DESIGN & DEVELOPMENT OF MINI-RACING AUTOMOBILE KART

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ABSTRACT

Karting is a form of racing with a small four-wheel vehicle known as a Go-kart. In the beginning, the first ever Go-kart was created in L.A. by Art Ingels in 1956. A Go-kart, is a type of open wheel Vehicle Which Is Compact, Simple and Easy to Operate. A Go-kart is a small four wheeled vehicle which runs on I.C Engine having no suspensions and no differential. They are usually raced on scaled down tracks. The Go- Kart Is Designed for Flat Track Racings and it mainly comes in all shapes and forms, from motorless models to high-powered racing machines. This paper explains the process and methodology to produce a low cost go-kart, Simple but innovative, we have made a simple, self-fabricated Go-Kart chassis formed by hollow circular pipe powered by Honda 125 cc engine fitted with a disc brake. Modelling and analysis are performed in SOLIDWORKS. Go karting helps in learning about health and safety, for youngsters it can help to teach them essential of safety skills, including road safety, and the importance of following instructions, which can be applied in everyday situations.

Keyword: - *Go-Kart, Chassis, Modelling, Analysis, Solidworks.*

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1. INTRODUCTION

Go-kart is a simple self-propelled, lightweight and compact vehicle easy for operation. Due to low ground clearance, this type of vehicles are specifically designed and fabricated for racing. Its main parts are chassis, axle, steering, engine, wheel, bumpers and tyres. As it is one of the racing vehicle, its ground clearance is low due to which no suspension system is placed. Its engine can be either two-stroke or four stroke. Chassis in one of the main component of this vehicle as the total weight of the vehicle should be beard by it. Due to this, chassis should have high strength and stability.

Go-karting is adventurous and great sporting vehicle for those who have interest in racing, due to its low cost, simple construction and safer way of racing. Its racing track could be indoor or outdoor. The chassis is designed in such a way that it requires less pipes and is able to withstand optimum loads applied on it. They are usually raced on almost any plain tracks with no pits and speed breakers. This is considered as the first vehicle for starting a career in racing field. A driver could easily prepare for racing through this vehicle, wheel-to- wheel racing for high speed, precision control, impulsive racing skills and spontaneous decision-making skills. These vehicles, now called as “Go-Karts” had grown into a billion dollars industry in the USA and most of the developed countries in the world. They are made, sold, and used exclusively as recreational activity for racers. However, these vehicles are not designed for transportation and are considered illegal in most places to drive them on the road.

Go-Kart is a racing vehicle having very low ground clearance. The design process of this single person go-kart is iterative and based on several engineering processes. The designing work is completed to achieve the best standardized as well as optimized design possible to fulfill international standards. Besides performance, consumer needs the serviceability, endurance ability and affordability were also kept in concern which we got to know through the market and internet research and reviews for go- kart vehicles. There is no suspension provided for go-kart so it becomes very complicated to design such a flexible chassis which may work for suspension during the turns. After the primary specifications were set, 3-D software model is prepared in SOLIDWORKS software. After the solid modeling the design is tested against all types of failure by conducting various simulations and stress analysis in SOLIDWORKS Software. Based on the result obtained from these tests the design is modified accordingly. The design objectives set out to be achieved were three simple goals applied to each component of the car: durable, light-weight, and high performance.

Table-1: Specifications of Kart

Roll Cage	
Weight	9.51 kg
Material	AISI 1010
Outer Diameter	31.75 mm
Thickness	1.5 mm
Engine – Honda CBF Stunner 125	
Displacement	124.7 CC
Max. Torque	11 Nm
Max. Power	11.6 Bhp
Vehicle Dimensions	
Wheel Base	1170 mm
Front Track Width	1010 mm
Rear Track Width	1380 mm
Overall Length	1420 mm
Overall Width	1380 mm
Ground Clearance	45 mm
Steering	
Type	Four Bar Steering
Turning Radius	2.7 m
Braking	
Type	Rear Hydraulic
Disc Diameter	190 mm
Performance Target	
Max. Speed	50 kmph
Max. Acceleration	1.5 m/s^2

