iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: IV Month of publication: April 2024

DOI: https://doi.org/10.22214/ijraset.2024.61034

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IV Apr 2024- Available at www.ijraset.com

Design and Manufacturing of EV Go-Kart

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Abstract: Go-karts are small-size and small-weight vehicles that were developed for racing. These are made with materials that are strong and durable. It consists of many parts which include a chassis, engine, steering and braking system, and electronic controls. The chassis is the main part that is responsible for the stability of the vehicle. Chassis is made with the material having greater endurance and rigidity. It was developed in the 1950s in the USA and now getting popular. These are now used in amusement parks as a recreational activity. Many researchers have done work on go-karts and improve their design. This project was intended to design and fabricate a reliable and durable go-kart. Its primary objective to build a go-kart using local resources and applying different techniques to limit the cost of vehicles. These objectives were achieved by going through a detailed literature review and studying different techniques which can be implemented. A reliable design was chosen which can be implemented and can be completed in our period. Critically evaluate the design of the vehicle and then different parts were designed. This paper presents an approach to a go-kart chassis design, vehicle dynamics calculation, Li-ion battery capacity analysis, and electric motor choice for optimized vehicle performance. The chassis analysis shown in this paper was performed using a CAD/FEA software package, SolidWorks Student Edition. Three highlights can be found in this paper: An original design was implemented; the basic analysis was composed of chassis optimization using beam elements and modelling such an optimized chassis "locally" with solid elements for sub-modelling purposes. The most stressed tube joint was sub-modelled to calculate the risk of tube wall stability. Vehicle dynamics were calculated for the case of braking on a curved path and the case of a collision with the front tire due to road imperfection. The authors intend to install a data acquisition system in the future to analyse the stress of local chassis tubes.

Keywords: SolidWorks, Ansys, Ergonomics, Dimensional specifications, Mechanical properties, Chassis, Modelling, Torsional stress, Stiffness, Bending moment, Impact load.

I. INTRODUCTION

The general definition of any kart, a vehicle without suspension and differential. It is a vehicle specially designed for a flat track race. A wide range of engine karts were on track since the mid of the twentieth century. The Go-kart Vehicle is made with Four tires, seat, steering, brakes, and without suspension and differential. Go-kart structure refers to quadracycle vehicle that is used in sports and competition. Go-kart could also be called as the open-wheel car on land which could be made with or without the body-framework It has four harmonious wheels with the bottom, of which two of them assist for the turning of the vehicle with the control of steering and others would facilitate the transmit of the go-cart. Usually, the whole-body frame of the go-cart is made-up of steel pipes, apart from the other key components like engine and the wheels. There were some other parameters such as the types of materials used for the structure of the vehicle in-order to make it mechanically rugged and design of the chassis, these choices are very well concerned because they determine the safety of the vehicle and the structural analysis. now, due to the advancements in the technology and manufacturing materials go-carts are expected to be lighter, faster and should be more efficient in-terms of fuel consumption and overall performance as well. Due to road irregularities, engine loads, and other factors, lighter chassis structures can cause structural resonance as part of a rigid-body vibration. A result of this is riding discomfort and problems with ride control and safety. Finite element analysis is a proven method for designing and creating engineering products using computer-based analytical tools. Finite element modelling is already seen as a vital part of the style, as it can be used for analysing and predicting various structures with a dynamic performance within an engineering environment. Modality analysis is a common way to identify the modal parameter of a structure. In Go-kart, we divided it to four sub-divisions:

1) Chassis
2) Engine,
3) Steering,
4) Brake and Tire.

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A. Design Of Chassis

The chassis is made from a thick metal tube. The chassis type we used is a space frame which contains triangulation of tubes and forms nodes. The material used to make chassis is AISI 4130 graded steel which is also known as chromoly steel. And the chassis is held together by tig welding by notching the edges of the tubes.

1) Chassis Material Selection

The foundation of any chassis lies in its accoutrements. Historically, sword tubing has been the go- to choose, but the arrival of advanced accoutrements has introduced new possibilities. High-strength sword blends and featherlight aluminum woofer compelling druthers, enabling contrivers to strike a balance between structural integrity and weight reduction. The pursuit of a featherlight yet robust lattice material is a central theme.

2) Chassis Figure And Dynamics

The chassis Figure plays a vital part in the kart's running characteristics. Variables similar as wheelbase, track range, and caster angle are strictly optimized to achieve the asked balance between stability and maneuverability. Similarly, considerations of Ackermann steering Figure and camber angles are integrated to enhance cornering performance, ensuring that the go-kart remains responsive and predictable during high-speed maneuvers.

B. Powertrain Design

EVs have a single-speed transmission which sends power from the motor to the wheels. The motor is powered by a battery or by multiple batteries which store the electricity required to run an EV. The higher the kW of the battery, the higher the range.
We have used chain drive type Transmission Between motor and drive shaft.
The main advantage being its lightweight, highly efficient, low maintenance characteristics.
The E-power train system has the following objectives are:

- To have a combustion free vehicle.
- To have agility in the performance.
- To achieve flexibility on the road.

1) Motor

An electric motor is a device used to convert electrical energy into mechanical energy. Scientifically speaking, the electric motor is a unit used to convert electric power into motive energy or electrical energy into mechanical energy.
The most important feature of the Permanent Magnet Synchronous Motor (PMSM) is its high efficiency, given the ratio of input power after deduction of the loss to the input power. Permanent Magnet Synchronous Motors have the potential to provide high torque-to-current ratio, high power-to- weight ratio, high efficiency, and robustness. Due to the above favourable points, PMSMs are commonly used in latest variable speed AC drives, particularly in Electric Vehicle applications.

2) Accumulator

An accumulator is an energy storage device that accepts, stores, and releases energy as needed. Based on our requirements, we chose a 64V And 75 amps lithium-ion phosphate battery, which consists of 5 cells connected in parallel and 20 cells connected in series, where each cell has 3. 2volt.Dimensions of the Accumulator: 810×240×175mm.

C. Vehicle Dynamics

Vehicle dynamics is the application of classical mechanics in physics to cars to predict and control motion. The understanding of various types of Forces, moments and their effects on the vehicle is a critical study to understand and predict the behaviour of the vehicle in dynamic conditions.

1) Weight Distributionb And Balance

Weight distribution is the linchpin of kart dynamics. Achieving a harmonious distribution of weight among all four tires is essential for maintaining traction, reducing understeer or oversteer tendencies, and optimizing cornering performance. Inventions in chassis design allow for precise weight distribution adaptations to acclimatize to varying track conditions and motorist preferences.

2) Steering

The steering gear mechanism is used for changing the direction of two or more of the wheel-axles with reference to the chassis, to move the automobile in any desired path. In go kart the two back wheels have a common axis, which is fixed in direction with reference to the chassis and the steering is done by means of the front wheels. To avoid skidding, the two front wheels must turn about the same instantaneous centre to avoid the wear of tyres. This is perfectly fulfilled by Ackermann steering geometry method.

D. Braking System

Braking system helps slow down the rotation of the wheels when the brake pedal is pressed, ensuring a vehicle comes to deceleration. Brakes work on the principle of Pascal's law. According to this law when some pressure is applied on fluid it will travels uniformly in all the directions. when we apply some pressure on brake fluid it will transmit that pressure to the pistons of the calliper which actuate the brake pads which makes the disc to stop, so that the kart slow down.

II. LITERATURE REVIEW

1) William F. Milliken and Douglas L. Milliken

Written for the engineer as well as the race car enthusiast, Race Car Vehicle Dynamics includes much information that is not available in any other vehicle dynamics text. Truly comprehensive in its coverage of the fundamental concepts of vehicle dynamics and their application in a racing environment, this book has become the definitive reference on this topic.

2) Dr. B. Vijaya Kumar

Tungsten Inert Gas (TIG) welding, a widely utilized fusion welding process, plays a pivotal role in various industrial sectors due to its ability to create high-quality welds. The mechanical properties of TIG-welded joints, such as hardness and tensile strength, are intricately linked to several key parameters: welding current, filler materials, groove design, and bead dimensions.

3) T.Z Quazi

Taking part in a run Over the last 50 times, go- kart racing has developed into one of the most competitive forms of motor racing in the United States. Kart racing has acted as a turning gravestone for numerous motorists seeking careers in NASCAR and Formula One; all began their careers in this less expensive but high- octane style of motorsports contending.

4) Koustubh Hajare, Yuvraj Shet

The drivers in these are very professionals and accurate. They can drive it very fast. But there are also motor sports which do not need professional drivers and need not much speed. The vehicles used are also fewer amounts Such a motor sport is Go-kart. They resemble to the formula one car, but it is not as fast as F1, and cost is very less. The drivers in go-kart are also not professionals.

5) Ammar Qamar Ul Hasan

A go-kart is a small four wheeled vehicle. Go-kart, by definition, has no suspension and no differential. 'Carting is commonly perceived as the stepping stone to the higher and more expensive ranks of motor sports. Kart racing is generally accepted as the most economic form of motor sport available.

6) Shubham Kolhe, Vrushabh U. Joijode

A Go Cart also spelled as Go-Kart is a four wheeled vehicle designed and meant for racing only. It is a small four-wheeler run by I.C Engine. It is a miniature of a racing car. This report documents the process and methodology to produce a low-cost go-kart.

7) Kiral Lal, Abhishek O S

The chassis is an extremely imported element of the kart, as it must provide, via flex, the equivalent of suspension to give good grip at the front. Karts have no suspension and are usually no bigger than is needed to mount a seat for the driver.

8) Prof. Alpesh V. Mehta

The fibre to take load in the form of a structural element, but the matrix phase only sustains small amount of applied load. In addition, beside the matrix material is ductile; it also protects the individual fibres from mechanical abrasion or chemical reaction with the environment which will cause surface damage.

9) Mat and Ghani's

This research is conducted in 2012 carried out a light chassis development for "Eco-Challenge" race cars that could safely withstand loads and compulsions. Chassis analysis was carried out by addressing normal carloads such as engine and driver weight, acceleration, braking and cornering forces.

10) Tsirogiannis E, Stavroulakis GE

In the 2019 study conducted by Tsirogiannis and his friends, an integrated methodology of developing an electric car chassis was demonstrated.

The main criteria for the development of the electric car chassis are the elimination of cost and time, as well as an increase in hardness and strength, which is subject to mass reducing.

11) Joel.Ja, Kalaiarassan Ga

A structurally balanced chassis was designed for an electric motorcycle in a 2018 study by Joel et al. simulated the real-time forces on the chassis and suspension geometries. Cost and weight of the chassis to determine the material most suitable for the chassis.

12) S. Arshibad

He went on to show that a vehicle's chassis is crucial to preserving its speed and performance, making it necessary to do static and dynamic analyses of go-kart chassis. Electric go-karts are replacing conventional go-karts due to all the benefits they provide, which include less pollution and environmental friendliness.

13) N.A.Z. Abdullah et al.

The model update approach is crucial for enhancing the dynamic features of the go-kart chassis structure. By handling the record of dynamic reactions from test structures to have an accurate model for any reenacted examination and limited component, they showed that model refreshing is concerned with the remedy of limited component models.

14) Santosh Kumar et al.

He comprised the study on the frame of go-karts; at times, researchers were concerned with material selection, simple structural analysis, safety, and structural stability. He offered a detailed examination of the systems used in a go kart, including the steering and braking, transmission and consideration fostering selection.

15) Mr. Nikunj (2011)

The fibre to take load in the form of a structural element, but the matrix phase only sustains small amount of applied load. In addition, beside the matrix material is ductile; it also protects the individual fibres from mechanical abrasion or chemical reaction with the environment which will cause surface damage.

16) Raghunanda, A. Pandiyan, Shajin Majeed,

The chassis material is considered depending upon the various factors such as maximum load capacity, absorption force capacity, strength, rigidity. The material selected for the chassis building is AISI 4130

17) Prof. Nirmal Chohaun

He written report on “DESIGN AND FABRICATION OF ELECTRIC GO-KART” published on IRJET. Year of publication: 15 SEP 2020. The goal of this report is to design and build a working model of an electric go-kart.

18) Karale, S. Thakre

The EV's chassis was designed and developed based on assumptions about the vehicle's gross weight for carrying a suitable size of sprayer attachment, considering the agronomical requirements of the field crops available in the region, and validated using the Finite Element Method (FEM) with ANSIS software.

19) Rahul Thavai, Quazi Shahezad

The chassis is made up of AISI-1018 which is a medium carbon steel. This material was selected due to its good Combination of all the typical traits of Steel – high tensile strength, ductility, light weight, better weldability, and comparative ease of machining.

20) Abhinay Nilawar, Harmeet Singh

The Go-kart, by definition, has no suspension and no differential. They are usually raced on scaled down tracks but are sometimes driven as entertainment or as a hobby by non-professionals.

21) P. Bhatt, Hemant Mehar

A comparison of the most common kinds of electric motors in use across time is offered, along with their efficiency, power density, reliability, and size. An article published by RATHEESH NAIR in Ev reporter-e-magazine on.

22) Babaarslan's

In 2014 study investigated the design and production of an optimal vehicle for an M1-class electric sports vehicle with the help of analyses and tests. This vehicle design is planned to be a faultless, world-class vehicle by carrying out production controls.

III. CHAPTER 3

A. Design Of Chassis

The chassis is made from a thick metal tube. The chassis type we used is a space frame which contains triangulation of tubes and forms nodes. The material used to make chassis is AISI 4130 graded steel which is also known as chromoly steel. And the chassis is held together by TIG welding by notching the edges of the tubes.

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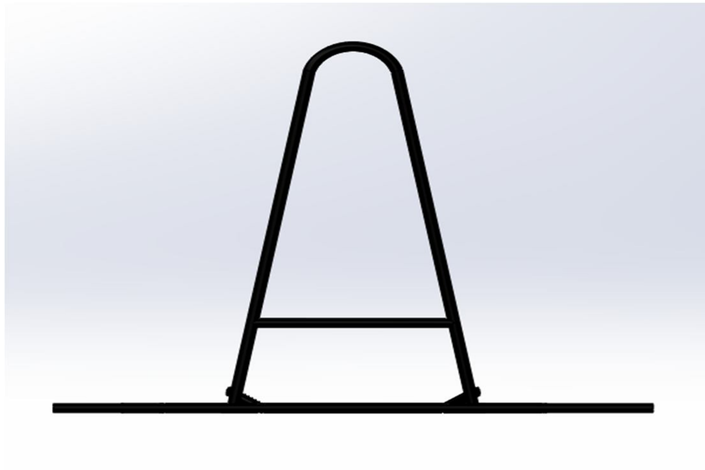

Fig: 3.1(i) Front view of chassis

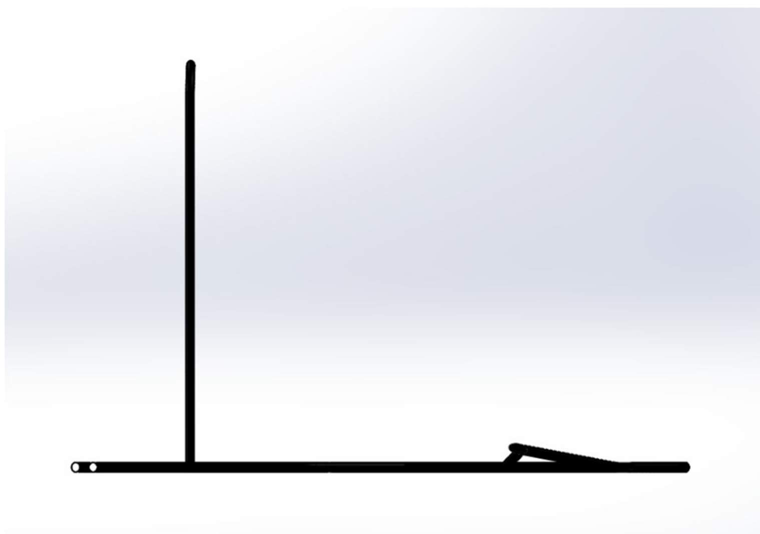

Fig: 3.1(ii): Side view of the chassis

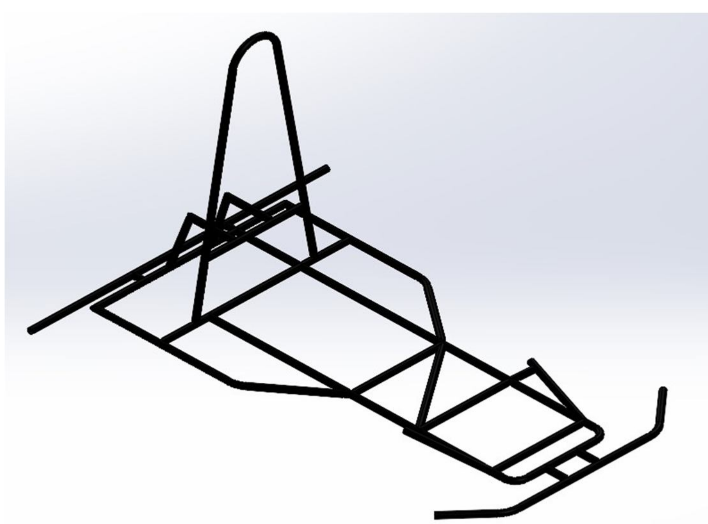

Fig: 3.1(iii) Isometric view of the chassis

The wheelbase is considered for construction to be 960 mm and the front track width is 910 mm, and the rare track width is 1090 mm.
The total length of the chassis is = 1932 mm.
The total width of the chassis is = 1275 mm.
The total height of the chassis is = 1152mm.

1) Materialistic Properties:

Table 3.1.1: Materialistic properties of AISI 4130

s.no	property	Values in Metric
1	Density	7.85 g/cc
2	Hardness, Brinell	197
3	Hardness, Knoop	219
4	Hardness, Rockwell B	92
5	Hardness, Rockwell C	13
6	Hardness, Vickers	207
7	Tensile strength, ultimate	670 MPa
8	Tensile strength, yield	435 MPa
9	Elongation at break	25.5%
10	Reduction of area	60%

2) Composition Of Material:

Table 3.1.2: Composition of material

s.no	Element	Content %
1	Iron, Fe	97.03 - 98.22
2	Chromium, Cr	0.80 - 1.10
3	Manganese, Mn	0.40 - 0.60
4	Carbon, C	0.280 - 0.330
5	Silicon, Si	0.15 - 0.30
6	Molybdenum, Mo	0.15 - 0.25
7	Sulfur, S	0.040
8	Phosphorous, P	0.035

3) Analysis Of Chassis

The analysis of the chassis that is the forces acting on the chassis and the reactions to be observed. The analysis conducted here is called the static structural analysis of the chassis members. The forces acting on the chassis during the running of the vehicle is considered as the loads acting on the chassis.

Calculations for loads acting upon the vehicle.

a) Force acting during the torsional test.

The force acting upon the chassis during the torsional test is torque. The torque applied is the product of the amount of load applied during the dynamic bump condition times the horizontal length from the point of application.

Torque applied = load applied X perpendicular distance

T= P x L

= Mg X L

= 130 X 9.81 X 1(total mass X perpendicular length)

= 1275.3 N-m

b) Load acting for impact test.

The load acting for an impact test is the amount of dynamic force that a body can exert during collision and the amount of load transmitted.

Dynamic load = total load x distance of impact

P = Mg X L

= 130 x 9.81 X 1

= 1275.3 N-m

c) Static stability factor

The static stability factor is the factor through which the stability of the vehicle is determined. The lower the value of the factor, the higher the risk of rolling it over when turned at higher speeds. The roll factor determines the handling and dynamic characteristics of the vehicle. It is determined by the formula,

SSF = track width / 2 X height of C.G from the ground.

= T/2H

= 110 cm / 2 X 23.6 cm

= 2.33

All the tests on the chassis are done by using the simulation ANSYS SOFTWARE.

- *Torsional test*

Testing of torsional stiffness on the chassis can be simulated by design chassis with finite element method. but for achieving high analytical accuracy requires validation using tools testing for actual chassis

The force acting upon the torsional test is a couple acting upon the frontal members of the chassis. The force is equivalent of the total weight of the total vehicle. The assumed weight of the vehicle is 130 kgs. When converted to force, it is 1275.3 N. and the results are obtained below.

