe-out we decided to go with zero Toe.

Table 5.11

5.8 Weight Optimization

- Aluminium parts were used in the steering system and tested on ANSYS for safety.
- Knuckle design was optimized in order to make it compact. The part of it experiencing null stress/deformation was made thinner to reduce weight.
- The pitman arm was provided with a central slot to reduce weight after analysis was done ensuring safety of the part.
- Carbon fibre steering wheel was used for weight reduction after extensive analysis.

6. Power Train

6.0 Material Selection

i. Driveshaft: EN8

Initially, we decided to use EN8 shaft, but, because of the common hub, several forces were being concentrated on a single point, causing deformations. Hence, we used EN24 to be on the safer side.

ii. Bearing: Series 6205

Series 6205 bearing was used.
We have used a normal pillowblock bearing with a casing of Aluminium instead of the standard cast iron one.

iii. Key: EN8

We decided to use EN8 ($8\times8\times40mm$) key instead of EN24 since it was readily available (we would not have to manufacture it) making it feasible.

iv. Fuel Tank: Aluminium 5052(H32)

Capacity of fuel tank is 3.5 litres.
To further reduce weight, we opted for a self-manufactured fuel tank rather than a pre-designed model made up of plastic or steel.

6.1 Engine Selection

We used manual transmission over CVT to reduce belt-drive losses, acceleration delay, and avoid the problem of belt slipping. The engine we bought is a Honda CBF Stunner 125.

6.2 Advantages of the Stunner engine over other engines of the same capacity

- Maximum power and torque- higher
- Power to weight ratio- higher
- Lower gear ratio combined with final drive reduction helps in faster acceleration and better performance.

6.3 Engine Positioning

We decide to incline the engine at 30° to the horizontal to reduce the wheelbase, have a compact chassis design that does not compromise the engine's performance.
Since the engine is inclined, we encountered a problem in lubricating the gearbox entirely. Therefore, we decided to fill it with oil above standard levels.

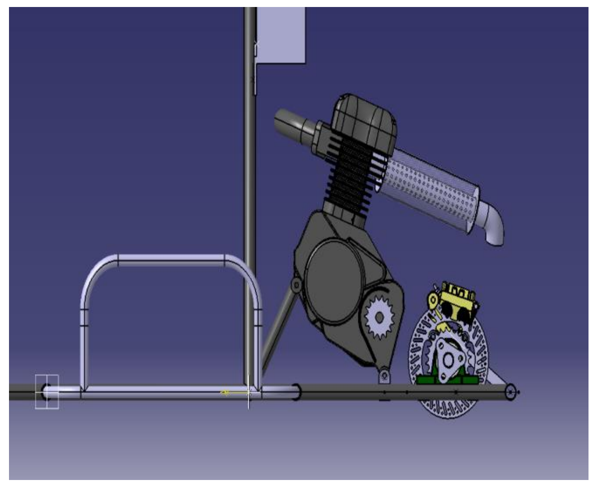

Figure 6.0: Engine inclined at 30°

6.4 Sprocket Selection

We decided to aim for maximum acceleration instead of a certain top speed due to more number of corners in the track and to improve the performance while maintaining a decent top speed.

Maximum acceleration	0.85g
Material	Mild Steel
Number of teeth	24
Chain	08B chain Pitch = 12.7cm

Table 6.1

6.5 Common Hub

Material	Mild steel 1018
Thickness	10 mm

Table 6.2

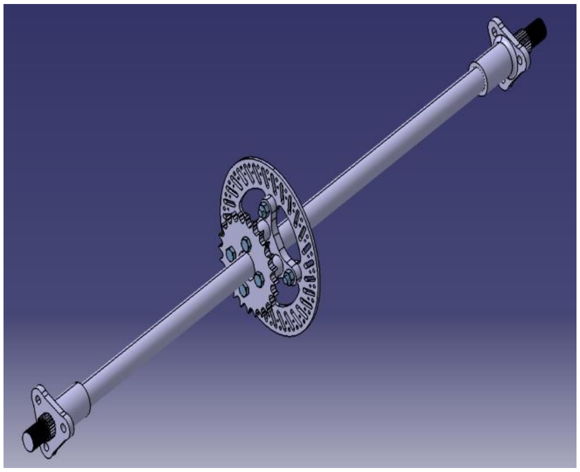

Figure 6.1: Common Hub

We have used a common hub for braking and transmission of power from engine to driveshaft. This created some problems while assembling the CAD Model with nuts and bolts. We made the required modifications.

6.6 Splines

Outer diameter	25.4 mm
Inner diameter	21 mm
Number of splines	24
Length	70 mm

Table 6.3

6.7 Exhaust

Since we self-manufactured the exhaust muffler, we calculated the appropriate length to create resonance and therefore reduce mass.

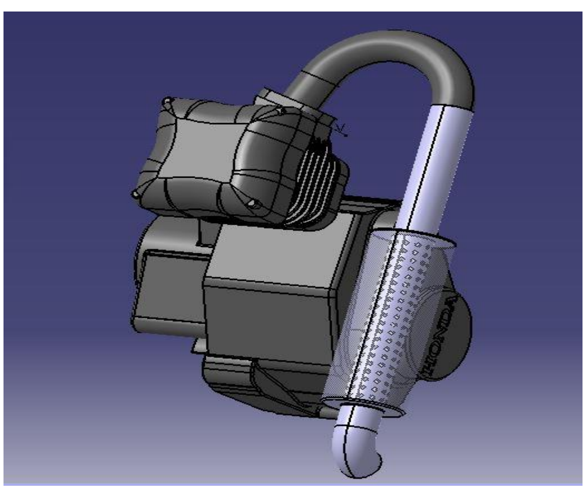

Figure: Exhaust

6.8 Gear Shifting

We use a push-pull rod mechanism for gear shifting.