Max. Deceleration	11.19 m/s^2
Overall Weight	105.51 kg

2. ROLL CAGE DESIGN

The primary function of roll cage is to protect the driver, provides a rigid support for the assembly of sub systems, engine and drive train. The roll cage is designed to meet the technical requirements of competition. The objective of the chassis is to encapsulate all components of the kart, including a driver, efficiently and safely. Proper numbers of members are used in the roll cage to ensure complete driver safety. These include the front and rear bumpers, the side bumper, battery cover and firewall. The bumpers are so designed that they will serve as protection from front and rear and will also add impressive look to the kart. All the bends are of constant radius. In this design, use variable thickness pipes in order to reduce the weight of chassis. For members 31.75 mm diameter with 16 gauge pipe is used.

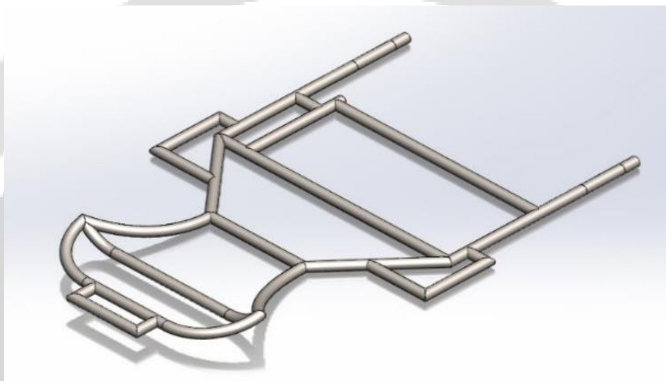

Figure-1: CAD Model of Roll Cage

Table-2: Design Parameters

Wheelbase	1170 mm
Front Track Width	1010 mm
Rear Track Width	1380 mm
Outer Diameter	31.75 mm
Thickness	1.5 mm

2.1 Material

The selection of material for chassis is done by detailed study of properties of materials regarding strength and cost, results found that two materials AISI 1008 and AISI 1010 which are having similar properties. But prefer to use AISI 1010 over AISI 1008, because of its higher yield strength and high strength to weight ratio.

The material AISI-1010 is used in the chassis design because of its good weld ability, relatively soft and strengthens as well as good manufacturability. A good strength material is very important in a roll cage because the roll cage must absorb the maximum amount of energy as possible to prevent the roll cage material from fracturing at the time of high impact. AISI- 1010 has chosen for the chassis because it has structural properties that provide a high strength to weight ratio.

Table-3: Properties of Material

Tensile Strength	505.819 MPa

Yield Strength	313.684 MPa
Density	7900 Kg/m^3
Elongation	21.4 %

2.2 Chemical Composition of Material

Carbon	C = 0.13 %
Manganese	Mn = 0.504 %
Silicon	Si = 0.0803 %
Sulphur	S = 0.0448 %
Phosphorus	P = 0.040 %
Iron	Fe = 98.81 %

3. Finite Element Analysis

Structural integrity of the frame is verified by comparing the analysis result with the standard values of the material. Analysis was conducted by the use of finite element analysis FEA on SOLIDWORKS software. To conduct finite element analysis of the chassis an existing design of chassis was uploaded from the computer stresses were calculated by simulating three different induced load cases .The load cases simulated were frontal impact, side impact, and rear impact. The test results showed that the deflection was within the permitted limit.

3.1 Meshing

Auto meshing has been done in SOLIDWORKS 2019 software. Following data has been found after meshing of chassis –
No. of Nodes = 446
No. of Elements = 340

3.2 Front Impact

For the front impact, engine and driver load was given at respective points. The kingpin mounting points and Rear wheels position kept fixed. Front impact was calculated for an optimum speed of 50 kmph. From impulse momentum equation, 5g force has been calculated. The loads were applied only at front end of the chassis because application of forces at one end, while constraining the other, results in a more conservative approach of analysis. Time of impact considered is 0.2 seconds as per industrial standards.