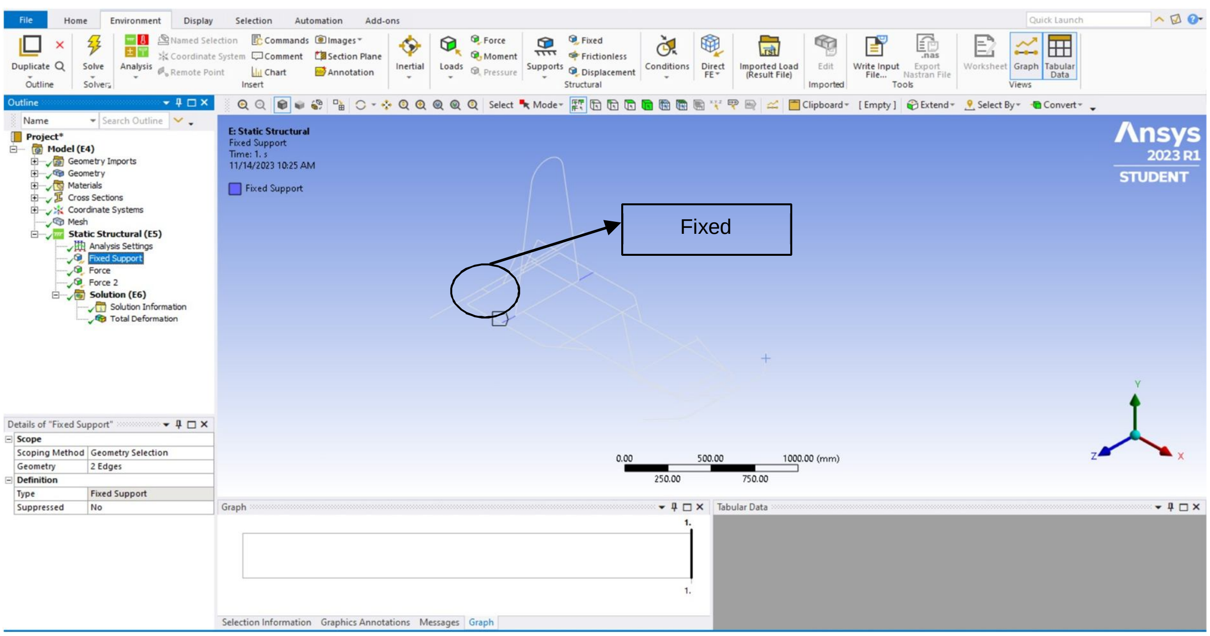

Fig I: Fixed support for torsional support

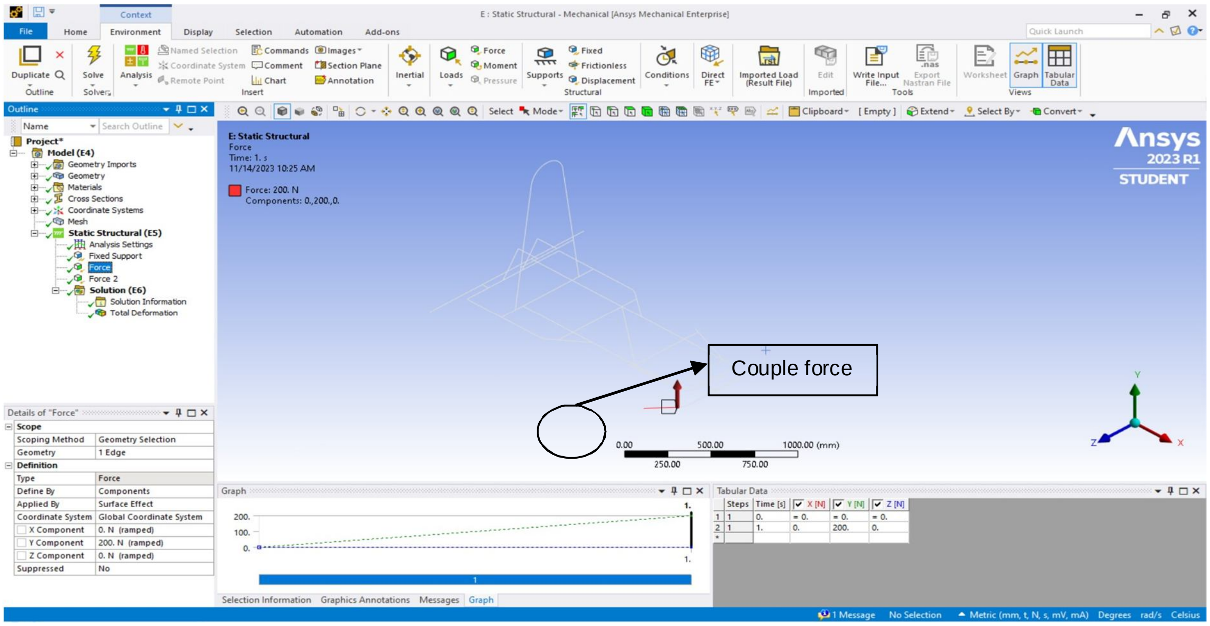

Fig I (i): Couple force 1

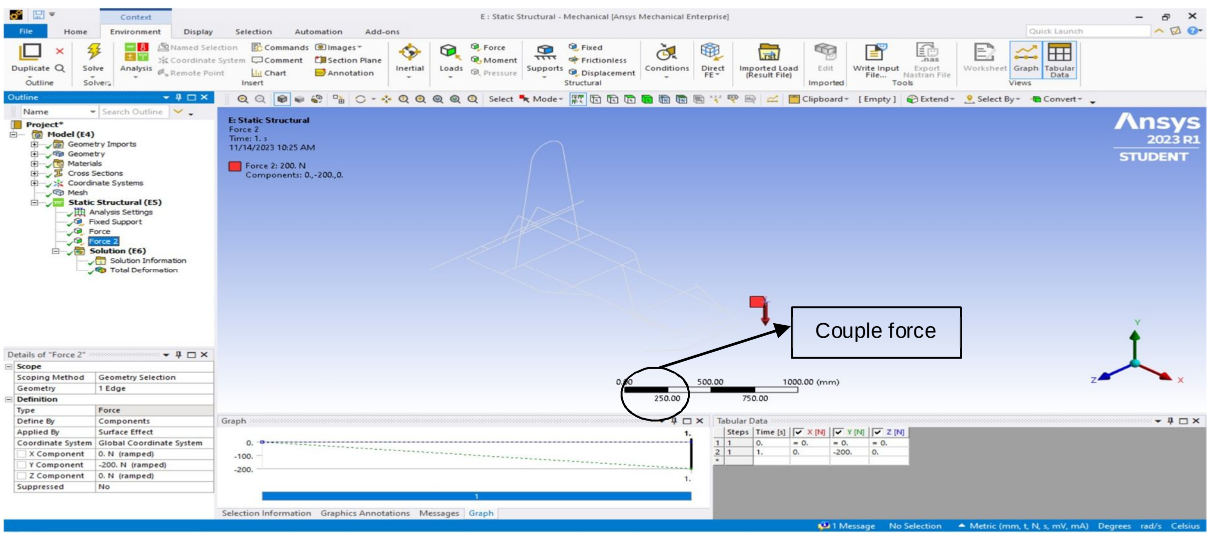

Fig I (ii): Couple force 2

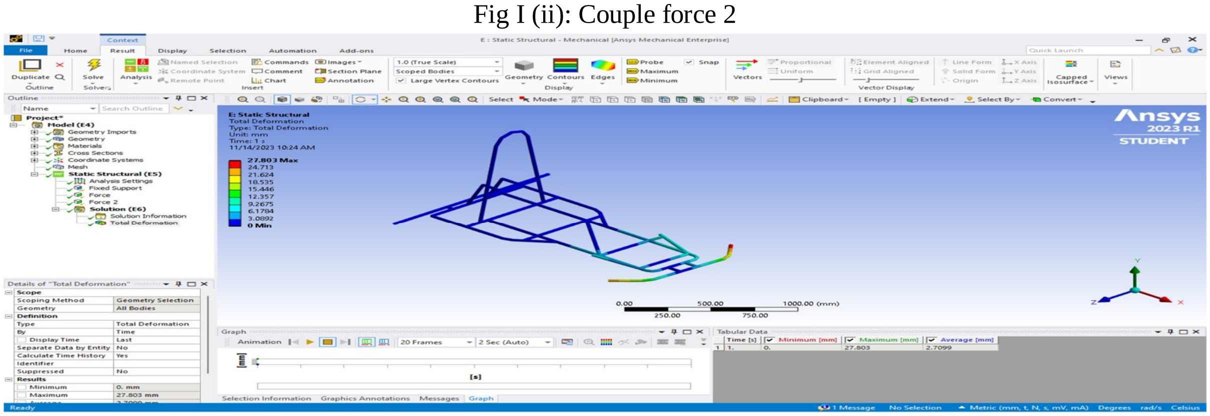

Fig I (iii): Result torsional test.

Maximum deformation in mm = 27.80 mm in vertical plane

- *Bending test:*

Vertical bending strength is a strength that shows chassis endurance towards other car components' weight such as engine, body, wing, drivetrain, and driver under gravitation effect Vertical bending using car weight to determine whether the frame is strong enough to hold car's weight. Vertical bending strength can be found by applying static force with car's components weight. One way to measure vertical bending strength on chassis is using FEA test. In the FEA test, the boundary condition is four wheels place on the chassis become the fixed support. The chassis act as a supported beam and the four wheels as fixed supports and the weight of the other components mounted to the frame Moreover, then the other cars component weight affected with gravitation become the force that pushes chassis vertically. In this test, chassis is fixed in both ends clamped and forced downward. The strength of chassis determined by safety factor and Von Misses Stress.

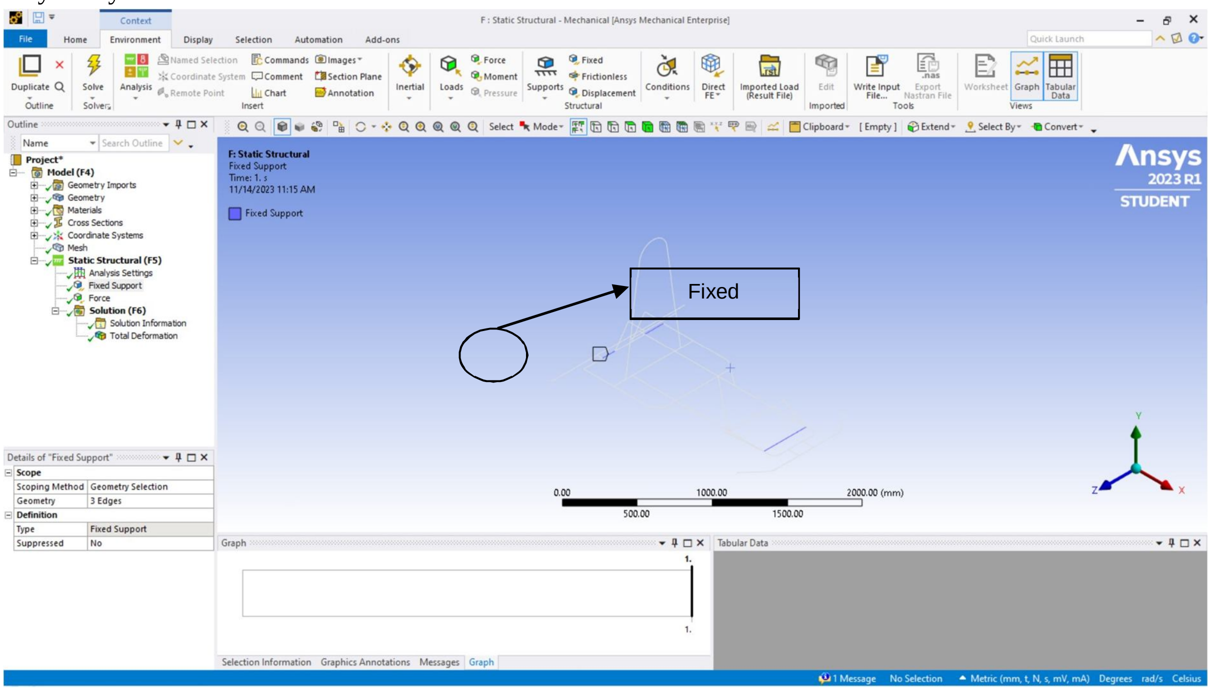

Fig II: Fixed support for bending moment.

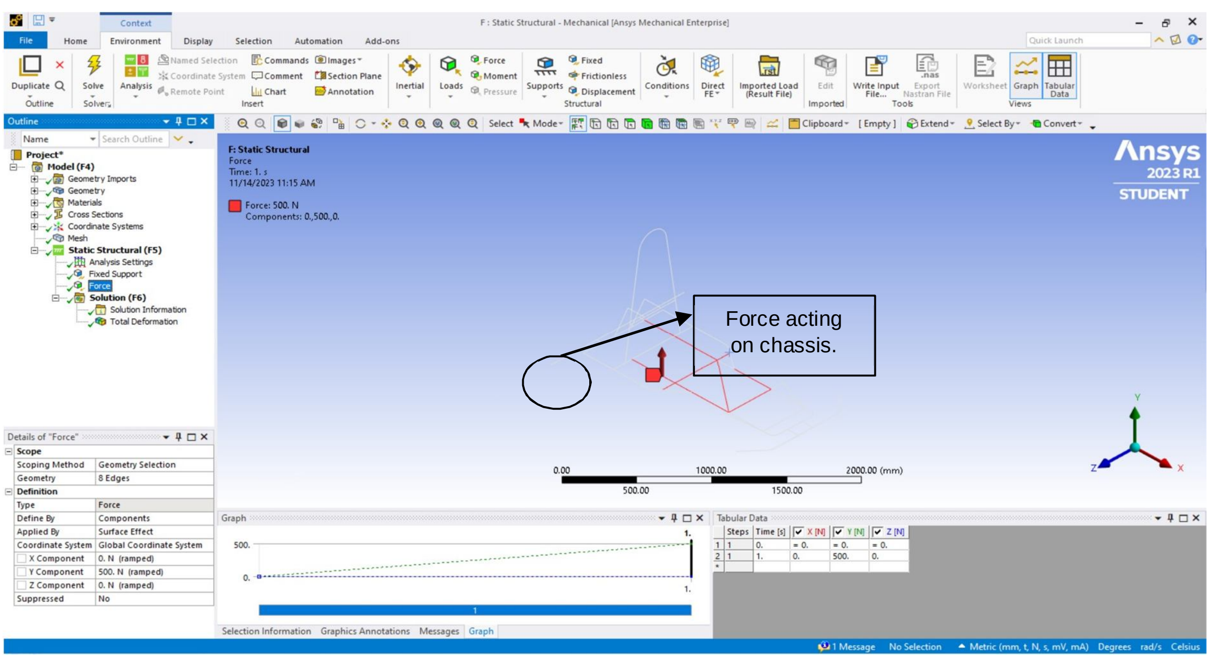

Fig II (i): Force applied for bending moment.

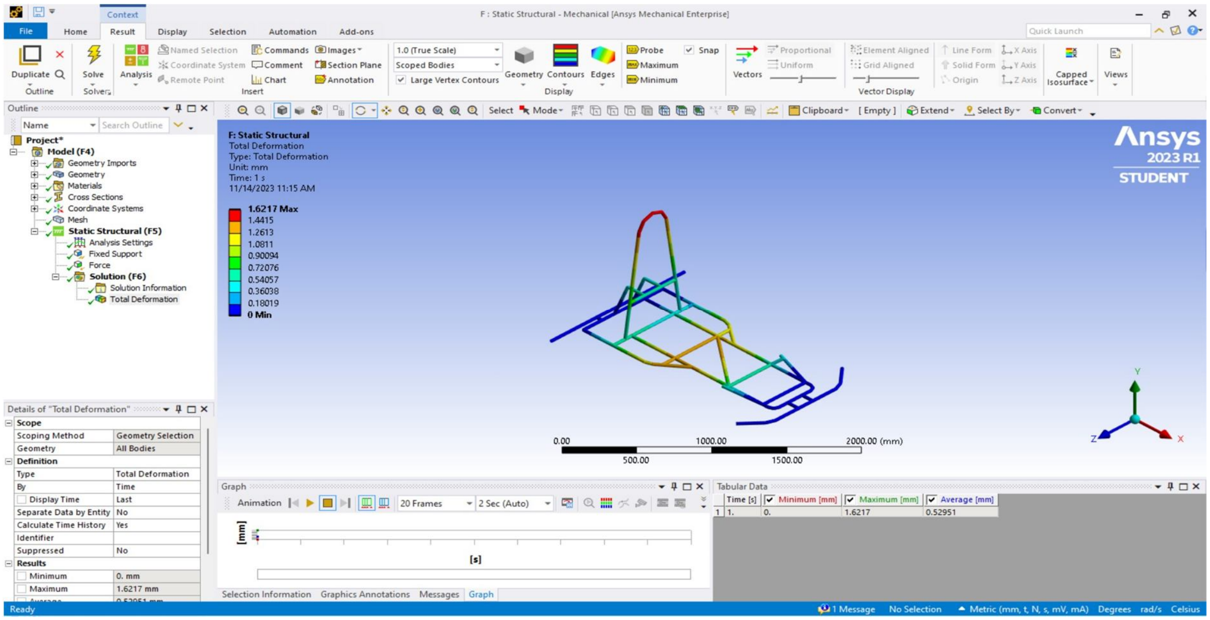

Fig II (ii): Result of bending moment

The maximum deformation in vertical plane by spreading out all the load applied on the chassis = 1.4415 mm in vertical plane

- *Front impact:*

Impact was calculated for an optimum speed of 80 kmph. The impact test force is calculated by the change in momentum in the unit interval of time (1 second). Hypothetically, the kart is given a velocity of 80 Kmph and stops in one second. This gives an impact force on the frame. The analysis based on the mass of the vehicle 180 kg. The force 4000 N is applied to calculate front impact, back impact, and side impact conditions.

In frontal impact test, the rear of the chassis is kept fixed and then the force is applied on the front most member and the amount of force applied is equivalent of impact when a vehicle hits the chassis moving at the speed of 60kmph. The equivalent force of the impact is equal to 2.2 Gs of the vehicle i.e. 2805.5 N.