6.9 Weight Optimization

- Weight of the power transmission system including harnessing and the battery = 41 kg
- We have used a 3.5 litres fuel tank made up of Aluminium 5052(H32) which was self-manufactured.
- We have used a common hub for braking and transmission of power instead of using two different hubs.
- We have used a pillowblock bearing with a casing of Aluminium instead of standard cast iron one. This reduced the weight by approximately 1 kg.

7. Brakes

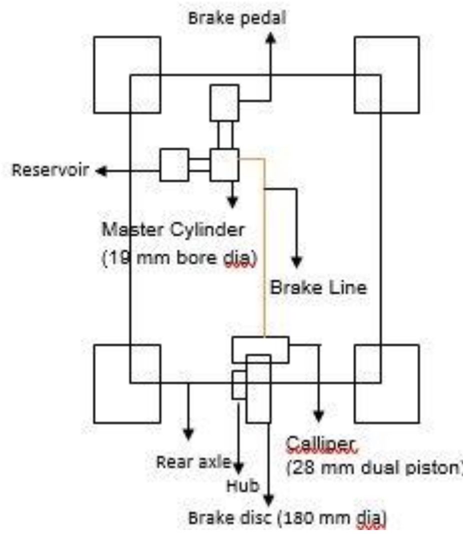

Figure 7.0: Brake Circuit

7.0 Material Selection

i. **Disc: SS420**

SS420 was chosen over mild steel because of its higher strength to weight ratio. It was economical as well.

ii. **Clevis: Mild steel**

It is economical and has good strength.

iii. **Pedals**

The pedals were made from Aluminium 6 series

7.1 Brake Disc

Disc brakes were used instead of drum brakes to ensure weight reduction, ease of repair and manufacture.
We decided to go with minimum disc area which was approximately equal to the area of the brake pads. The selected Pitch Circle Diameter was 100mm.

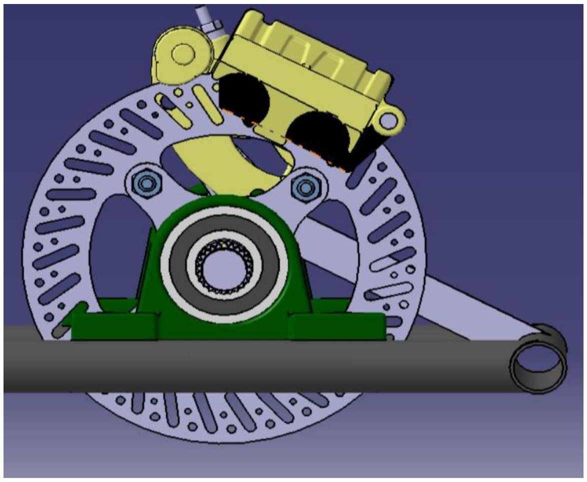

Figure 7.1: Caliper Disc Assembly

Initially, we made 30 slots in the disc for heat dissipation. ANSYS analysis revealed the disc temperature to be higher than expected. We made holes and slots where the temperature was high. After analysis of the second prototype, we found out that we could further lower the temperature without compromising the strength, and decided to make another set of holes. The ANSYS results were now satisfactory

7.2 Pedals

Initially, we decided to make the pedals out of Aluminium sheets, 2.5mm thick, and then weld them together. We went ahead with the calculations and designed a pedal. Later, we realized that if we use 3 different components and weld them together, effective strength of the manufactured pedal would be less compared to its CAD model.

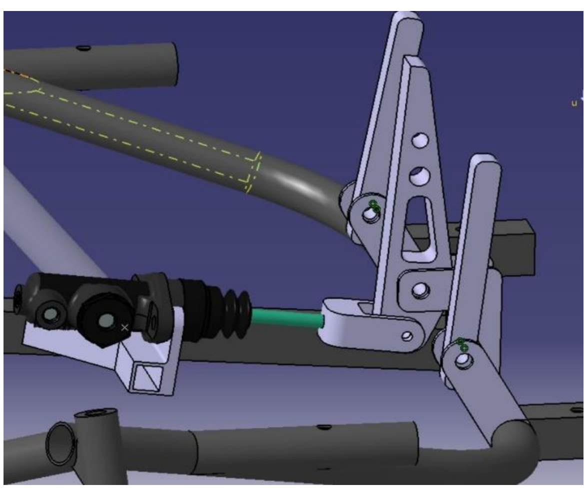

Figure 7.2: Pedal Box

Hence, we designed a unibody pedal with a Carbon Fiber head. We made different CAD models having a pedal ratio of 4, analyzed them, and selected the optimal design.
We made holes and slots where stress was less for reduction of weight.

7.3 Clevis

We used a clevis to connect the pedals with the master cylinder.

7.4 Weight Optimization

- Weight of the brakes system without the mounts = 2.55 kg.
- We have made slots in the three brake pedals and brake disc to remove material without affecting the strength of the material.