$F \times t = m \times (V_i - V_f)$

$F \times 0.2 = 105.51 \times (13.89 - 0)$

$F = 7.327$ KN

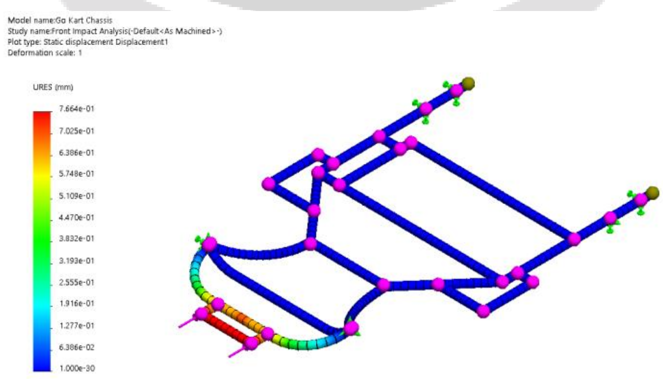

Figure-2: Deformation

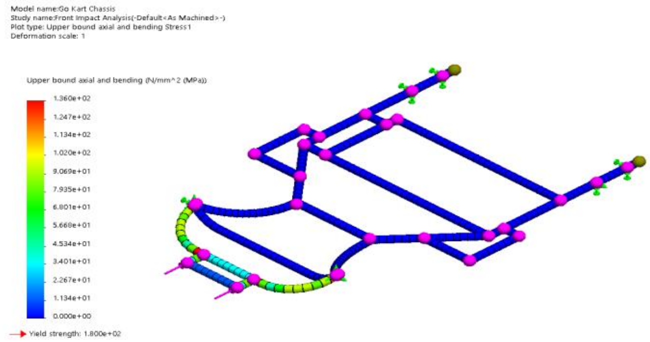

Figure-3: Stress

Table-4: Frontal Impact

Deformation	0.99 mm
Max. Stress	178.3 MPa
Factor of Safety	1.01

3.3 Rear Impact

Considering the worst case collision for rear impact, force is calculated as similar to front impact for speed of 50 kmph. The value of 5g force has been calculated. Load was applied at rear end of the chassis while constraining front end and king pin mounting points. Time of impact considered is 0.2 seconds as per industrial standards.