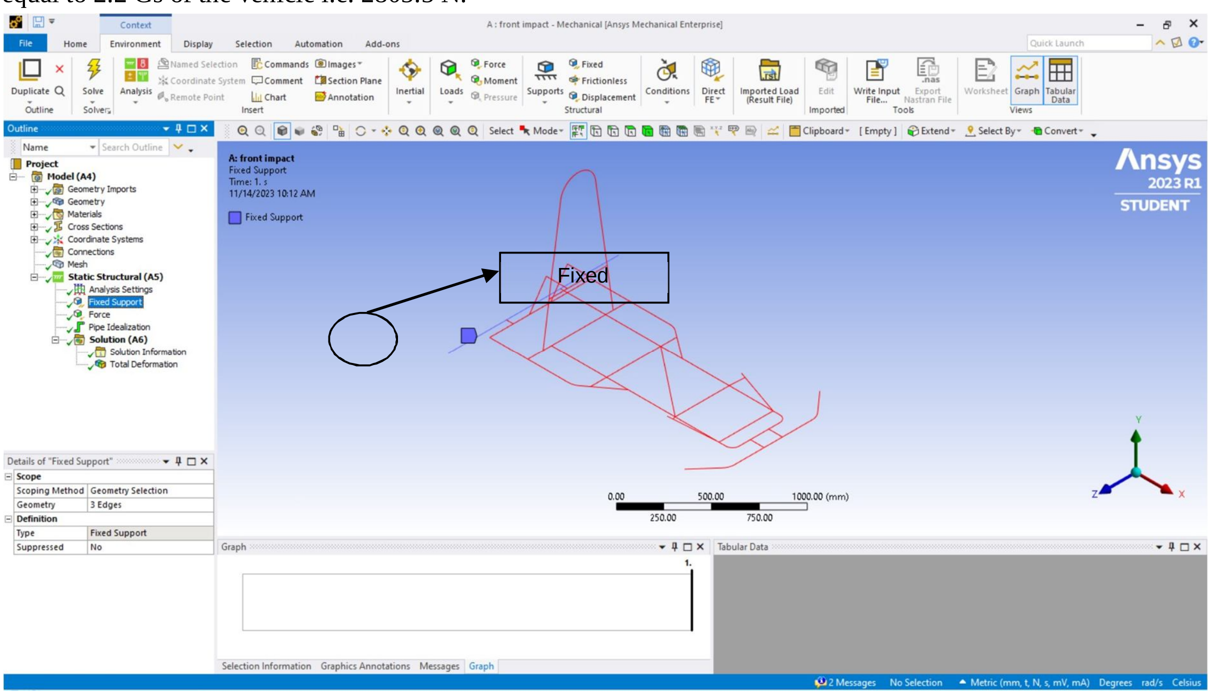

Fig III: Fixed support for frontal impact

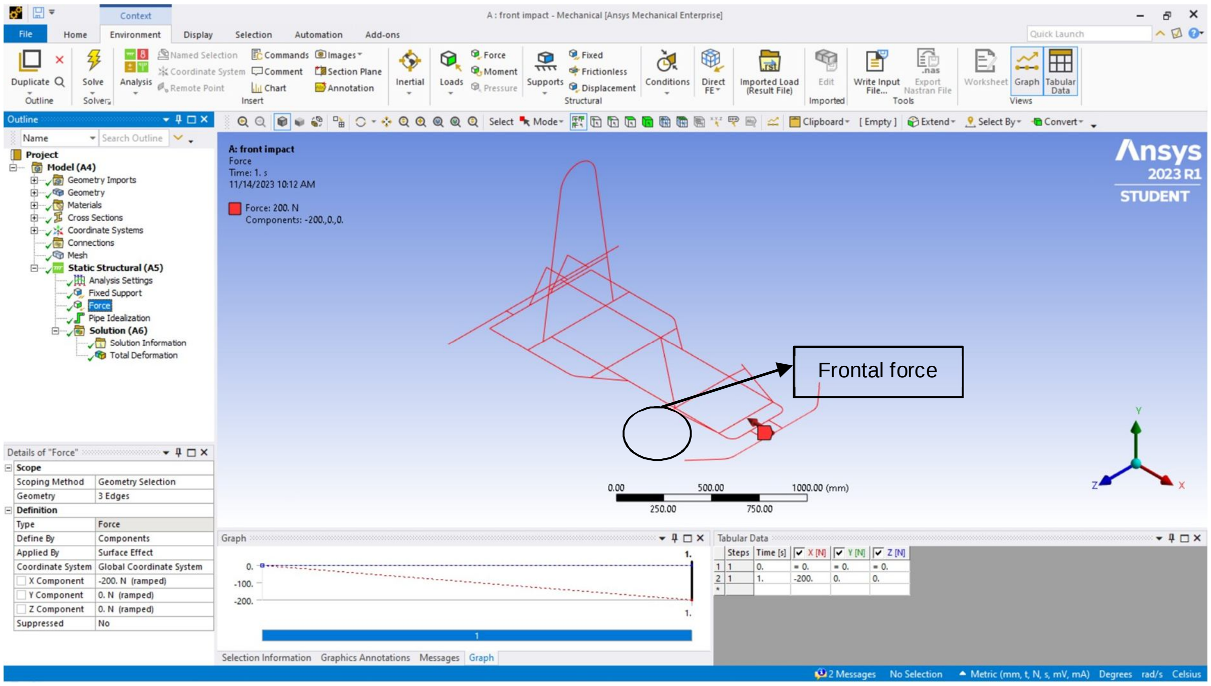

Fig III (i): Force acting from front.

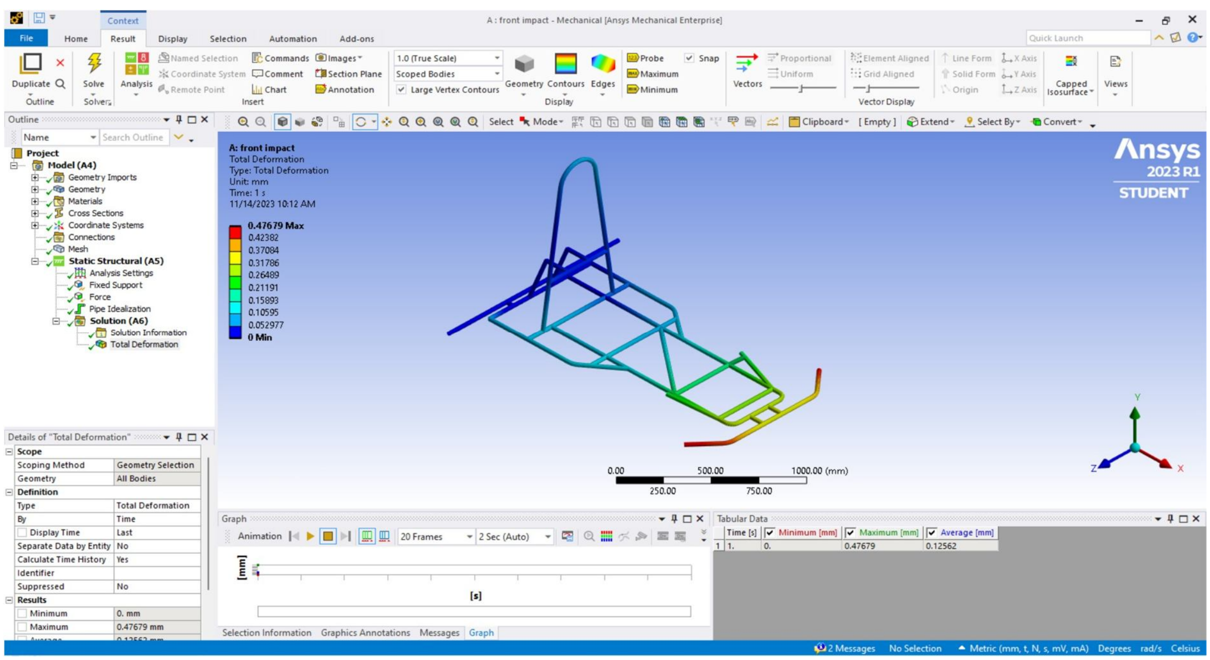

Fig III (ii): Result of frontal impact

In frontal impact test due to the cross bracing forming the nodal point the deformation was reduced and the vehicle is much safer. The maximum deformation is = 8.47 mm

- *Side impact test*

Impact was calculated for an optimum speed of 80 kmph. The impact test force is calculated by the change in momentum in the unit interval of time (1 second). Hypothetically, the kart is given a velocity of 60 Kmph and stops in one second. This gives an impact force on the frame. The analysis based on the mass of the vehicle 180 kg. The force 4000 N is applied to calculate front impact, back impact, and side impact conditions.

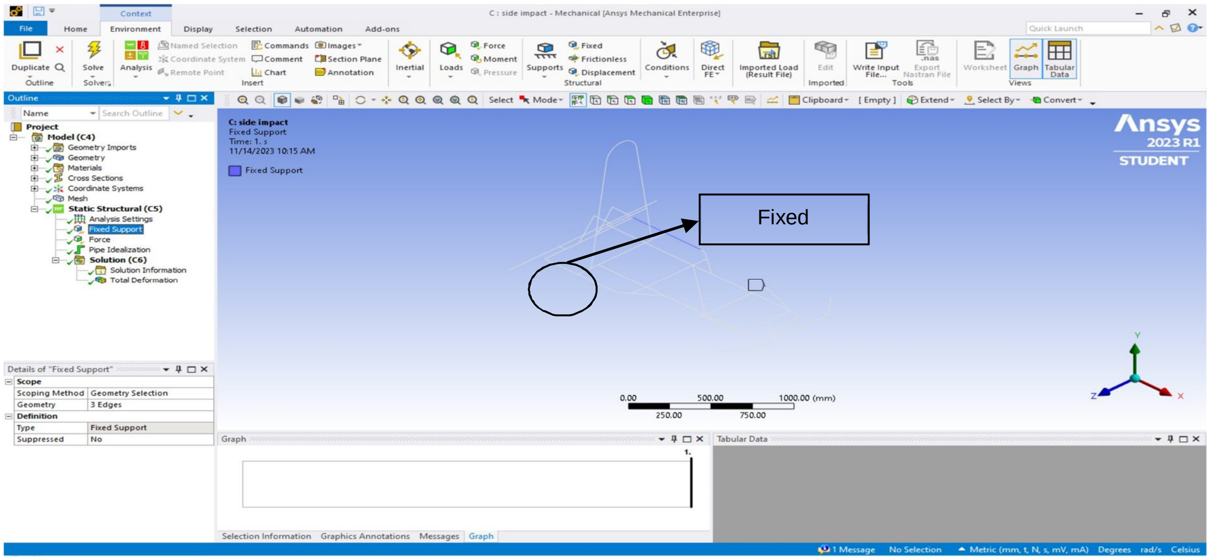

Fig IV: Fixed support for side impact

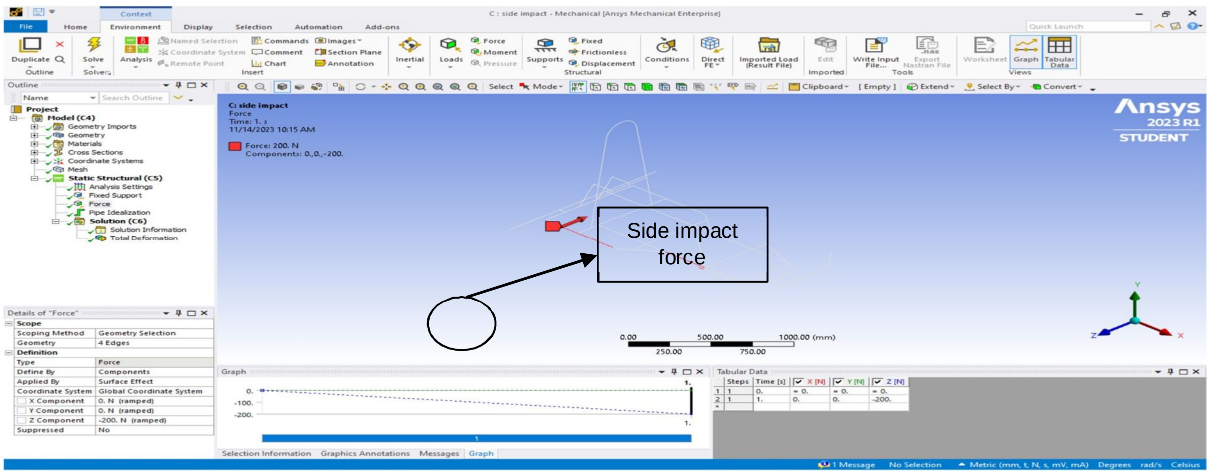

Fig IV(i): Force acting upon sides.

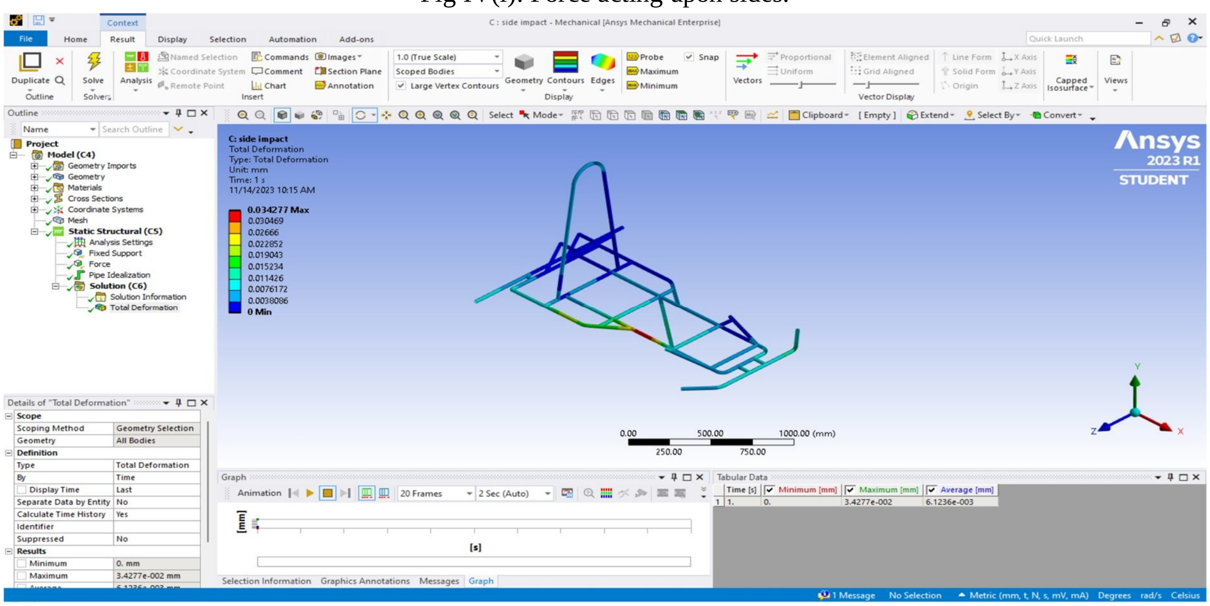

Fig IV (ii): Result of side crash impact

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- *Rear Impact Test:*

Impact was calculated for an optimum speed of 80 kmph. The impact test force is calculated by the change in momentum in the unit interval of time (1 second). Hypothetically, the kart is given a velocity of 60 Kmph and stops in one second. This gives an impact force on the frame. The analysis is based on the mass of the vehicle 209 kg The force 2058 N is applied to calculate front impact, back impact and side impact conditions.

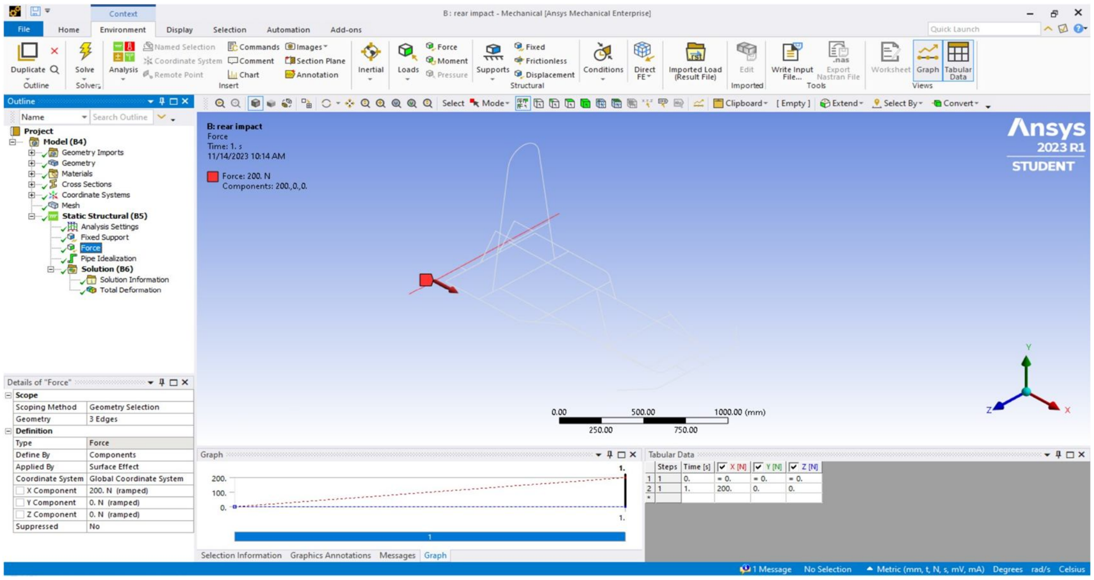

Fig V: Force acting for rear impact.

In the rear impact test, the front is kept fixed, and the force is applied from the rear side i.e., from the rear bumper. The force applied is as a vehicle hits the chassis at 60 kmph and is of 2.2 Gs of its own weight. The equivalent force is 2085 N.

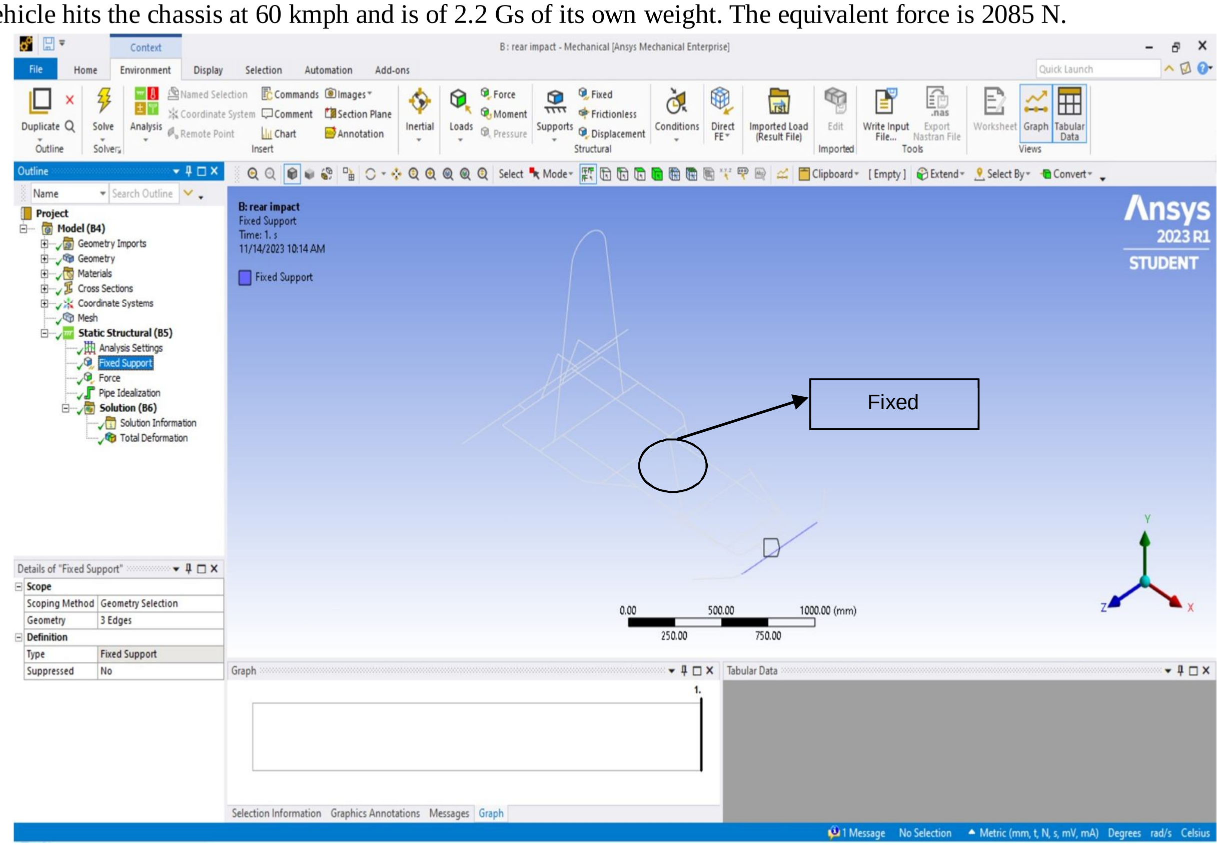

Fig V(i): Fixed support for rear impact

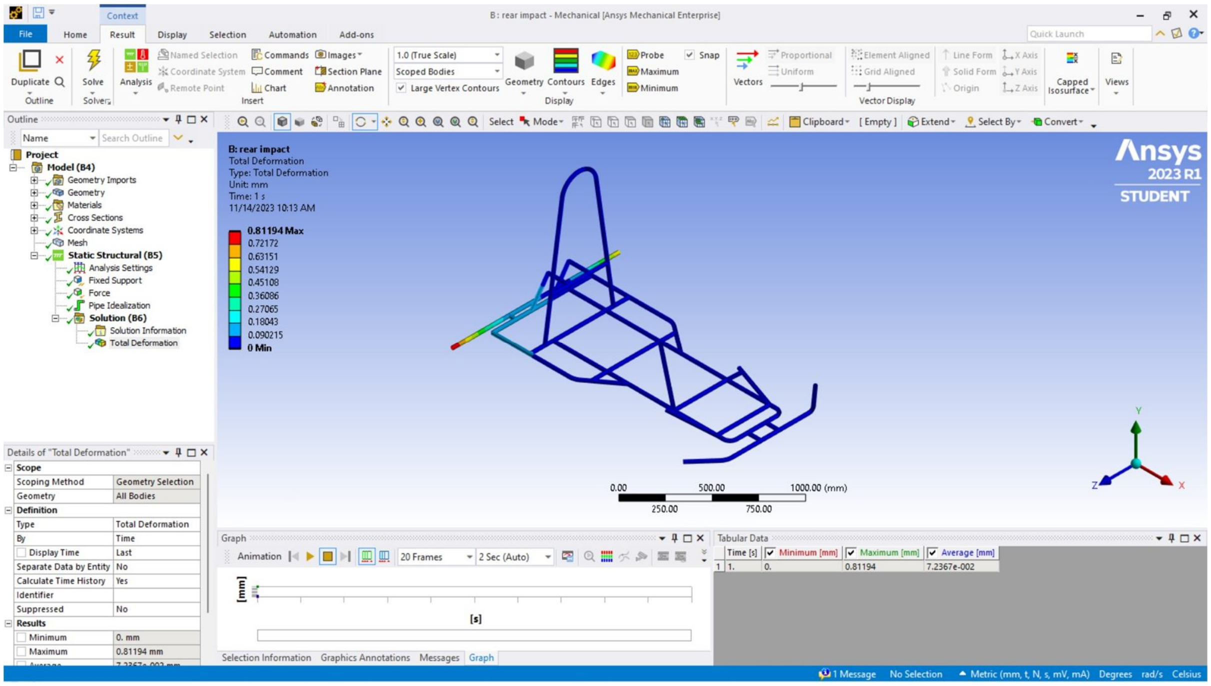

Fig V(ii): Result for rear impact test

IV. CHAPTER 4

A. *Powertrain Design Components Report*

Introduction

EVs have a single-speed transmission which sends power from the motor to the wheels.