F x t = m x (Vi-Vf)
F x 0.2 = 105.51 x (13.89 -0)
F = 7.327 KN

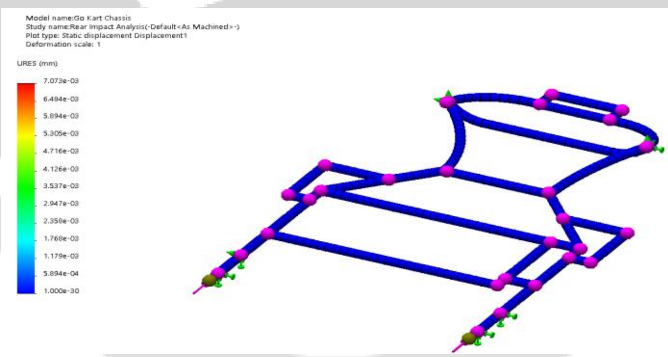

Figure-4: Deformation

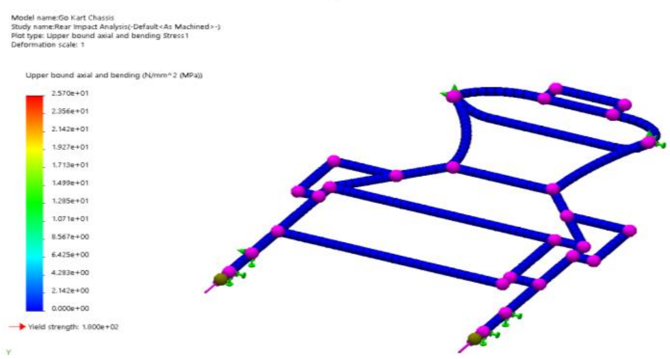

Figure-5: Stress

Table-5: Rear Impact

Deformation	0.007 mm
Max. Stress	25.7 MPa
Factor of Safety	7

3.3 Side Impact

The most probable condition of an impact from the side would be with the vehicle already in motion. So it was assumed that neither the vehicle would be a fixed object. For the side impact the velocity of vehicle is taken 46 kmph and time of impact considered is 0.2 seconds as per industrial standards. Impact force was applied by constraining left side of chassis and applying load equivalent to 2.5g force on the right side.

F x t = m x (Vi-Vf)

F x 0.2 = 115.51 x (16.67 -0) x 0.5

F = 4.813 KN

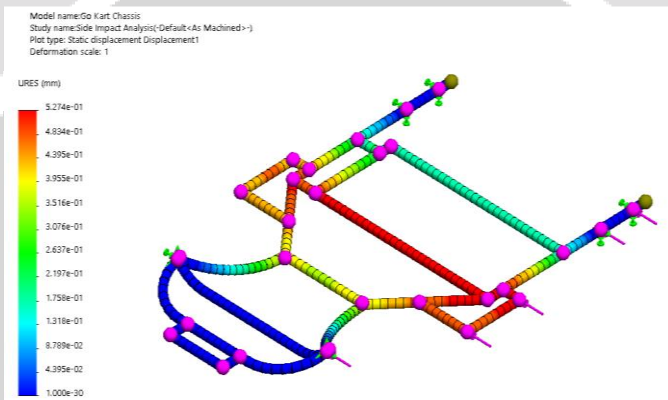

Figure-6: Deformation

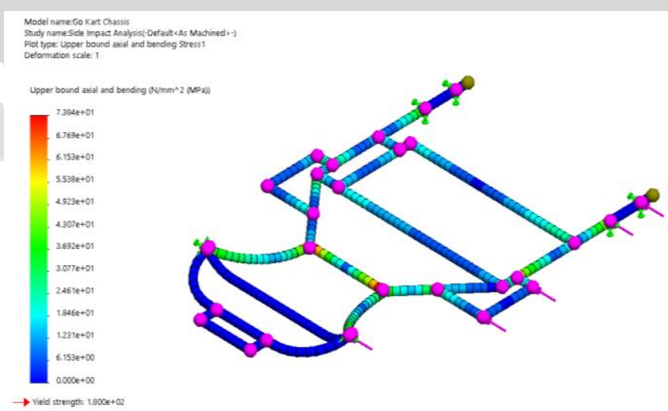

Figure-7: Stress

Table-6: Side Impact

Deformation	0.72 mm
Max. Stress	97.37 MPa
Factor of Safety	1.8

4. STEERING SYSTEM

The steering system for the vehicle has to be designed to provide maximum control of the vehicle. Simplicity and safety were the main design specifications for the vehicle's steering system. The main goal for steering is to have steering radius of 4m or less. Along with controlling the vehicle, the steering system must provide good ergonomics and be easy to operate. After researching multiple steering systems, the four bar steering type was selected which provides easy operation, less weight, requires low maintenance, provides excellent feedback and is cost effective. Ackerman steering mechanism has been selected for steering system because it does not slip during the turning of tires and it reduces the steering efforts. The positive 3 degree caster is given for self-centering of the kart. Mechanical steering linkage system has been used to make steering simple to manufacture, decrease the steering effort and also the amount of steering wheel travel.

4.1 Steering Calculations

The Ackerman condition is expressed as
$\cot \theta^{o} - \cot \theta^{i} = c / b$
Where, θ^{o} − outer steering angle
θ^{i} − inner steering angle
c − distance between king pin
b – Wheelbase
Assuming, $\theta^{i} = 18.60^{o}$
Wheelbase (b) = 1170 mm
King pin distance (c) = 770 mm
Therefore from above condition
$\theta^{o} = 15.40^{o}$
Now, Ackerman angle (α),
$\tan \alpha$ = king pin distance / (2 x wheelbase)
Therefore, $\alpha = 18.21^{o}$
Turning Radius (R) = (b / sin θ^{o}) − length of stub axle
Therefore R = 4.26 m

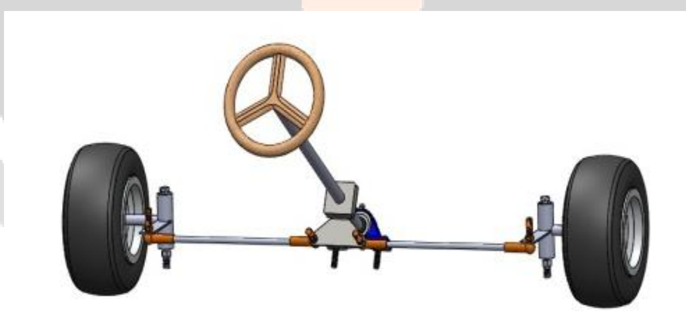

Figure-8: Cad Model of Steering

Table-7: Steering Parameters

Wheelbase	1170 mm
Front Track Width	1010 mm
Rear Track Width	1380 mm
King Pin Distance	770 mm
Tie Rod Length	350 mm

Max. Inner Angle	25.31°
Max. Outer Angle	18.60°
Self-aligning Torque	35.66 Nm
Min. Turning Radius	2.29 m
Caster Angle	5°
Ackerman Angle	23.17°
King Pin Inclination	7°
Length of Steering Arm	100 mm

5. BRAKING SYSTEM

The objective of Braking System is to provide reliable and prompt deceleration of vehicle. In order to achieve maximum performance from the braking system, the brakes have been designed to lock up rear wheels, while minimizing the cost and weight. Moreover, the driver must have complete control of the vehicle while brakes are actuated. A hydraulic disc brake has been chosen as a suitable way to accomplish these requirements. The disc of diameter 190 mm, which is operated by single piston calliper hydraulic braking system, has been selected according to vehicle design demands. The disc is mounted on the rear axle as shown in figure below. Master cylinder is placed front side of the vehicle beside the steering column for easy maintenance.

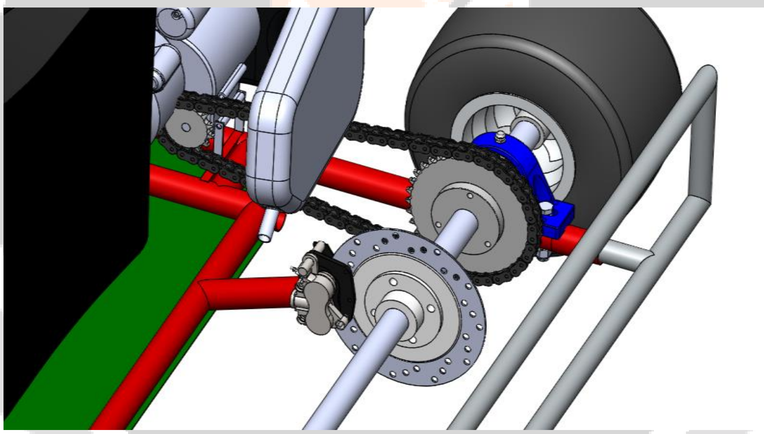

Figure-9: Braking System

Table-8: Braking Parameters

Brake Type	Hydraulic Disc Brake
Disc Diameter	170 mm
TMC Diameter	19 mm
Caliper Piston Diameter	24 mm
Disc Thickness	4 mm
Pedal Force Applied	100 N
Pedal Ratio	6 : 1
Velocity	11.11