The motor is powered by a battery or by multiple batteries which store the electricity required to run an EV. The higher the kW of the battery, the higher the range.

We have used chain drive type Transmission Between motor and drive shaft. The main advantage being its lightweight, highly efficient, low maintenance characteristics.

The E-power train system has the following objectives are:

- To have a combustion free vehicle.
- To have agility in the performance.
- To achieve flexibility on the road.

1) *Motor*

An electric motor is a device used to convert electrical energy into mechanical energy. Scientifically speaking, the electric motor is a unit used to convert electric power into motive energy or electrical energy into mechanical energy.

The most important feature of the Permanent Magnet Synchronous Motor (PMSM) is its high efficiency, given the ratio of input power after deduction of the loss to the input power. Permanent Magnet Synchronous Motors have the potential to provide high torque-to-current ratio, high power-to- weight ratio, high efficiency, and robustness. Due to the above favourable points, PMSMs are commonly used in latest variable speed AC drives, particularly in Electric Vehicle applications.

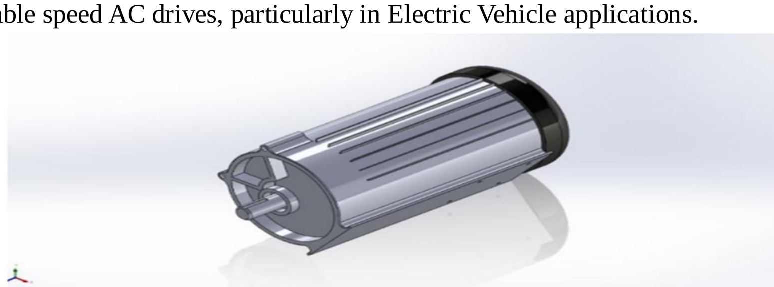

Fig 4.1.1: Cad Model of the Motor

2) Motor Specifications

Table 4.1.1: Motor Specifications

Type:	Permanent Magnet Synchronous Motor
Voltage(V):	60V
No load current (A):	7A
Rated current (A):	80A
Rated speed (RPM):	3500±100
Rated Torque(N-M):	18.9
Max Output Torque (Nm):	56
Rated power(W):	4000
Max. Power Output (W):	5000
Efficiency	>88%
Number of poles:	8
Insulation class:	B

3) Motor Controller

A motor controller is a device used for operating an electric motor and is coordinated in some predetermined manner. A controller can have a manual or automatic system to start and stop the motor, for changing the direction of rotation from forward to reverse, for selection and regulation of speed and for limiting the torque. It is also used to protect the motor from overloads and faults.

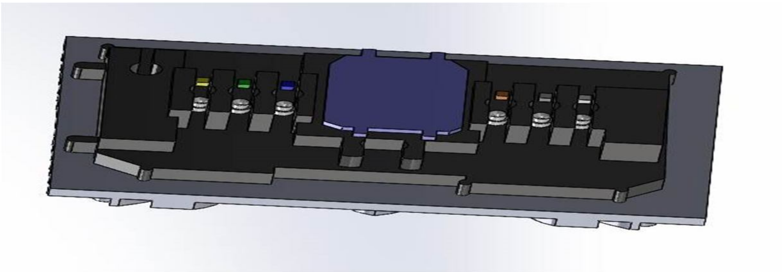

Fig 4.1.2: Motor Controller

- Motor Controller Calculation:

Motor controller discharge power(peak)=Rated Voltage × Peak protection current
= 60×120
= 7.2kw
Motor controller discharge power(continuous)=Rated voltage ×Rated current
= 60×80
= 4800watts
= 4.8kw

- Motor controller Specifications:

Table4.1.2(ii): Motor Controller Specifications

Rated Voltage	60V
Peak protection current	120A
Rated power	7200W
Under Voltage Protection	53V
Throttle voltage	1V to 4.5V
Phase commutation	120 degrees
Brake De-energize	High
Heat dissipation	Natural cooling
Ambient temperature	20 degrees to 60 degrees

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4) Tractive System Disconnect

Fig 4.1.3: Tractive System Disconnect

Specifications:

Table 4.1.3: Tractive System Disconnect specifications

Current Rating	450A
Voltage Ratings	600A
Contact Barrel Wire Size (AWG/mm2)	1/0 to 300 mcm 53.5 to 152.0
Maximum Wire Insulation Diameter (mm)	27.9mm
AVG Contact Resistance (micro-ohms)	50
Insulation Withstanding Test Voltage (Volts AC)	2200
Contact Retention Force (ibf)	150
a. No load (Contact/Disconnect Cycles) b. Under Load Hot Plug 250 cycles @120V	To 10,000 100A
Avg. Connection/Disconnect (ibf)	30
Operating Temperature Range	(-20º to 105º/-4º to 221º) (-40º to 125º/-40 to 257º)

5) Accumulator

An accumulator is an energy storage device that accepts, stores, and releases energy as needed. Based on our requirements, we chose a 64V And 75 amps lithium-ion phosphate battery, which consists of 5 cells connected in parallel and 20 cells connected in series, where each cell has 3.2volt.

Dimensions of the Accumulator: 810×240×175mm

Accumulator calculation:

Lithium-ion battery:

Voltage:64 volts

Ampere:75 amps

Each cell voltage: 3.2volt

Number of cells :20×5=100 cells

Peak voltage:64V

Continuous rating:1.5C

Peak Rating=5C

Charge=75Ah

Accumulator Discharge Power (Peak)= (Peak Rating ×Charge) ×Voltage

= (5×75) ×64

= 24000watts

= 24kw

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Accumulator Discharge Power (continuous)= (Continuous rating charge) ×Voltage
= 1.5×75×64
= 7200watts
= 7.2kw
Accumulator Peak Voltage = Individual cell voltage × no. of parallel cells
= 3.2×20
= 64V
Cell type: Cylindrical cell
Because of the light weight, we are using a cylindrical cell.

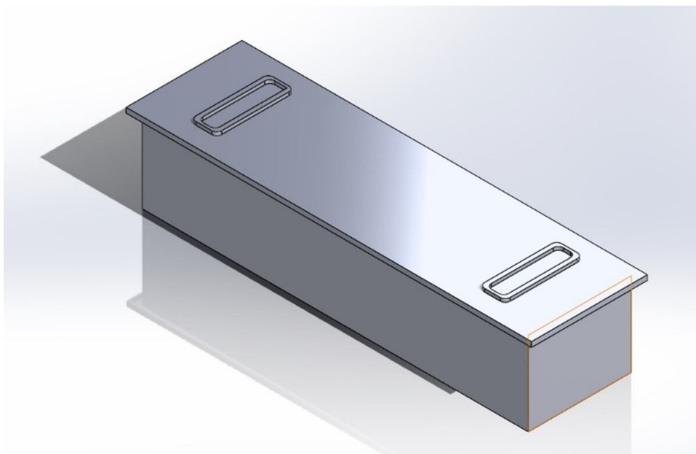

Fig 4.1.4: Accumulator

- Battery cell data specifications:

Table 4: Battery cell data specifications

1	Company	Mechatronic
2	Model	11048/11060
3	Voltage	3.2V
4	Charge	75Ah
5	C rating	5C
6	Rated C Rating	1.5C
7	Dimensions	810×240×175
8	Cell type	Cylindrical

- Battery pack data:

Table 5: Battery pack data specifications

1	Voltage	64V
2	Charge	75 Ah
3	Dimensions	810×240×175
4	Weight	39.5kgs
5	Wall Thickness	2mm
6	Insulation	Hard Foam
7	Series	20 series

- Accumulator management system:

Table 6: Accumulator specifications

1	Model	JK-B1A24515P
2	Battery type	Lithium Ion
3	Balance Method	Active Balance
4	Balance Current	1A
5	Continuous Current	150A
6	Peak current	300A
7	No. of Battery Strings	8-24

6) Accumulator Charger

Table 4.1.5: accumulator charger specifications

S.no	Product Model	LF1C6908
1	Rated Voltage	260V-50Hz
2	Rated Input power	AC-632W
3	Output Current	DC:69.3V
4	Rechargeable Range	DC8A±10%

Fig 4.1.5: Accumulator charger

7) Sprocket Calculation:

$$\frac{Teeth\ in}{Teeth\ out} = \frac{Torque\ in}{Torque\ out} = \frac{Rpm\ out}{Rpm\ in}$$

Assume secondary teeth=27

Torque in =126 N-m

Teeth in =12

Rpm out =3500

$$\frac{Teeth\ in}{Teeth\ out} = \frac{Torque\ in}{Torque\ out}$$

$$\frac{12}{27} = \frac{56}{X}$$

X=126 N-m

RPM calculation:

$$\frac{Teeth\ in}{Teeth\ out} = \frac{Rpm\ out}{Rpm\ in}$$

$$\frac{12}{27} = \frac{X}{3500}$$

X=1555.55 rpm

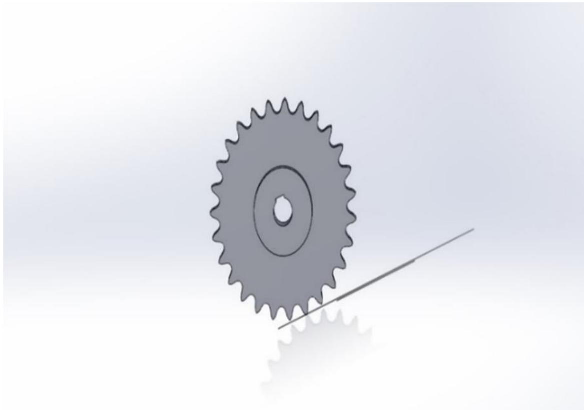

Fig 4.1.6: Sprocket

Rpm converted to speed:
Formula for finding the rpm to speed.
K= D×R×0.001885
Where:
K=Speed in kmph
D=Diameter of wheel in cm
R= Revolutions per minute (RPM)
Diameter of the wheel in cm= 27.9
Rpm =1555.55
K= 27.9×1555.55×0.001885
K=81kmph

8) Force Appiled On Shaft

- Shaft Material:

The selection of the mild steel material has specific applications in cost-effectiveness, machinability, weldability, ductility and formability, moderate strength, and versatility.

- Shaft Material Specifications:

Table 4.1.7: Shaft Material Specifications

Shaft Material	Mild Steel
Length	1100mm
Diameter	29mm

- Shaft Calculation:

The forces applied to the shaft are the whole force, like engine torque, and the remote load that is being rotated by the shaft.
Here, torque on the shaft per 1 sec equals the angular momentum.
Torque=200
Yield strength=250MPA
Finding the shear stress:
Torque(T)=$\frac{\pi}{16} \times d^3 \times \tau$
$\tau = \frac{200 \times 16}{\pi d^3}$
$\tau = \frac{1018.59}{d^3}$
Tyre weight= 6kgs
Gravitational Force=9.81
Co-efficient friction of track =0.8
σt=$\frac{load}{\text{area}}$

$\sigma t=\frac{6\times 9.81\times 0.8}{\frac{\pi}{4}\times d^2}$

$\sigma t=\frac{59}{d^2}$

Maximum principal stress theory:

$\frac{\sigma t}{2}+\frac{1}{2}\sqrt{(\sigma t)^{2}+4\tau^{2}}=\frac{\sigma y}{FOS}$

Where:

σ y = yield strength = 205×10^6

FOS=Factor of Safety =4

$\frac{29.5}{d^{2}}+\frac{1}{2}\sqrt{(\frac{59}{d^2})^{2}+4(\frac{1018.59}{d^3})^{2}}=\frac{205\times 10^6}{4}$

D=0.02709m

D=27mm

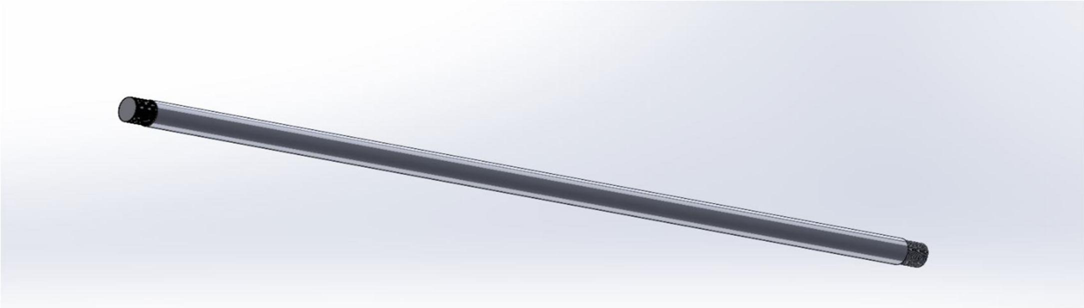

Fig 4.1.7(iii): Mild Steel Solid Shaft

- Mesh Analysis:

Fig 4.1.7(iv): Shaft mesh Quality

- Stress Analysis

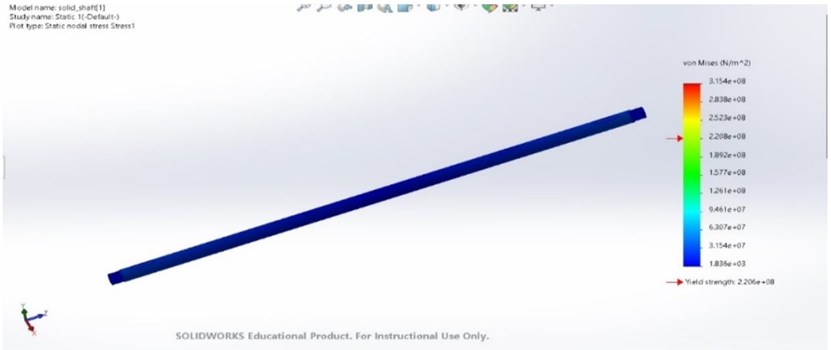

Fig 4.1.7(v): Shaft static stress yield strength = 2.206N/m^2

- Strain Analysis:

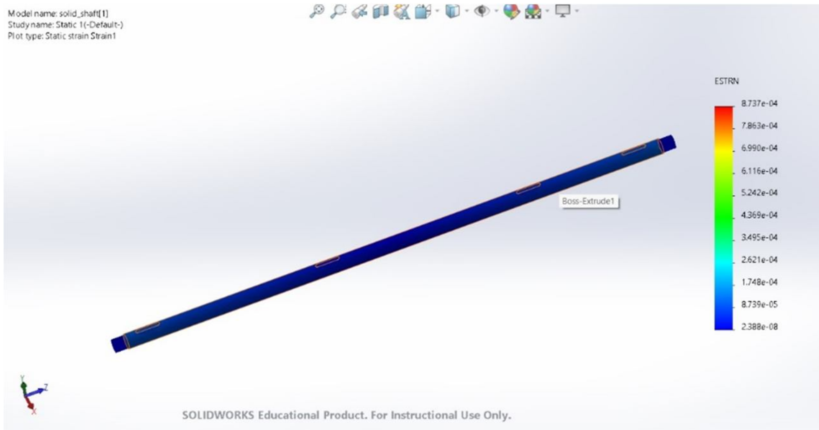

Fig 4.1.7(vi): Shaft static strain Maximum strain = 8.737N/m^2 Maximum strain = 2.388N/m^2

- Displacement Analysis:

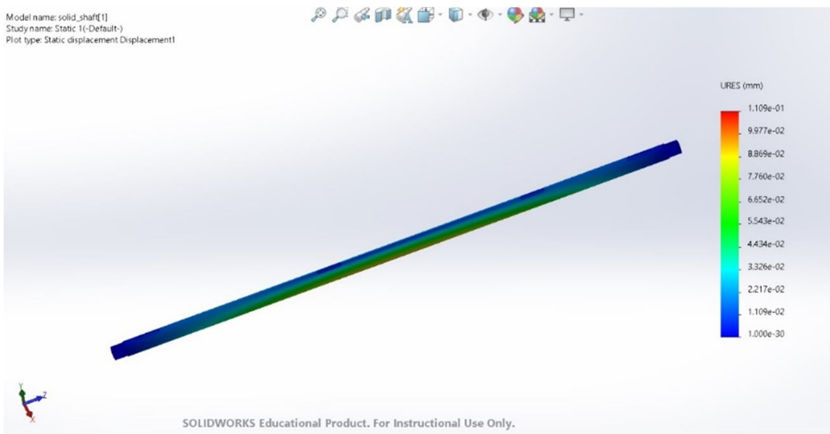

Fig 4.1.7(vii): Shaft static displacement = 1.109N/m^2

- Factor of Safety Analysis:

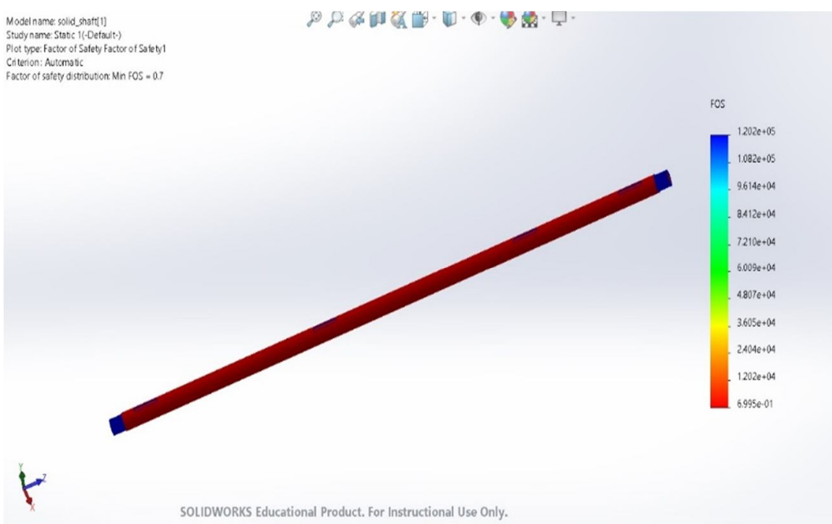

Fig 4.1.7(viii): Factor of safety distribution Minimum FOS = 0.7

B. Relay Box

A relay box is a container which is used to store the Low Voltage circuits and we have manufactured and re-designed this box as per our requirements.

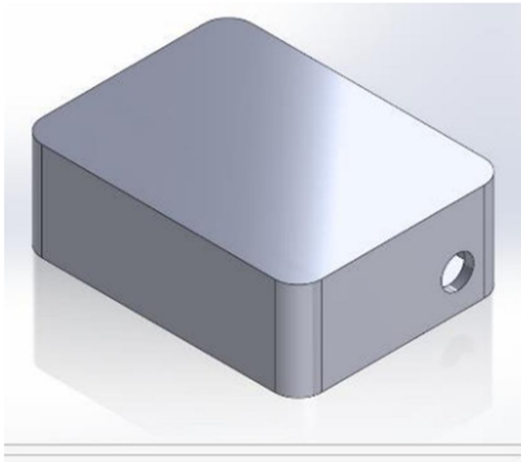

Fig 4.2: Relay Box

C. Chain Guard

Chain guards are utility casings enclosing the sprocket and chain assembly. In simpler terms, they refer to the outer covering that surrounds our drive chain. It protects its chainrings from being bashed and destroyed by debris, rocks, and humans. We have chosen mild steel with the thickness of 2mm for the better stability and sustainability.

Fig 4.3: Chain Guard

V. CHAPTER 5

A. Vehicle Dynamics

Vehicle dynamics is the application of classical mechanics in physics to cars to predict and control motion. The understanding of various types of Forces, moments and their effects on the vehicle is a critical study to understand and predict the behaviour of the vehicle in dynamic conditions.

1) *Vehicle specifications:* - The vehicle was designed for the event Go-kart Design Challenge. Thus, it's designing we have done according to the rules specified in the rulebook.

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Table5.1(i): Vehicle specification

Mass of vehicle	120kg
Mass of vehicle with driver	180kg
Mass on front wheels	63kg
Mass on rear wheels	117kg
CG height	0.12m
CG distance from front tire	0.66m
CG distance from rear tires	0.35m
Wheelbase	0.96m
Front track width	0.91m
Rear track width	1.09m
Front tire nomenclature	10*4.5-5
Rear tire nomenclature	11*7.10-5
Rim diameter	0.12m
Front tire outer diameter	0.25m
Rear tire outer diameter	0.27m

2) Steering

The steering gear mechanism is used for changing the direction of two or more of the wheel-axles with reference to the chassis, to move the automobile in any desired path. In go kart the two back wheels have a common axis, which is fixed in direction with reference to the chassis and the steering is done by means of the front wheels. To avoid skidding, the two front wheels must turn about the same instantaneous centre to avoid the wear of tyres. This is perfectly fulfilled by Ackermann steering geometry method.

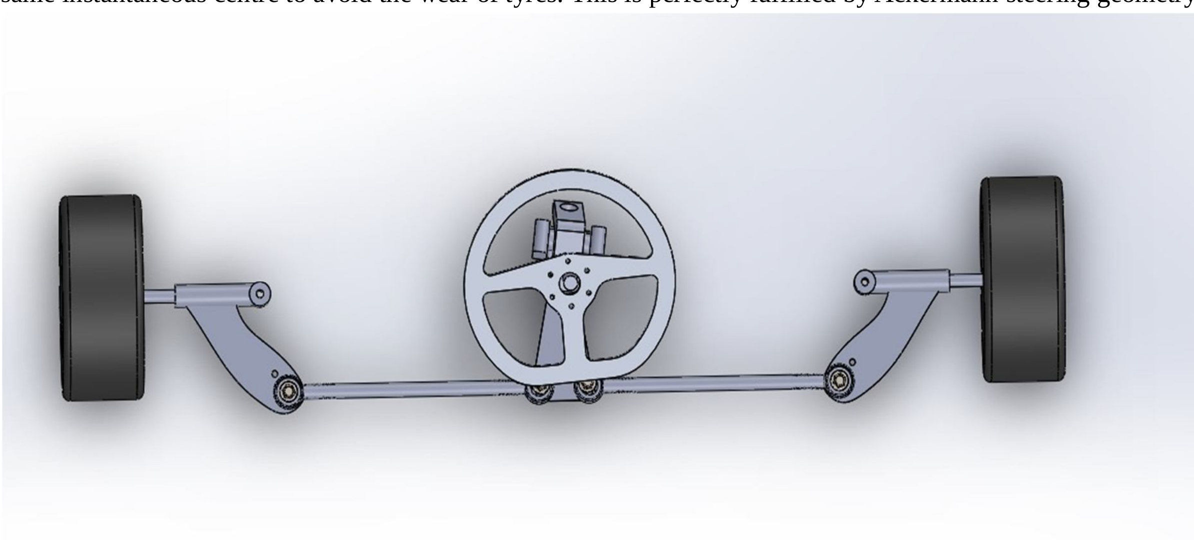

Fig 5.1(ii): Steering setup

3) Steering parts

Material selected for all the steering components is mild steel except steering column Became Mill steel is a popular choice for many applications due to its versatility, availability, and com effectiveness and by considering its advantages as follows: -

- Strength to weight ratio
- Ductile
- Weldable
- Ideal mechanical properties
- Favorable chemical properties

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B. Mechanical properties of mild steel: -

Table 5.2: Mechanical properties of mild steel

Properties	value
Density	7.87 g/cm^3
Ultimate tensile stress	350 Mpa
Yield tensile stress	220 Mpa
Youngs modulus	210 Mpa
Poisson's ratio	0.33

1) C Mount:

C Mounts consists of 3 parts: kingpin, stub axle and steering arm and it is also called knuckle. A knuckle is a rigid link mounted on a fixed joint known as king pin which acts as pivot to direct the tyre by rotating the link called stub axle on which the wheel is mounted. This stub axle is controlled by steering arm link which is adjacent to stub axle at certain angle attached to pivot of knuckle. The angle between stub axle and steering arm equals ninety degrees plus Ackermann angle.

2) knuckle: -

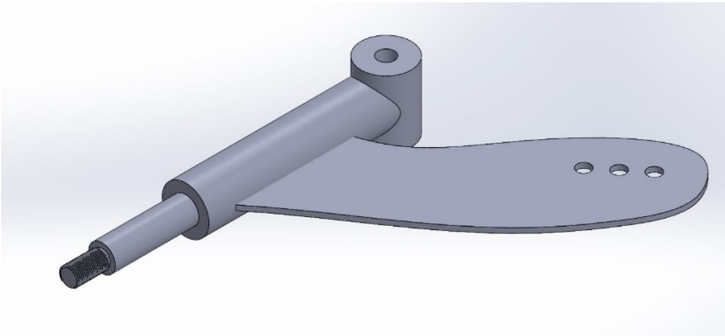

Fig 5.2(ii). CAD Model of Knuckle

Fig 5.2(ii): Model of Knuckle

C mount Specification: -
Material-MS
Thickness -3 mm

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C. Analysis of C mount: -

1) c mount mesh: -

Fig 5.3(i): C mount

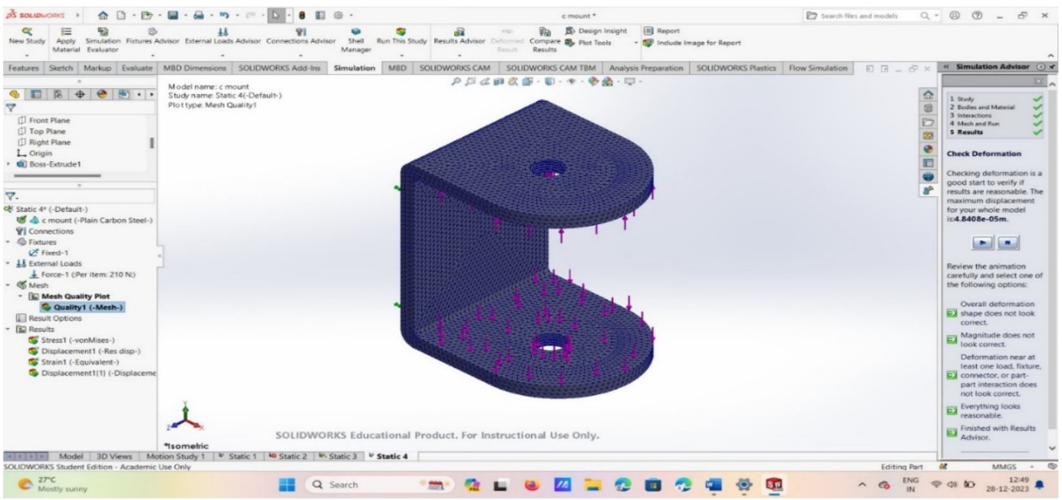

Fig 5.3(i) : Mesh analysis of c mount

2) C mount stress: -

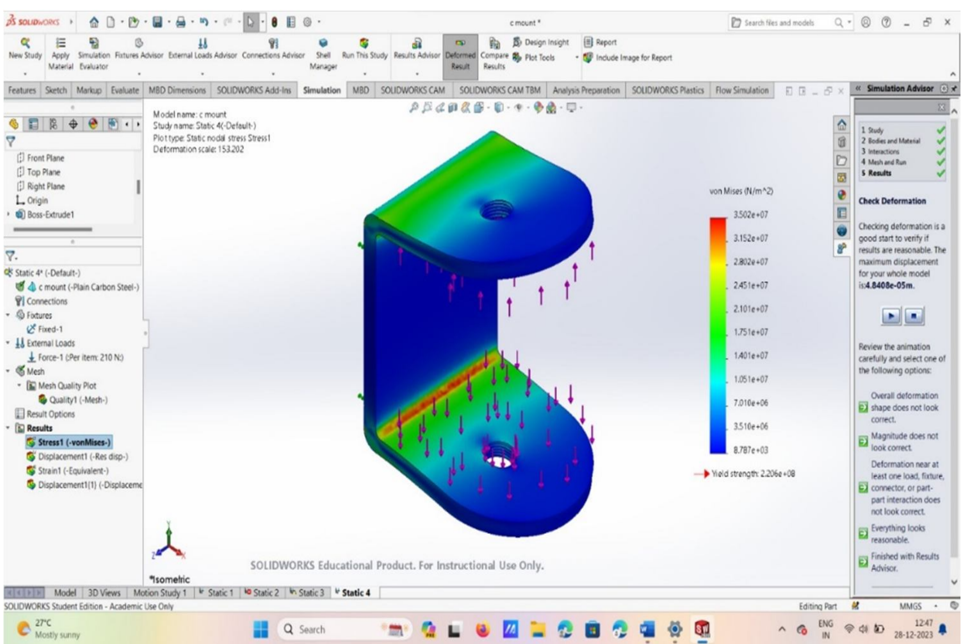

Fig5.3(ii): Stress analysis of c mount

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3) C mount displacement: -

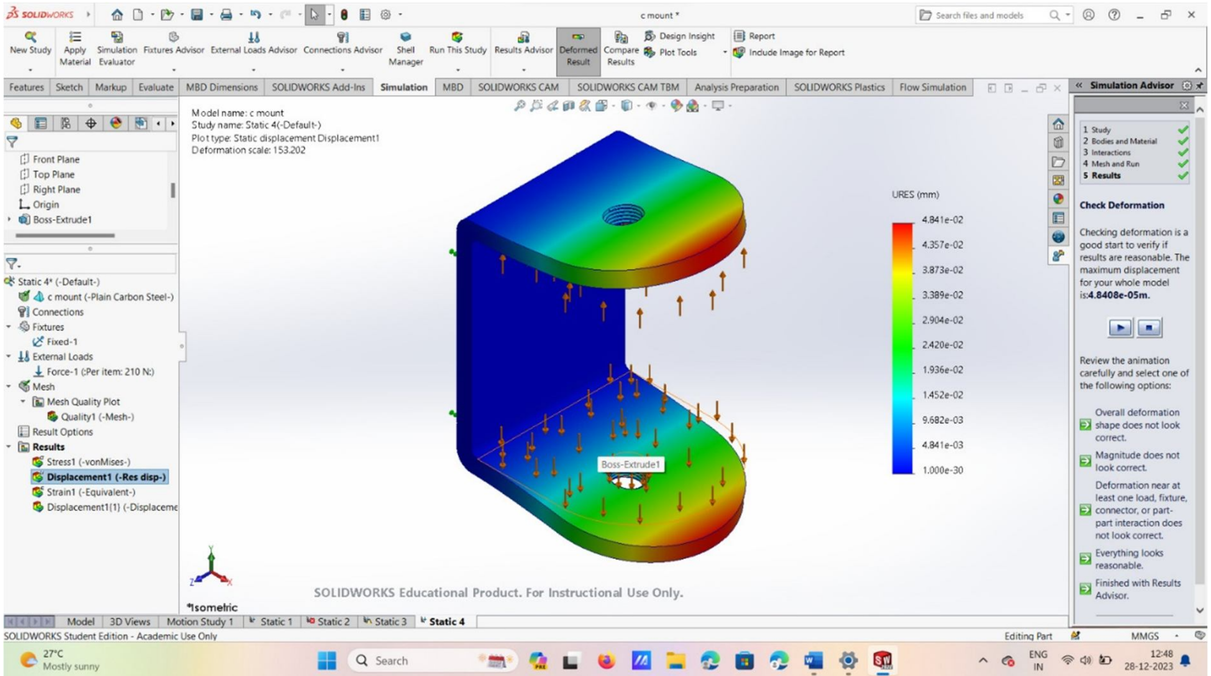

Fig5.3(iii): Displacement of c mount

D. King Pin

It is a joint usually a bolt which holds an axis about which the knuckle rotates the wheel. It can also be called as the pivot point of knuckle.

Fig5.4: King pin bolt

E. Tie Rod

It is a simple free moving link connected between steering zarm and pitman arm and uses rod end bearing as joints.

Fig5.5: Tie rods

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Specifications: -
Material – MS rod
Thickness – 2.5mm
Dimensions – 28 cm length

F. Tripod:

It is a member, usually a plate fixed perpendicular to steering column with holes drilled in it to further assemble with tie rods.

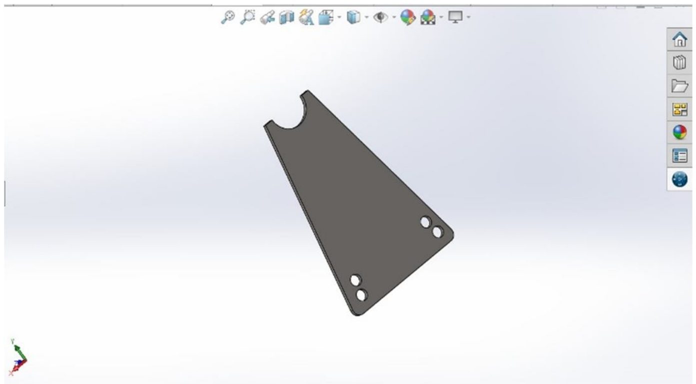

Fig 5.6: Tripod cad model

Specifications: -
Material: mild steel
Thickness:3mm

1) Analysis of tripod: -

- Tripod mesh: -

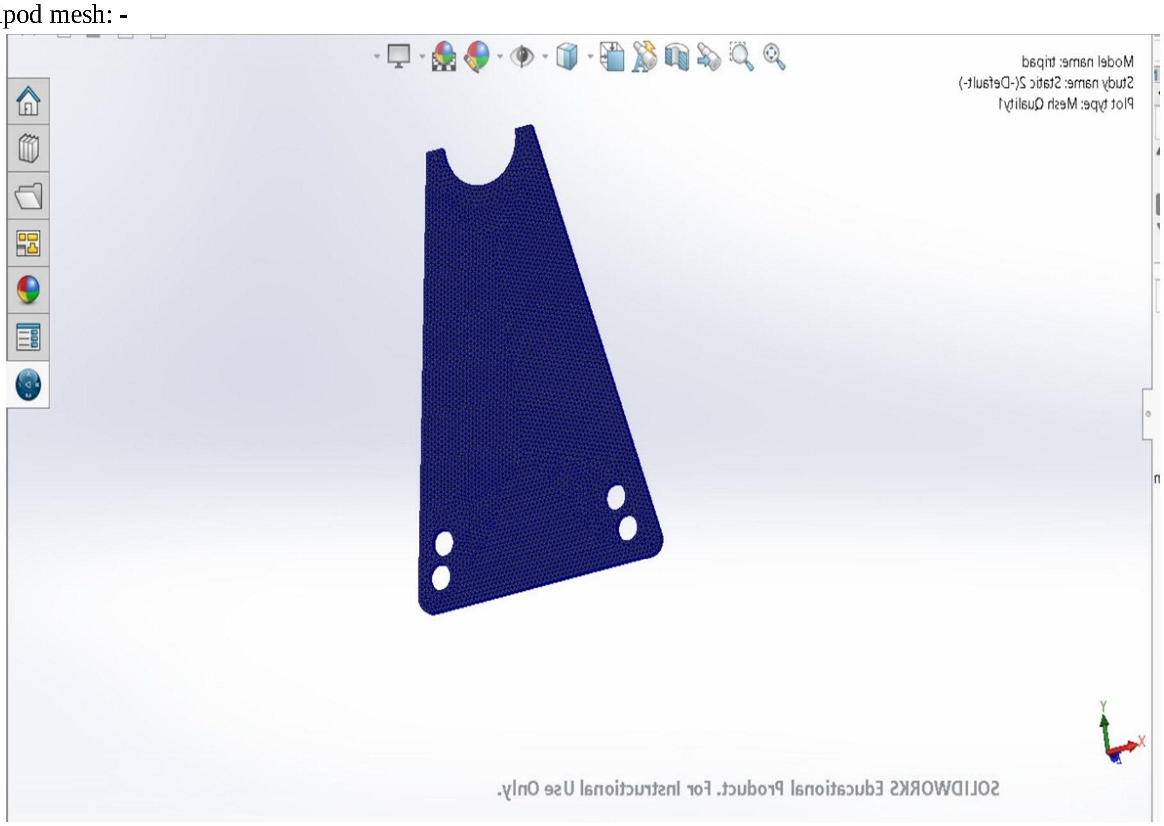

Fig 5.6.1(i): Mesh analysis of tripod

- Tripod stress: -

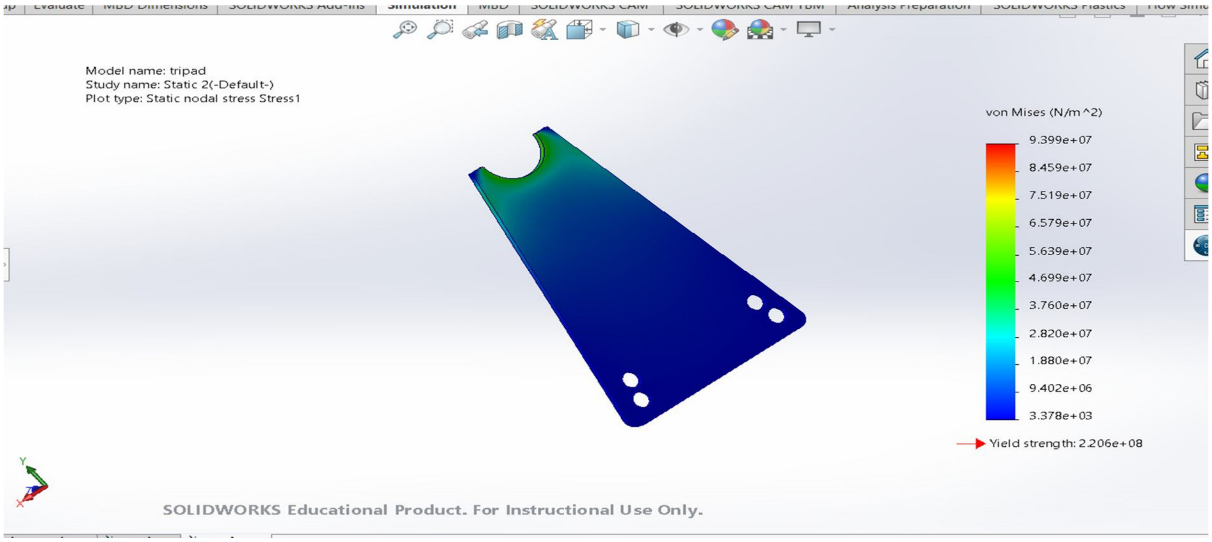

Fig 5.6.1(ii): Stress analysis of tripod

- Tripod strain: -

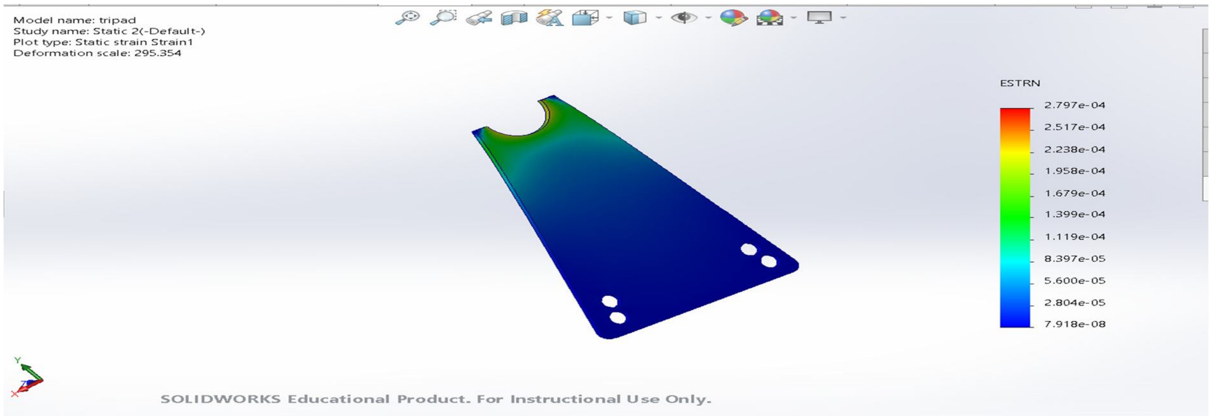

Fig 5.6.1(iii): Strain analysis of tripod

- Tripod displacement: -

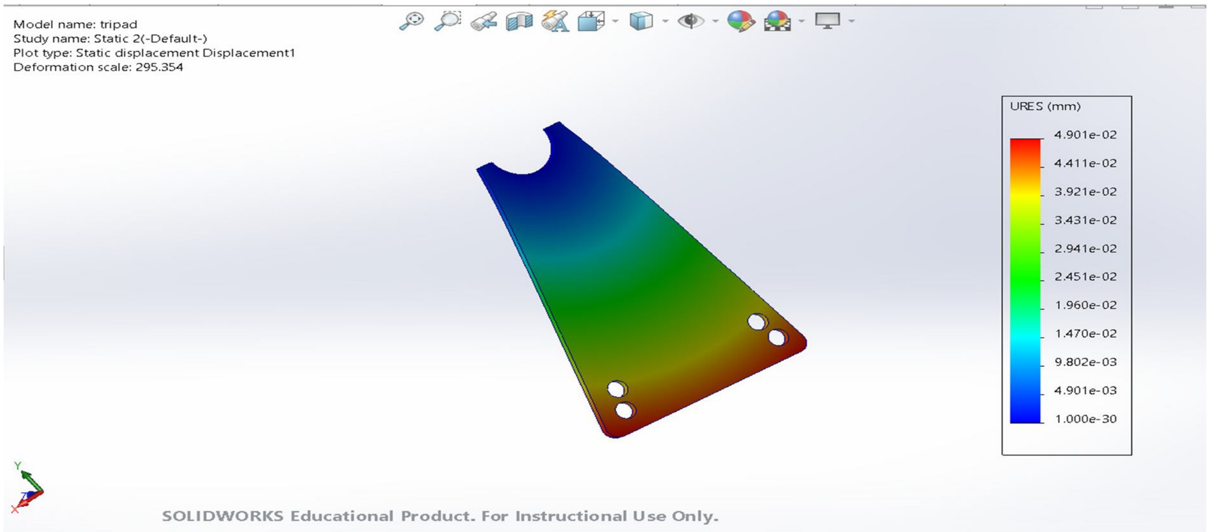

Fig 5.6 .1(iv): Displacement of tripod

G. Steering column

It is a shaft connected to steering wheel by means of hub. Steering Wheel. It is member used to rotate the steering column by driver. We have used chromoly steel because of its high yield strength, tensile strength, and hardness. AISI 4130 (chromoly) is a low-alloy steel that contains 1% chromium and 0.2% molybdenum, which act as strengthening agents.