Table-9: Calculated Values

Force Generated By Caliper	957.3 N
Effective Radius of Disc Brake	0.122 mm
Pressure Inside TMC	2.11 MPa
Braking Force	3829.12 N
Frictional Force	2297.47 N
Braking Torque	281.44 Nm
Deceleration	11.19 m/s^2

5.1 TYRES

The tyres used in go-karts are plane and has no tread on its surface and this type of tyres are called as 'slick'. These are dry-weather tyres since without tread they cannot clear water efficiently and will aquaplane, losing grip. Slicks have higher grip than wets since they have more rubber in contact with the surface, so they are preferred when it's dry.

Figure-10: Tyres

Table-10: Tyres Specification

Tyre Used	Slick Tyres
Front Tyre Size	4.5"/5"-10"
Rear Tyre Size	7.1"/5"-11"
Rim Diameter	5"

6. ENGINE POWER TRAIN

A single cylinder four stroke 125 cc engines is selected. So there had number of options for the selection of engine such as Honda shine, Bajaj discover, TVS Phoenix etc. After long research work and survey, it is decided to use Honda CBF Stunner 125 engine to power a kart. It have inbuilt gear box of manual 5 speed constant mesh gear box, with the multi plate wet clutch. So the design is according to the engine specification.

Table-11: Engine Specification

Engine	Honda CBF Stunner 125

Max. Torque	10.8 Nm
Max. Power	13 PS
Fuel Economy	68 kmpl
Dry Weight	22 Kg
Overall Dimensions	16.5” x 12.5” x 10.5”
Gearbox	5 Speed

Table-12: Gear Reduction Values

Primary Gear Reduction	3.08
1st Gear Reduction	2.83
2nd Gear Reduction	1.71
3rd Gear Reduction	1.33
4th Gear Reduction	1.08
5th Gear Reduction	0.91
Max. Engine RPM	8000

6.1 SHAFT DESIGN

The rear axle is used to transmit the power from engine to the rear tires through chain drive. It is the solid shaft of diameter 30 mm and length of 1200mm according to design calculations. The material used is EN8 which is also known as AISI 1040. It is the medium carbon steel with improve strength over mild steel and it is easy to machine at supplied condition.

Table-13: Material Properties

Mechanical Properties	
Ultimate Tensile Strength	620 MPa
Yield Strength	415 MPa
Hardness	58 Rockwell
Density	7.845 g/cc
Young’s Modulus	210 GPa
Chemical Composition	
Iron (Fe)	98.6 %
Manganese (Mn)	0.60 %
Carbon (C)	0.40 %
Sulphur (S)	0.050 %
Phosphorus (P)	0.040 %

6.2 CHAIN DRIVE

For this system, chain drive type transmission is most preferable as it is easy to install, simple in design and cost effective. The chain type used is of roller chain and pitch of chain is decided from power rating table. After interpreting the chain data, numbers of teeth on driving sprocket are decided according to application and power of engine. The secondary gear reduction is calculated on the basis of how much maximum rpm driven sprocket should possess in order to run the kart at top speed of 50 kmph after considering the transmission efficiency , manufacturing deficiencies and how much maximum rpm is available at the driving sprocket. From the analytical calculations, 1.71 is the tabulated value of secondary reduction ratio.

Table-14: Chain Drive

Chain	
Max. Torque at Rear Axle	242 Nm
Shock Factor	1.25
Chain no.	8 B
Chain Pitch	12.7 mm
Length of Chain	685.5 mm
No. of Links	54 links
Roller Diameter	8.51 mm
Gear Ratio	2.57
Diameter of Shaft	30 mm
Driving Sprocket	
No. of Teeth	14
Pitch Circle Diameter	57.07 mm
Driven Sprocket	
No. of Teeth	36
Pitch Circle Diameter	145.75 mm

6.2 EXHAUST SYSTEM

The design of exhaust system needs to be in such a way that it should be lighter in weight and should have minimum resistance to gas flow (back pressure) and keeping it within the limits specified for the particular engine model and rating to provide maximum efficiency, reducing exhaust noise emission, to meet local regulations and application requirements. Providing adequate clearance between exhaust system components and engine components, machine structures, engine bays, enclosures to reduce the impact of high exhaust temperatures on such systems.