We have used **universal joint** for better adjustment and driver ergonomics.

Specifications: -

Material-4130 chromyl steel

Thickness-1.4mm

Fig 5.7(i) : Universal joint

Fig 5.7(ii): CAD model of steering column

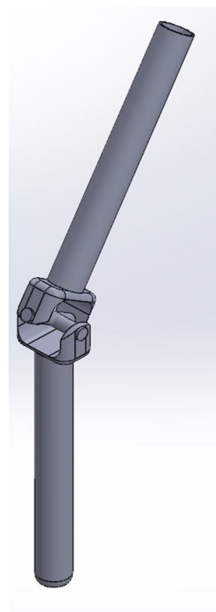

Fig 5.7(iii): CAD model of universal joint

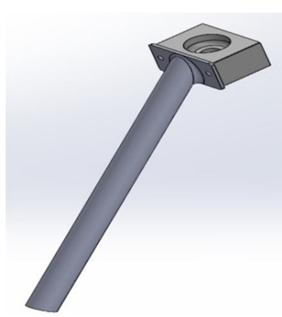

Fig 5.7(iv): CAD model of steering column support

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H. Mechanical properties of 4130 Steel

TABLE5.8: Mechanical properties of 4130 steel:

Properties	Value
Tensile strength	731 Mpa
yield strength	460 Mpa
Density	7850 kg/m^3
Modulus of elasticity	205 Gpa
Poisson’s ratio	0.285

1) *Steering Wheel:* It is wheel used to rotate the steering column by driver.

Material – mild steel

Thickness – 2.5mm

Dimensions – 127 mm radius

Fig 5.8.1: Design of steering wheel

2) *Steering wheel hub:* - the steering wheel hub is the central part that connects the steering wheel to the steering system. It enables the driver to control the go-kart's direction and is linked to the steering column. The hub incorporates a quick release mechanism, chosen for driver comfort and ease of use.

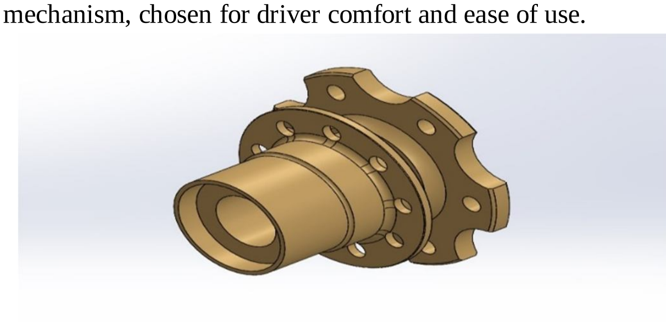

Fig 5.8.2(i): Design of quick release hub

Fig 5.8.2(ii): Quick release hub

I. Steering Geometry: -

1) Camber angle: -Camber angle is the angle between the vertical axis of a wheel and the vertical axis of the vehicle when viewed from the front or rear of the vehicle. It is used to design steering of a vehicle. If the top of the wheel is farther out than the bottom, then it is called positive camber and if the top is closer to the vertical axis than the bottom then it is called as negative camber.

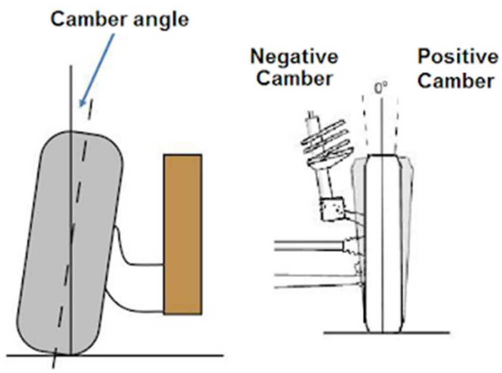

Fig 5.9.1: Camber angle

Negative camber was chosen as it increases stability and increases the contact patch during cornering. After multiple iterations -1.5 degrees provided the desired contact patch during turns in the front and camber change rate was between (-0.5 to -3 degrees). We have chosen negative camber for improving handling and stability during cornering for perfect turns, and we have chosen only 1.5 degrees of negative camber because if it is more it can lead to uneven tire wear and reduced traction.

2) *Caster angle: -* Caster angle is the angular displacement of the steering axis from the vertical axis of a steered wheel in a car or bicycle, when seen from side of the vehicle. it passes through the centre of the KPI for the cars having KPI.

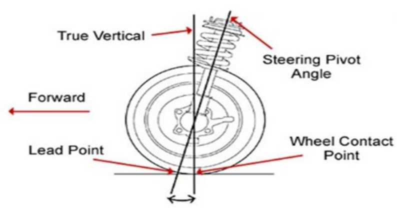

Fig 5.9.2: Caster angle

We have chosen the front wheel at 6 degrees of caster because it provides good centring force, does not wander around and provides straight- line stability and enhances handling during cornering etc.

3) *Toe in & toe out: -* Toe in (positive toe), is the front tires pointing towards the centre line of the vehicle when we look from the top, in the contrary toe out (negative toe), is the tire pointing away from the centreline of the vehicle.

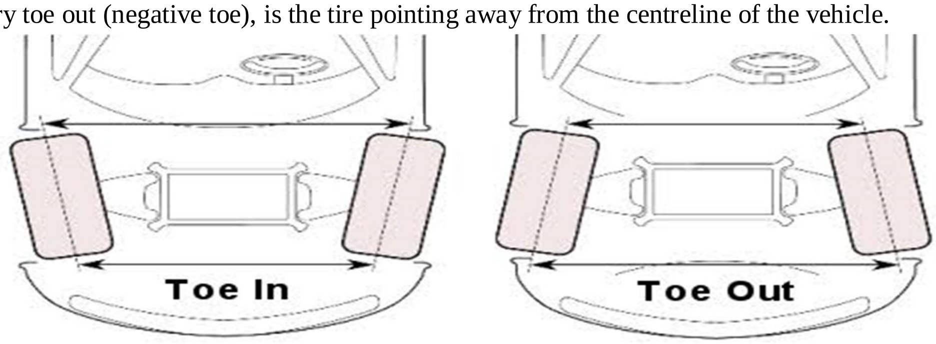

Fig 5.9.3: Toe in & Toe out angles.

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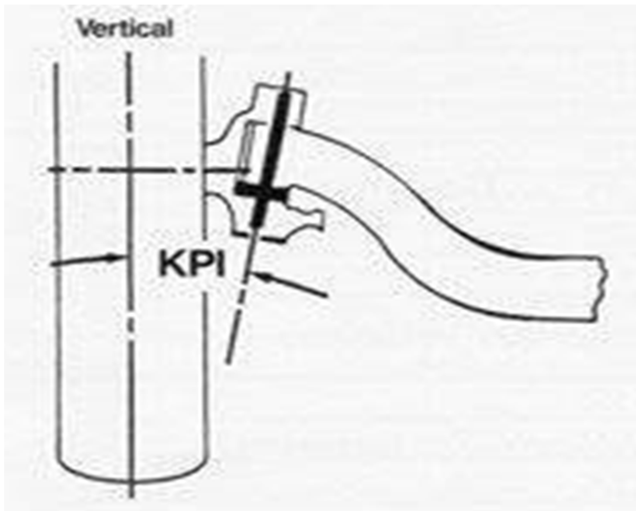
Toe in typically reduces oversteer and toe out, understeer. They enhance steering stability and improve the drive feel in cars etc. Running zero toe will make the car feel relatively stable in a straight line at high speeds. It will also make the car feel more neutral when taking long sweeping corners and slower tight corners. Zero toe on the rear wheels will reduce the acceleration capabilities of the car but will increase the top speed of the car due to the tyre rolling in its most efficient direction. This also means that the lifetime of the tyre is increased but it takes longer to heat up to its operating temperature. By comparing the effects of toe in and toe out, we have decided to keep zero toe in and toe out for our cart.

4) *King pin inclination (KPI) or steering axis inclination:* **-** KPI is the angle formed between the king pin centre and the vertical line or axis when viewed from the front or rear of the car. KPI was taken a



s Fig 5.9.4: king pin inclination angle

5) *Scrub radius:* **-** The scrub radius is the distance at the road surface between the tire centre line and the SAI or KPI line extended downward through the steering axis. The positive scrub radius helps while parking as it rolls the tire while turn the wheels and negative scrub decreases the sensitivity of the steering to brake input. As our kpi is 3 degrees we got 55 mm of positive scrub radius.

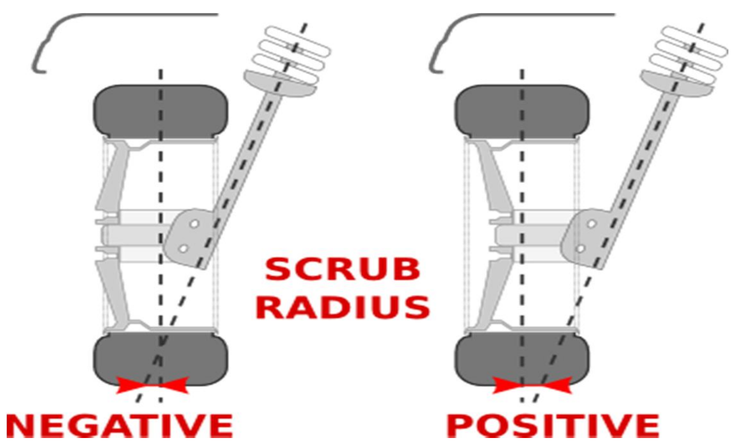


Fig 5.9.5: Scrub radius

6) *Calculation:* **-**

Wheelbase[l]:0.96m

front track width [ft]:0.91 m

rear track width[rt] :1.09 m

stub axle length[c]:0.66 m

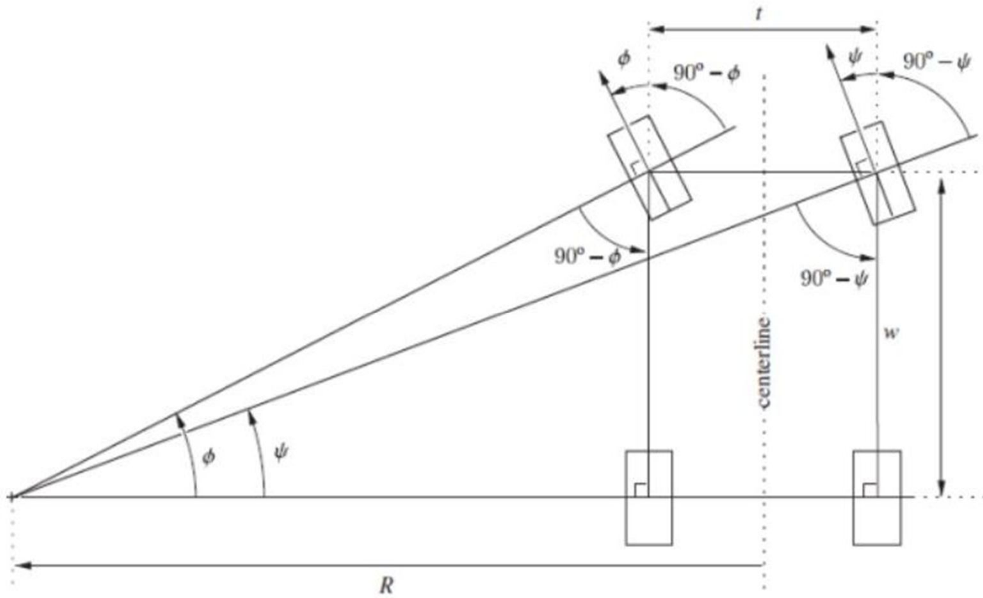


Fig 5.9.6: Ackermann layout

1.inner wheel angle(θ) = 2*$\tan^{-1}$ (ft/2l)
=2*$\tan^{-1}$ (0.91/2*0.96)
θ =50.71°

2.outer wheel angle(ϕ) = cot ϕ-cot θ=c/l
= cot ϕ-cot (50.71) = (0.66/0.96)
ϕ =33.58 °

3.Ackerman angle(α) = $\tan^{-1}$ (c/2l)
= $\tan^{-1}$ (0.66/2*0.96)
α =18.97

4.turning radius(r)=l/2sin α
=0.96/2*sin (18.97)
r =1.56m

5.Ackerman value= $\tan^{-1}\left(\frac{\mathbf{l}}{\frac{\mathbf{l}}{\tan\phi}-\mathbf{ft}}\right)$

= $\tan^{-1}\left(\frac{\mathbf{0.96}}{\frac{\mathbf{0.96}}{\tan(33.58)}-\mathbf{0.91}}\right)$

=60.82

6.Ackerman percentage = $\frac{\boldsymbol{\theta}}{\textbf{ackerman value}}\times 100$

= $\frac{\mathbf{50.71}}{\mathbf{60.82}}\times 100$

=83.37%

J. Steering effect

The steering effort varies with the speed of the go kart i.e., high at lower speeds and low at greater speeds as coefficient of friction goes on eliminating when velocity increases. The steering effort depends upon various factors of the steering geometry.

Calculation: -

1.Weight of the vehicle = 180kg =1765.19 N

2.Weight on front wheels (35% of total weightage on front side) =180*0.35 =63 kg =617.81N

3. Sliding friction between tyre and road(μ)=0.8

4.Friction force to overcome = Friction coefficient*Weight =0.8*617.81 =494.24 N

5.Force at Knuckle = $\frac{\textbf{(Frictional Force*Scrub Radius)}}{\textbf{Steering arm length}}$= = $\frac{(494.24*55mm)}{130mm}$ = 209.1N

6.Radius of steering wheel = 5 inch = 12.7 cm= 127mm

7.Torque at the tripod = tripod length*force to overcome at knuckle = 130mm*209.1

=27183N.mm

8.Steering effort = Torque/steering wheel radius = 27183/127=214.03N =21.8kg

K. Centre of gravity: -

CG is the point where the entire weight of the cart seems to be acted on. The Centre of gravity of the cart will be located at where, mass is most highly concentrated, which for a race car is typically around the engine and associated drive components. It is also expected that all accelerative forces experienced by a vehicle will act through its Centre of gravity. It is recommended that the Centre of gravity for a vehicle be kept as low as possible to reduce the moment generated as the vehicle experiences lateral acceleration.

Calculation: -

Total weight of the vehicle with driver(W) = 180 kg

Rear track width (Tr) = 1.09 m

Front track width (Tf)=0.91 m

Wheelbase(l) = 0.96 m

Mass on front axle =35 % of total weight = 35 % of 180 = 63kg

Mass on rear axle = 65 % of total weight = 65 % of 180 = 117 kg

Weight on front wheels (Wf) =$\frac{\text{mass of front axle}}{2}$ = $\frac{63}{2}$ =31.5 kg

W1=W2=31.5

Weight on rear wheels (Wr) = $\frac{117}{2}$ =58.5 kg

W3=W4=58.5 kg

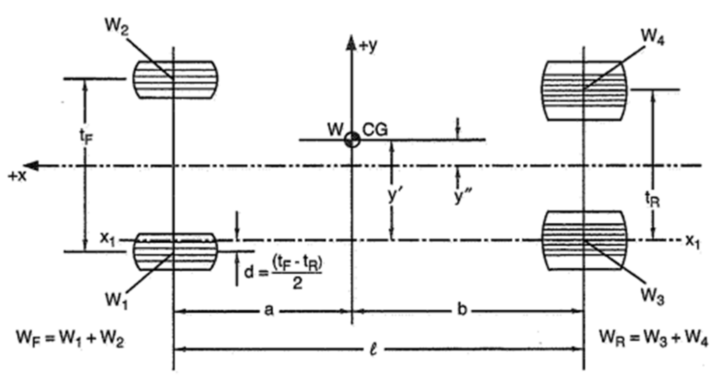


Fig 5.11(i): Horizontal location of centre of gravity

Moments of X axis: -

B= $\frac{Wf*l}{W}$ = $\frac{63*0.96}{180}$=0.336 m

a=l-b=0.96-0.336=0.624

offset (d) = $\frac{(Tr-Tf)}{2}$ = $\frac{(1.09-0.91)}{2}$ = 0.09 m

y'=$\frac{W2}{W}(Tf-d)$- $\frac{W1}{W}(d)$ + $\frac{W4}{W}(Tr)$

y'=$\frac{31.5}{180}(0.91-0.09) - = \frac{0.09}{180}(0.09) + = \frac{58.5}{180}(1.09)$
y'=0.482 m
y'' = y'-$\frac{Tr}{2}$
y'' =0.482-$\frac{1.09}{2}$
y'' = 0.063 m

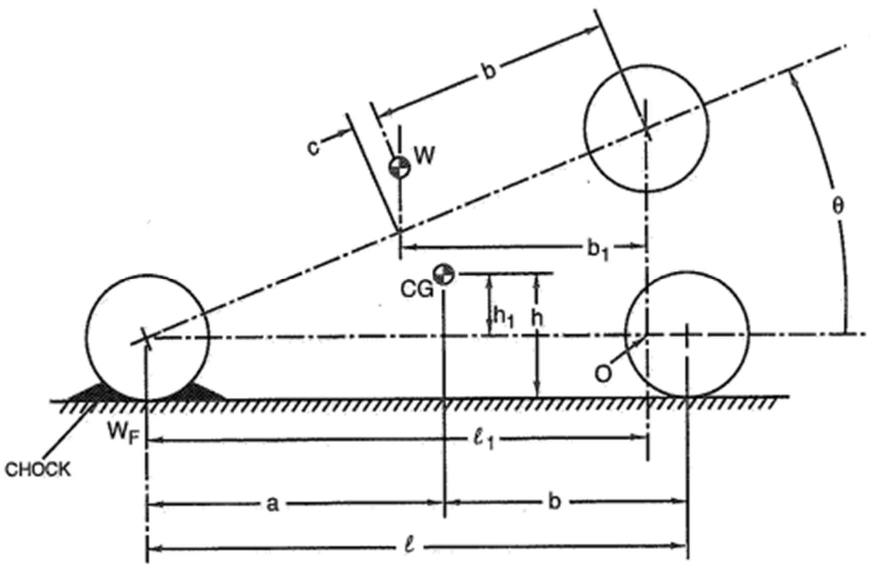


Fig 5.11(ii): Vertical location of centre of gravity

L1=l cos θ
L1 = 0.96 cos (35) =0.786
b1 =$\frac{Wf}{W}(L1)$
b1 = $\frac{63}{180}(0.786)$
b1 = 0.275 m
taking moments of the point O
Wf (L1) =W(b1)
63(0.786) =180(0.275)
49.5=49.5
C=$\frac{Wf}{W}(l) - b$
C = $\frac{63}{180}(0.96) - 0.336$
C = 0
H1 = $\frac{Wf(l)-W(b)}{W\tan(\theta)} = \frac{63\,(0.96)-180\,(0.336)}{180\tan(35)}$
H1 = 0
Loaded radius of front wheel = 0.11 m
Loaded radius of rear wheel = 0.127 m
$Rl_{cg} = Rl_f\,(\frac{b}{l}) + Rl_r\,(\frac{a}{l})$
$= 0.11\,(\frac{0.336}{0.96}) + 0.127\,(\frac{0.624}{0.96})$
Rl_{cg} =0.121m
H = Rl_{cg} +h1
H = 0.121+0
H = 0.121 m