6.2.1 BS 6

Bharat Stage VI Norms –

- NOx emission will come down by approximately 25% for the petrol engine and 68% for the diesel engines.
- The PM emission will see a substantial decrease of 80% in diesel engines.

- OBD will become mandatory for every vehicle and it will help monitor the pollution caused by the vehicle in real time.
- RDE (Real Driving Emission) will be introduced for the first time that will measure the emission in real-world conditions and not just under test conditions.

Catalytic Converter

- A catalytic converter is an exhaust emission control device that reduces toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants by catalyzing a red-ox reaction (an oxidation and a reduction reaction).
- The three harmful compounds are:
- Hydrocarbons (In the form of unburned gasoline.)
- Carbon monoxide (Formed by combustion if gasoline.)
- Nitrogen Oxides (Crested when the heat in the engine forces nitrogen in the air to combine with oxygen.)

In a catalytic converter, the catalyst (in the form of platinum and palladium) is coated onto a ceramic honeycomb or ceramic beads that are housed in a muffler-like packaged attached to the exhaust pipe. The catalyst helps to convert carbon monoxide into carbon dioxide. It converts the hydrocarbons into carbon dioxide and water. It also converts the nitrogen oxide back into nitrogen and oxygen.

The catalytic converter was specifically invented to decrease harmful pollution caused by the combustion of hydrocarbon-based fossil fuels in cars.

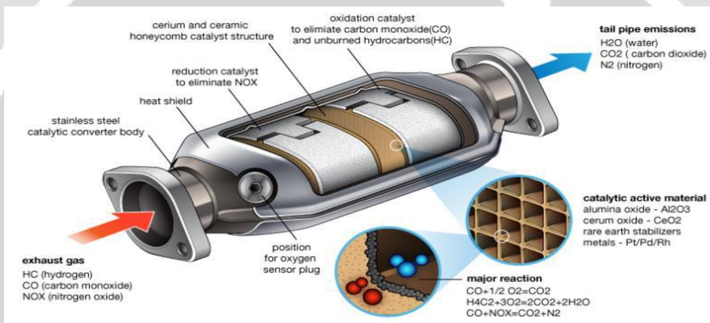

Figure-11: Catalytic Converter

7. OTHERS

7.1 BODY PANELS

The panels are designed such that they tends to reduce the aerodynamic moments like pitching from front, yawing from side and also helps to create the downward force to which tends to make the good traction of vehicle with the road & also provide the properties necessary to protect the driver and vehicle components from rocks and other debris. When the panels were integrated into the car, the panels were recessed into the chassis to provide visibility to the chassis members. The Black coloured body panels made up of fiber material is used, in order to reduce the weight of kart making the car aesthetically pleasing.

7.2 ELECTRICALS

In this Go kart, 12V - 5 Ah battery is used. The parallel circuits from battery are connected to the electrical appliances such as, Starter, Ignition system, Tail lights and two kill switches. These switches are located near front side of seat and other at the right side of the driver on the rear roll hoop. In case of accident, one can use the kill switch which is placed on the right of the driver to kill the engine. Brake light is mounted on the rear end of the chassis, which is clearly seen by rear vehicles.

8. ERGONOMICS AND SAFETY

The seat in this kart is designed to be very light and is made of plastic material. It is attached to the chassis by four points along with rubber bushes to reduce vibration to increase driver’s comfort. The pedal position is ergonomically compatible with the driver's driving style. This kart has compact cockpit which is comfortable yet safe. The steering wheel is designed so as to occupy less space and easy to steer.