L. Lateral load transfer:

1) Cornering force: -

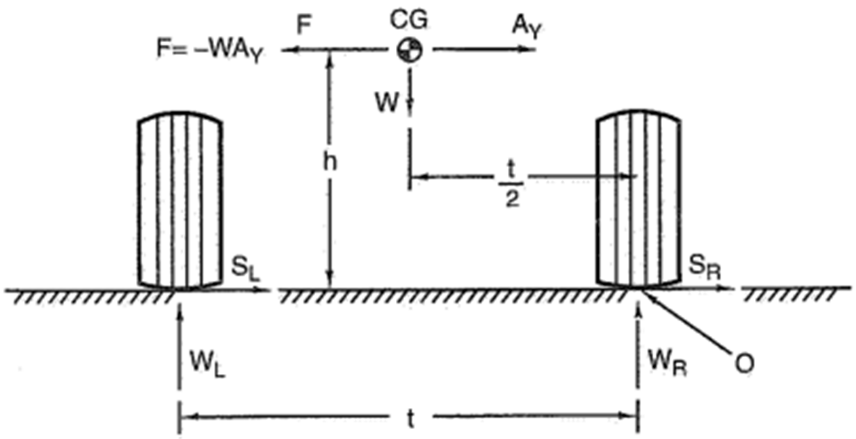


Fig 5.12.1: Lateral load transfer

Cornering force (F)= $\frac{M*V^2}{R}$

Mass of the vehicle (M) = 180 kg

Velocity of the vehicle (V) = as assuming vehicle speed 40 kmph = 12.5 Ms

Radius of turn (R) = 12 m

F = $\frac{180*12.5^2}{12}$

F = 2343.75 N

Lateral acceleration (ay) = F_L+F_R

As load transfer on both sides are same, F_L=F_R

ay = 2343.7+2343.7

ay = 4687.4

Ay = $\frac{ay}{32.2}$ = $\frac{4687.4}{32.3}$ = 145.5

Now taking the moments of O (the right side of track), we have

W_{Lt} = W ($\frac{t}{2}$) + W_{Ay}h (h = height of CG = 0.12 m)

W_L = $\frac{W}{2}$ +W_{Ay}h / t (t = track width of front = 0.91 m)

W_L = ($\frac{180}{2}$) + $\frac{180 \times 145.5 \times 0.12}{0.91}$

W_L = 3543.62

Since the initial weight on the left-hand side of aa symmetric vehicle is $\frac{W}{2}$, the weight transfer due to cornering is W_L - $\frac{W}{2}$.

ΔW = W_L - $\frac{W}{2}$ = W_{Ay}h / t

ΔW = 3543.62 - $\frac{180}{2}$ = $\frac{180 \times 145.5 \times 0.12}{0.91}$

ΔW = 3543.62 = 3543.62

Where, ΔW is the increase in left side load and decrease in right side load due to cornering.

Expressed as total weight this becomes.

Lateral Load Transfer = $\frac{Ay\ h}{t}$

LLT = $\frac{145.5 \times 0.12}{0.91}$

=19.1kg

=188.09 newtons.

M. Longitudinal weight transfer: -

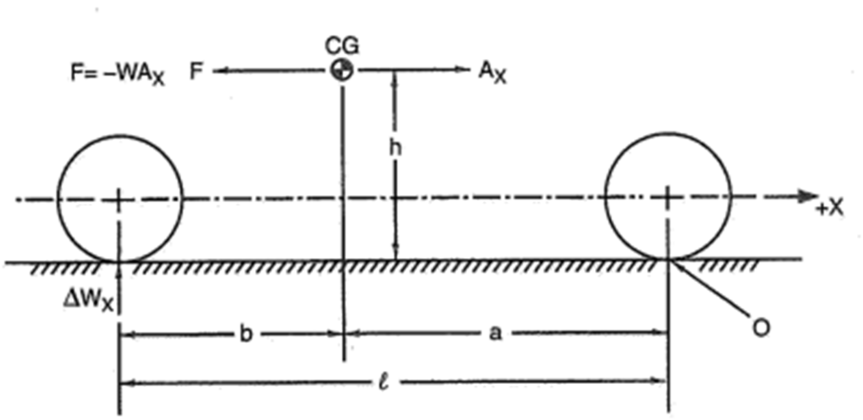


Fig 5.13: Longitudinal load transfer

Taking moments of O (the front tire contact patch location)

We have, $\Delta W_x l = h*W_{Ax}$

$$\Delta W_x = \frac{h}{l} W*A_x$$

W = weight in pounds

h =height of centre of gravity

l = length of wheelbase

A_x=longitudinal acceleration = acceleration $ms^{-2}/9.81ms^{-2}$ (by taking vehicle speed as 65 kmph and converting it into Ms = 18ms)

$= \frac{18}{9.81} ms^{-2} = 0.297$

Longitudinal acceleration(ΔW_x) = $\frac{0.12}{0.96} \times 396.8 \times 0.297$

(ΔW_x) =14.7312 pounds

(ΔW_x) =6.68 kg.

VI. CHAPTER 6

A. Braking System

Braking system helps slow down the rotation of the wheels when the brake pedal is pressed, ensuring a vehicle comes to deceleration.

Principle of Braking System: Brakes work on the principle of Pascal's law. According to this law when some pressure is applied on fluid it will travels uniformly in all the directions. when we apply some pressure on brake fluid it will transmit that pressure to the pistons of the calliper which actuate the brake pads which makes the disc to stop, so that the kart slow down.

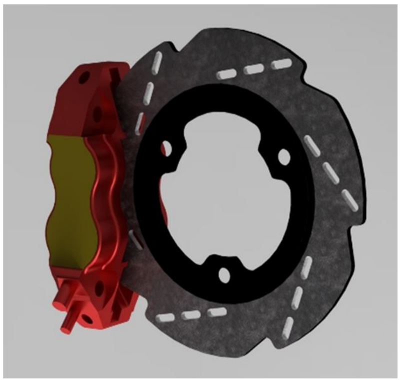


Fig 6.1: Calliper with disc

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Volume 12 Issue IV Apr 2024- Available at www.ijraset.com

Brake Components:
1) Brake Pedal
2) Push Rod
3) Master Cylinder
4) Hose Pipe
5) Brake Caliper
6) Brake Disc
7) Disc Hub

B. Brake Pedal

The Brake pedal is a device used to actuate the brakes of any automobile vehicle. The brake pedal must be durable and low weight.

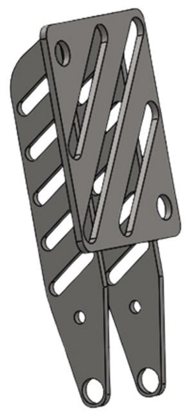


Fig 6.2: Brake pedal

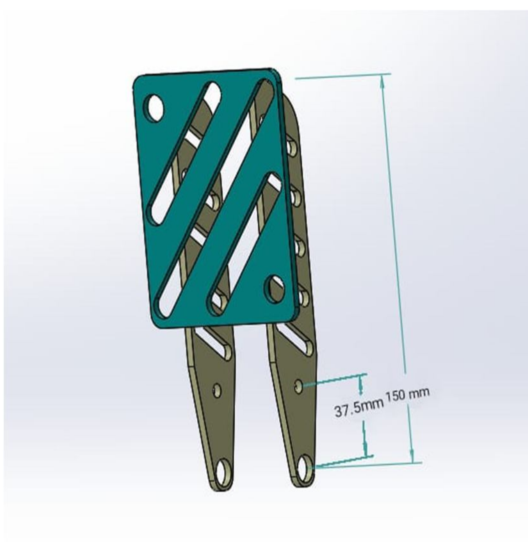
1) Brake Pedal Ratio

The brake pedal ratios are designed to achieve the desired balance between pedal feel, braking performance, and driver comfort. The pedal ratio tells the force we apply to the pedal is multiplied and transferred to the master cylinder.

It is the ratio of the distance from the centre of the pedal pivot point to the footpad to the distance from the pedal pivot to the master cylinder pushrod slot.

$$\text{Pedal Ratio}=\frac{\textit{The distance from the center of the pedal pivot point to the footpad}}{\textit{The distance from the pedal pivot to the master cylinder pushrod slot}}$$

Pedal Ratio = $\frac{150mm}{37.5mm}$ = 4 [it means that the Pedal ratio is 4:1]



C. Brake Pedal Material:

The brake pedal is made up of mild steel because of its high impact strength, good ductility, machinability, and weldability.

1) Mechanical properties of mild steel:

Table 6.3.1: Mechanical Properties of Mild Steel

Mechanical Property	Value
Ultimate Tensile Strength	350 MPa
Yield Strength	220 MPa
Elongation [in 200mm]	15%
Density	7.87 g/cm^3
Young’s Modulus	210GPa
Poisson’s Ratio	0.33

2) Brake Pedal Specifications:

Table 6.3.2: Brake Pedal Specifications

Brake Pedal Ratio	4:1
Distance between pedal pivot to the footpad	150mm
Distance between pedal pivot to the master cylinder pushrod slot	37.5mm
Total length of the pedal	150mm
Thickness of the pedal	3mm

D. Pushrod

It is used to transfer the force from brake pedal to master cylinder and it is made up of mild steel because of its high impact strength, good ductility, machinability, and weldability.

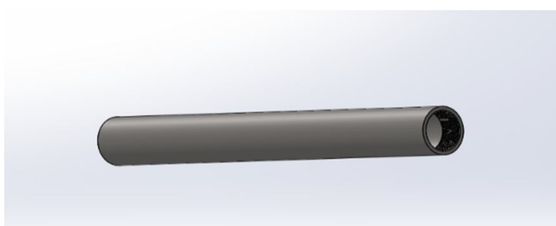


Fig6.4: Push Rod

1) Pushrod Specifications:

Table 6.4.1: Pushrod specifications

Pushrod Material	Mild Steel
Diameter of Pushrod	12mm
Length of Pushrod	95mm

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- Master Cylinder:

The Master cylinder converts the pressure on the brake pedal to hydraulic pressure by pumping brake fluid into the brake circuit.

Fig 6.4.1(i): Master cylinder

- Master Cylinder Specifications:

Table 6.4.1(ii): Master Cylinder Specifications

Master Cylinder Material	Aluminium
Piston Diameter	14mm
Bore Diameter	15mm
Height of the Cylinder	90mm

- Hose pipe:

The Brake hoses create a flexible connection between the master cylinder and brake caliper. The hose pipe is used to transfer the hydraulic pressure from the master cylinder to the brake caliper.

Fig 6.4.1(iii): Hose Pipe

Table 6.4.1(iii): Hose Pipe Specifications

Hose Pipe Material	Stainless Steel
Length of the Hose Pipe	1700mm
Diameter of the Hose Pipe	10mm

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- Brake caliper:

Brake calliper is also a component of a braking system and it consist of pistons which will be actuate the brake pads during the braking. The movement of brake pads directly proportional to piston motion

Fig 6.4.1(v): Brake calliper.

Table 6.4.1(iv): Brake calliper Specification

Brake Calliper Material	Aluminium
Brake Calliper Type	Fixed Calliper
No of Pistons	4
Piston Diameter	25.4mm

- Brake Disc:

The brake disc is arranged on shaft in which disc is mounted to disc hub and the caliper is placed over the disc. The disc consists of vent holes which will be helpful in heat dissipation.

Fig 6.4.1(vi): Brake Disc

E. Disc Material selection:

The disc is made up of stainless steel because of its corrosion resistant, high tensile strength, durability, temperature resistance, easy formability and low- maintenance.

1) Brake Disc Material Selection:

Table 6.5(i): Brake Disc Material Selection

Brake Disc Material	Stainless Steel 304
Stainless Steel Grade	304
Density	8.00 g/cm^3
Melting Point	1450^{0}C

Thermal Expansion	17.2×10^{-6}/K
Modulus of Elasticity	193GPa
Thermal Conductivity	16.2W/m. K
Electrical Resistivity	$0.072 \times 10^{-6}\Omega$.m

2) Mechanical Properties of Stainless Steel 304:

Table 6.5(ii): Mechanical Properties of Stainless Steel 304

Mechanical Property	Value
Ultimate Tensile Strength	505 MPa
Tensile Yield Strength	215 MPa
Hardness (Rockwell b)	70
Modulus of Elasticity	193-200GPa
Charpy Impact	325 J

3) Chemical Composition of Stainless Steel 304:

Table 6.5(iii): Chemical Composition of Stainless Steel 304

Elements	Percent %
Carbon (C)	0.07
Chromium (Cr)	17.50 – 19.50
Manganese (Mn)	2.00
Silicon (Si)	1.00
Phosphorous (p)	0.045
Sulphur (S)	0.015
Nickel (Ni)	8.00 – 10.50
Nitrogen (N)	0.10
Iron (Fe)	71.27 - 66.77

4) Specifications of Brake Disc:

Table 6.5(iv): Specifications of Brake Disc

Disc Outer Diameter	200mm
Pitch Circle Diameter	130mm
Disc Mount Diameter	12mm
Thickness of the Disc	3mm

F. Disc Hub:

The disc hub is designed to hold the brake disc rigidly, we used solid works software to design the hub according to the required dimensions.

1) Disc Hub Material Selection:

The disc hub is made up of aluminium T6-6061 because of its high tensile strength, high yield strength, high melting point.

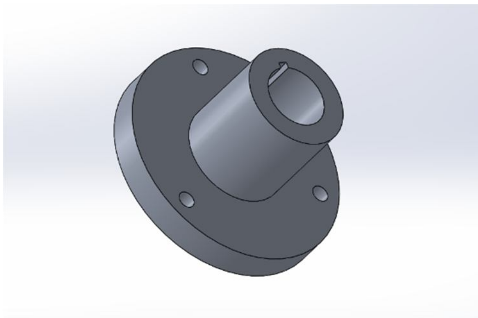


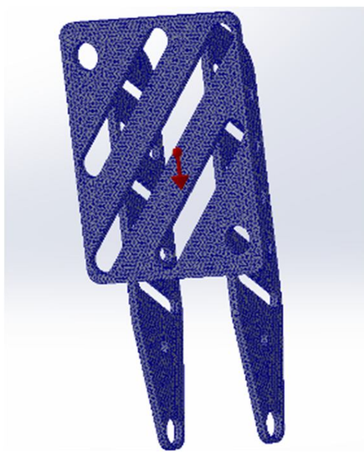
Fig 6.6.1: Disc Hub

G. Analysis of brake pedal:

The Analysis of brakes pedal is done in solid works.

Static structural analysis:

1) Pedal Mesh:



2) Pedal static displacement:

(Maximum displacement = 1.388mm)

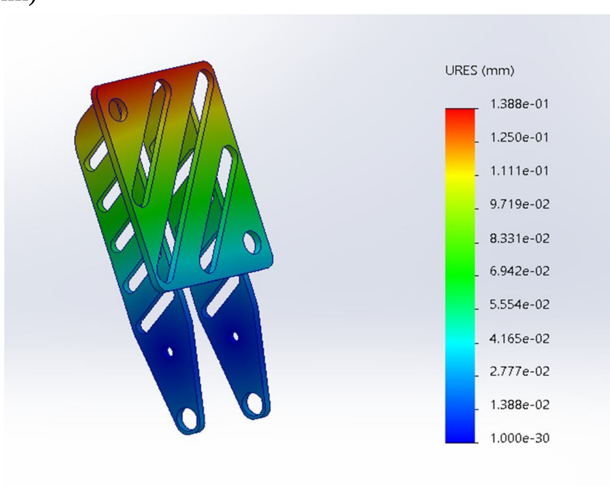


Fig6.7(ii): Pedal static displacement

3) Pedal static strain:
(Maximum strain = 1.2)

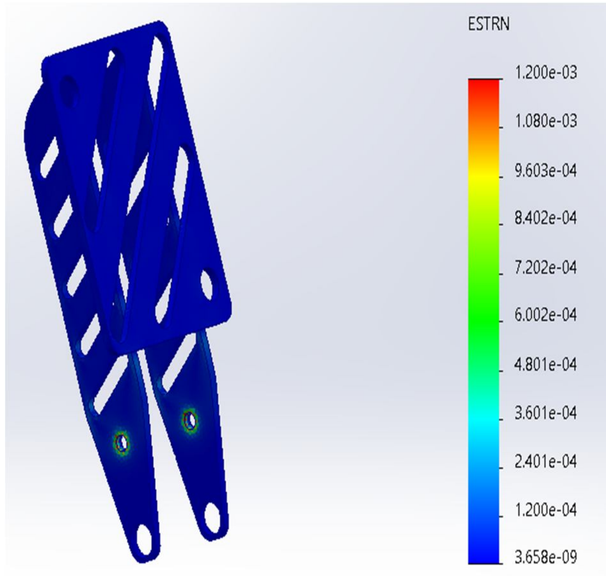


Fig6.7(iii): Pedal static strain

4) Pedal static stress: (Maximum stress = 2.206N/m^2)

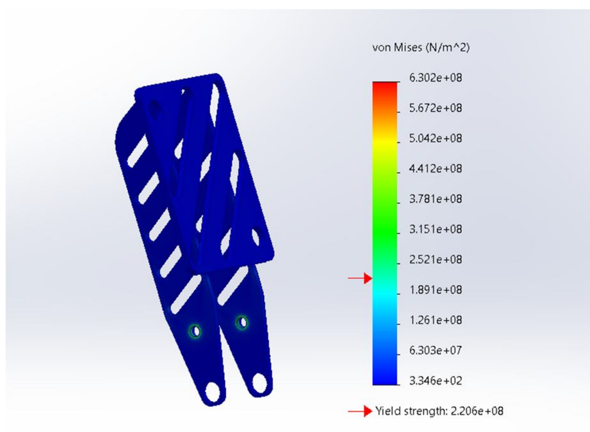


Fig6.7(iv): Pedal static stress

5) Pedal Factor of safety: FOS = 6.594

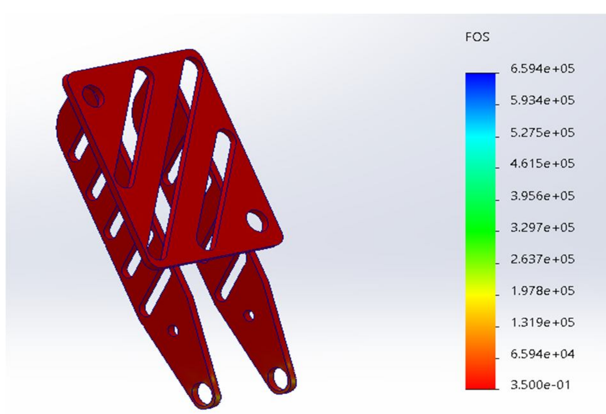


Fig6.7(v): Pedal FOS

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H. Analysis of Brake Disc:

Static Structural analysis:

1) Disc mesh:

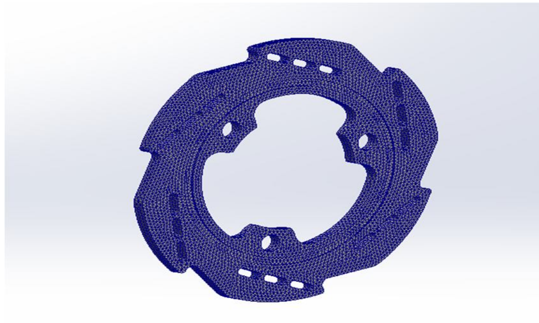

Fig 6.8(i): Disc Mesh

2) Disc static nodal stress:
(Maximum stress = 4.600N/m^2)

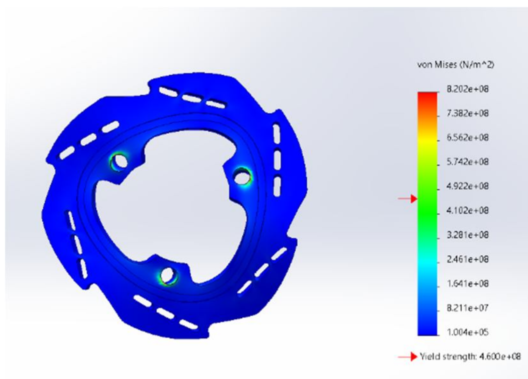

Fig 6.8(ii): Disc static nodal stress

3) Disc static displacement:
(Maximum displacement = 3.524mm)

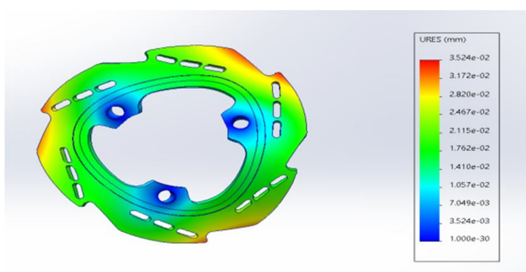

Fig 6.8(iii): Disc static displacement

4) Disc static strain:
(Maximum strain = 1.633)

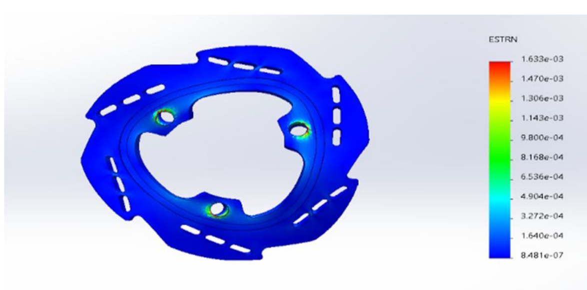

Fig 6.8(iv): Disc static strain

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5) Disc Factor of safety: FOS = 4.00

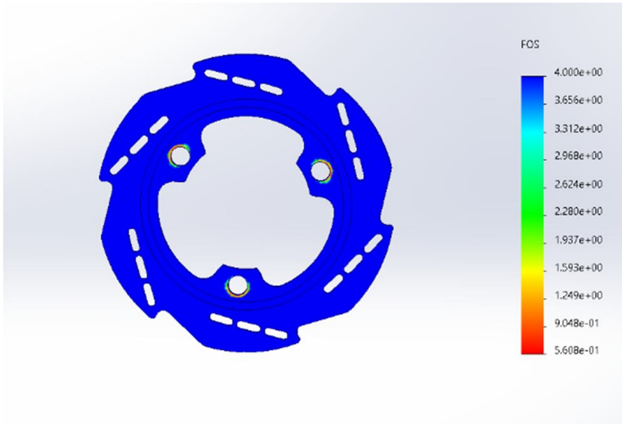

Fig 6.8(v): Disc FOS

I. *Analysis of Brake Disc Hub:*

Static Structural analysis:

1) Disc hub mesh:

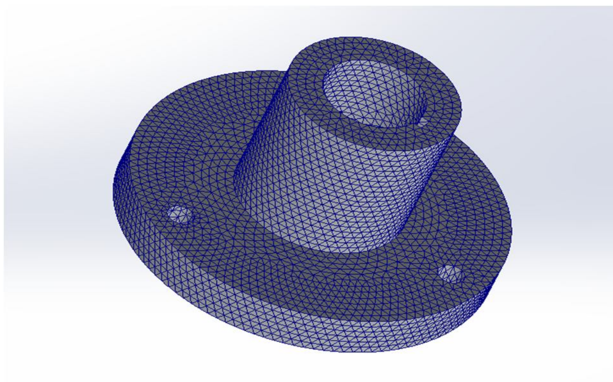

Fig6.9.1: Disc Hub Mesh

2) Disc hub stress:
(Maximum stress = 5.515N/m^2)

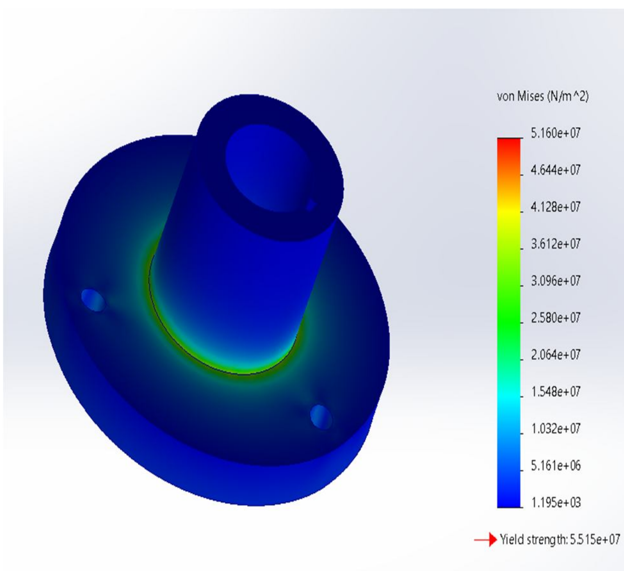

Fig 6.9.2: Disc Hub Stress

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3) Disc hub displacement:
(Maximum displacement = 1.961mm)

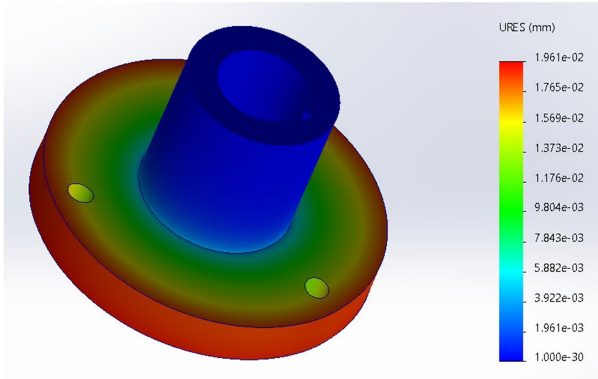

Fig 6.9.3: Disc Hub Displacement

4) Disc hub strain:
(Maximum strain = 5.836)

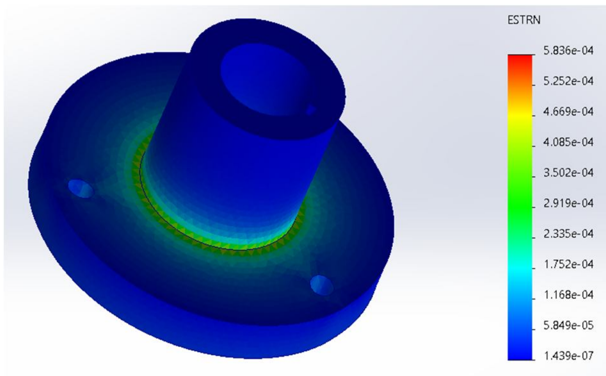

Fig 6.9.4: Disc Hub strain

5) Disc hub Factor of Safety: FOS = 4.614

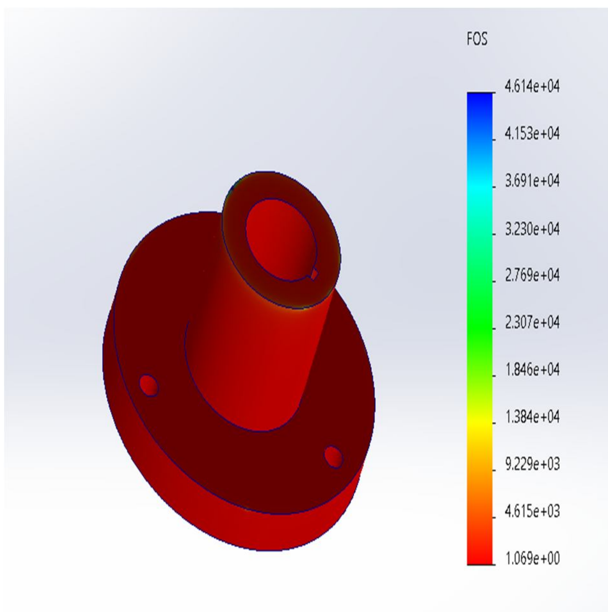

Fig 6.9.5: Disc Hub FOS

6) Considerations for the Braking System Selection:

Table 6.9.6: Considerations for the Braking System Selection

Pedal Ratio	4:1
Rear Disc Diameter	200mm
Calliper Type	Fixed Calliper
No of Calliper Pistons	4
Calliper Piston Diameter	30mm
Master Cylinder Diameter	14mm
Pay Load	65kg
No Load	120kg
Tyre Diameter	140.97mm
Speed of the Vehicle	40kmph

Force acting on the brake pedal = Weight of the driver x 9.81

= 65 x 9.81

F = 637.65 N (consider 15kg force applied by the driver)

Brake line pressure:

$$P = \frac{\text{Pedal Ratio} \times \text{Force on the brake pedal}}{\text{Area of master cylinder}}$$

$$P = \frac{4 \times 147.15\text{N}}{\left(\frac{\pi}{4}\right) \times (0.015)^2}$$

$$P = 3330794.649 \text{ Pa}$$

Clamping force (CF):

$$CF = Brake\ line\ pressure \times (area\ of\ calliper\ piston \times 2)$$

$$CF = 3330794.649 \times \frac{\pi}{4} \times (0.030)^2 \times 2$$

$$CF = 4708.8\text{N}$$

Rotating force (RF):

$$RF = CF \times No's\ of\ caliper\ pistons \times coefficient\ friction\ of\ brake\ pads$$

$$RF = 4708.8 \times 4 \times 0.3$$

Braking torque (BT):

$$\text{BT} = \text{Rotating force} \times \text{effective disc radius}$$

$$\text{BT} = 5650.56 \times 0.098$$

$$\text{BT} = 542.6797 \text{ N-m}$$

Braking force (BF):

$$BF = \frac{\text{Braking Torque}}{\text{Tire radius}} \times 0.8$$

$$BF = \frac{542.6797}{0.1397} \times 0.8$$

$$BF = 3107.6866\ N$$

Deacceleration:

$$\text{F} = -\text{ma}$$

$$\text{a} = -\frac{\text{f}}{\text{m}}$$

$$\text{a} = -\frac{3107.6866}{170}$$

$$\text{a} = -18.28\text{m/s}$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IV Apr 2024- Available at www.ijraset.com

Stopping Distance:

$$V^2 - U^2 = 2as$$
$$0^2 - 11.1111^2 = 2 \times 18.28 \times s$$
$$s = 3.376m$$

Piston Actuation Force:

$$\text{Brake line pressure} = \frac{\text{Actuation Force}}{\text{Area of Caliper piston} \times \text{No of piston} \times \text{Co-efficient of Friction}}$$

$$\text{Actuation Force} = \text{Brake line pressure} \times \text{Area of Caliper piston} \times \text{No of pistons} \times \text{Co-efficient of Friction}$$
$$\text{Actuation Force} = 3330794.649 \times \frac{\pi}{4} \times 0.03^2 \times 4 \times 0.3$$

Actuation Force=2825.28001N (for 4 pistons)

Actuation Force on each piston =706.320N

VII. MANUFACTURING PROCESS

A. Manufacturing of the chassis

The chassis is manufactured by considering the various factors that includes performance characteristics of the vehicle, required rigidity of the chassis, sustainability and safety factor and the quality of the components utilized in the process.

The chassis is manufactured by using the above-mentioned raw material and the processes involved are.

1) Cutting of tubes.

The tubes must be of seamless tubes. If there is a seam, the tubular structure may come apart under the severe loads which might be dangerous to the driver. The tubes are checked for the lengths using a template and cut into the required dimensions.

Fig: 7.1: Cutting of tubes.

2) Notching of tubular members

The notching is one of the major steps in manufacturing because it determines the strength of the nodal points formed due to the intersection of two or more tubular members. By notching them properly, the strength of the frame can be maintained, and it makes to join the tubes together easier.

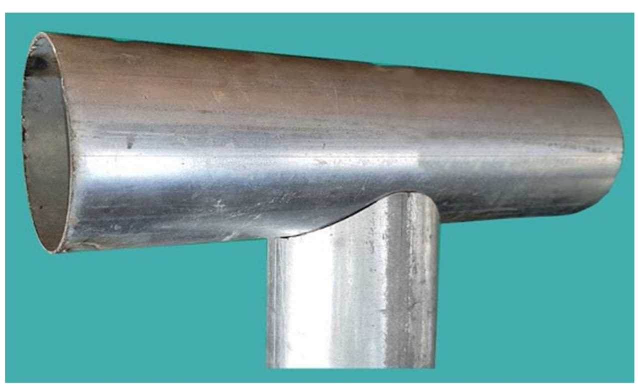

Fig: 7.1.2: Tube notching

3) Welding of tubular members

The tubes are to be welded followed by notching. The welds can be produced by any of the methods. But in our case, we welded members by TIG welding. It is because TIG welding requires less filler material compared to that of arc welding and MIG welding.

Fig: 7.1.3: Tig welding

4) Strength checking

After completion of welding, the strength of each weld is checked by exerting them with various loads and checking for the sustainability of that force.

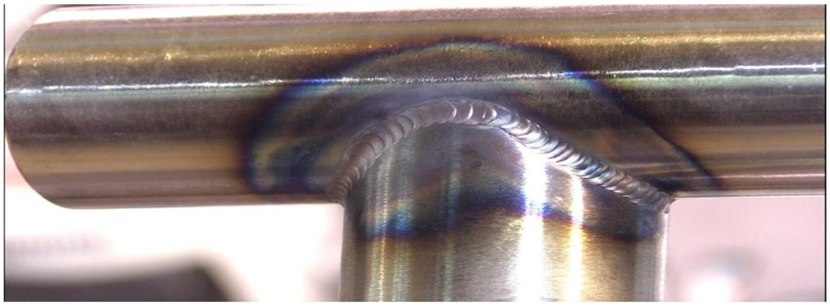

Fig: 7.1.4(i): Welded joint

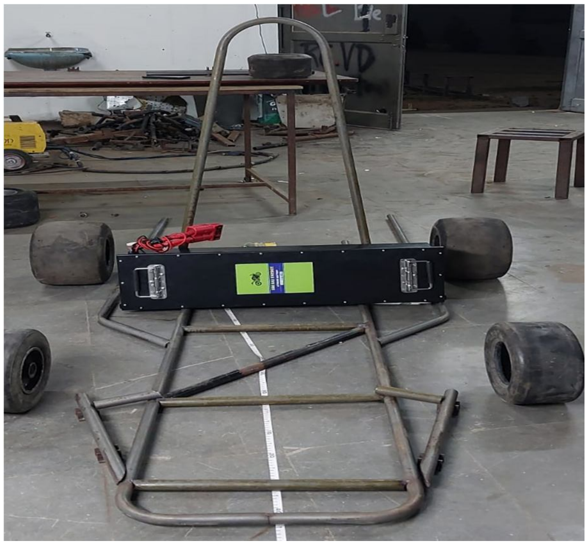

Fig: 7.1.4(ii): Welded Chassis

B. Manufacturing of the body works.

The body works of the go-kart must be aesthetically pleasing and must provide some protection in the crash zones by absorbing the forces when there is an impact load applied. There are many materials that can be used in the manufacturing of the body works. Some of the well-known materials are fibre glass material (either mat or flakes), Kevlar, carbon fibre, ABS plastics etc.

The material which has a good cost factor and strong, durable, and reliable is fibre glass mat. The fibre glass mat used is a WR type mat with a GSM value of 600 which is usually used for high grade applications and heavy-duty applications which provides good protection and gives better stance for the vehicle overall.

The mould is made from a hard form which will give a proper required shape and accuracy of the desired design. The method used for the body works is hand layup method where the fibre glass mat is layered several times and an adhesive or a binding agent is added to the mat so that all the layers bind together properly and forms a solid shape which will absorb the impacts and gives a neat design to the vehicle.

Fig 7.2: Body works of go-kart


Fig 7.2(i): Fibre glass layup

C. Circuit diagram for electronics

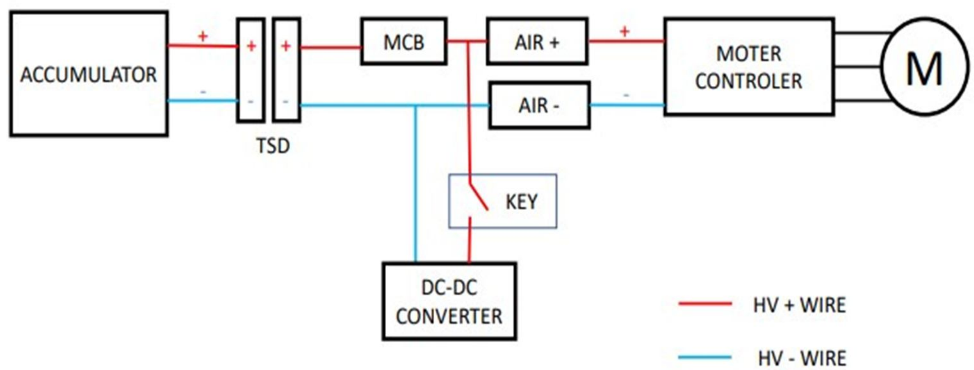

Fig 7.3(i): High voltage circuit

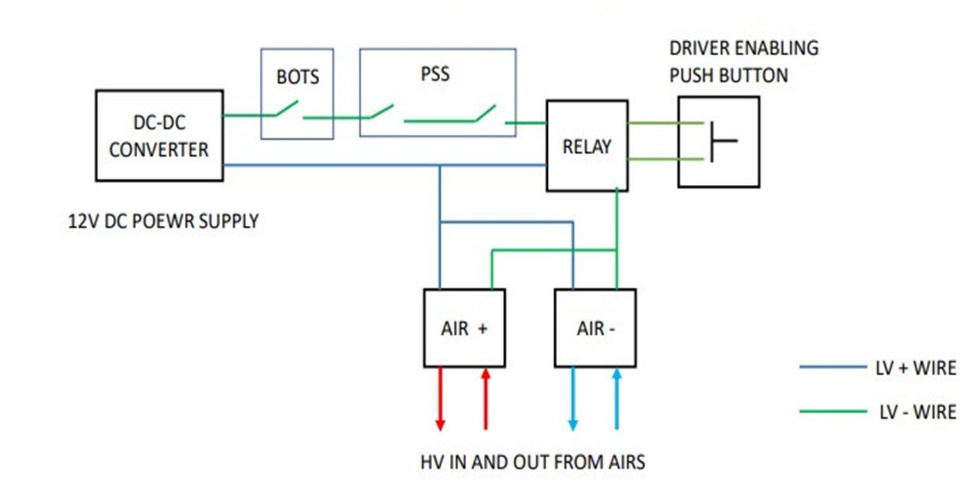

Fig 7.3(ii): Low voltage circuit

VIII. CONCLUSION

Overall goals for the chassis included, increasing torsional rigidity and decrease weight, deformation. Chassis should perform at an optimum level. The results gained in this section show that the chassis will experience very minimal deflections under race conditions. This is also going to allow the chassis to perform at an optimum level in conjunction with the rest of the vehicle setup. Like any vehicle, the chassis is the backbone of the system. Every critical component relies on the chassis either directly or indirectly. The driver of the vehicle also relies on the chassis for protection in the event of an accident. This dissertation covers the procedures that were used to successfully design and construct a functional chassis.

IX. FUTURE SCOPE

There are several factors to be considered that are common to all or any engineering vehicles. With an approach of engineers can come up with the most effective possible product for the society. The chosen design is the safest & the foremost reliable car for any racing vehicle. All the parameters like Reliability, safety, Cost, Performance, aesthetics, ergonomics, Standard dimensions & material were also taken in consideration on an equivalent time. Wherever possible finite element analysis was done on the regularly loaded parts & modifications were done accordingly to avoid any sort of design failure. The designing of Go-kart can develop many skills. The training of 3-D modelling software like Solid works is important to get desire design. The analysis of design determines the stresses developed within the chassis which plays a crucial role in factor safety. From the analysis we can predict the chassis is safe or not and by seeing the deformation and stresses modification within the kart chassis is feasible.

X. ACKNOWLEDGMENT

We owe our immense thanks to Dr. B. VIJAYA KUMAR our guide, Professor and Head of the Mechanical Engineering, & COE Guru Nanak Institute of technology for the sustained interest, constructive criticism, and constant encouragement at every stage of this endeavour.

We extend our deep sense of graduate to Dr. B. VIJAYA KUMAR, Professor & Head of the Mechanical Department & COE.

We owe our immense thanks to Dr. S. SREENATHA REDDY, Principal and the management of the Guru Nanak Institute of Technology for providing us the best amenities which enabled us to complete our project in the stipulated time.

Finally, yet importantly, we are very thankful to our parents, friends, and other faculty of Mechanical Engineering department for their constant support in completion of this project.

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