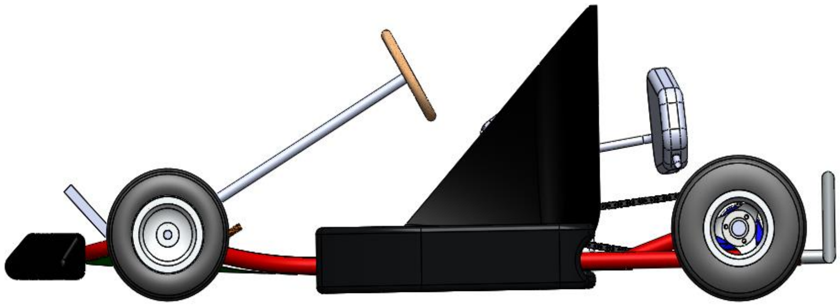

Figure-12: Side View

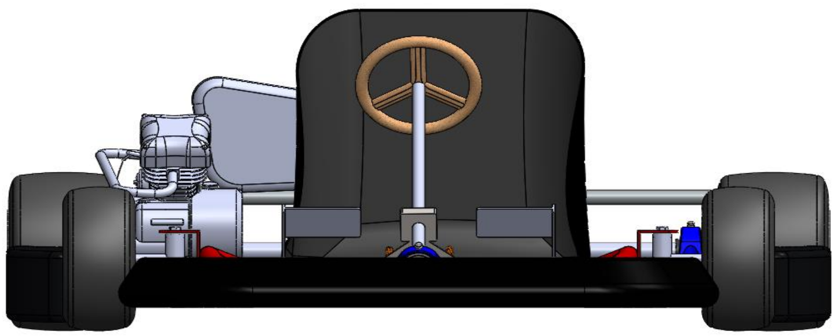

Figure-13: Front View

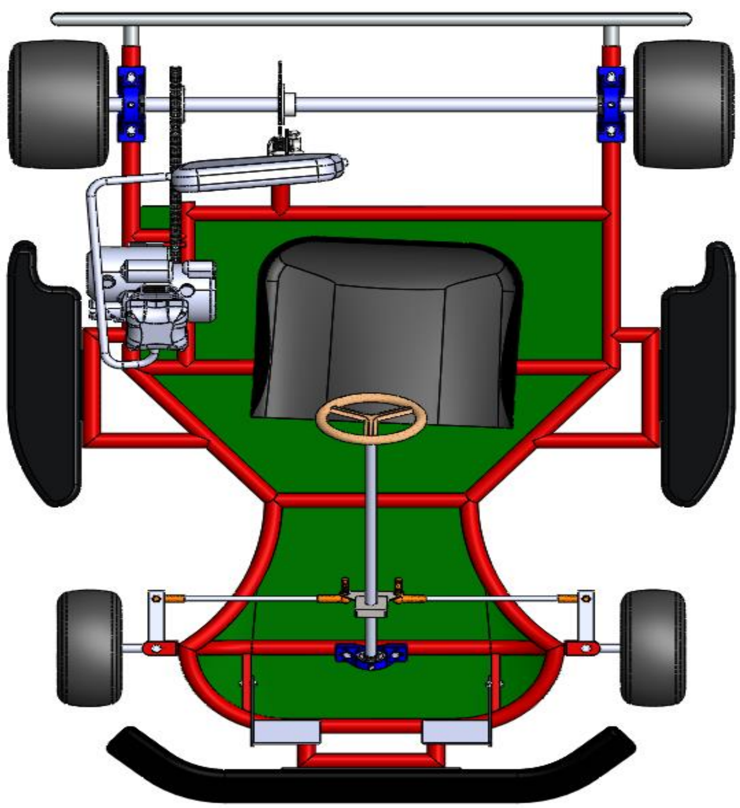

Figure-14: Top View

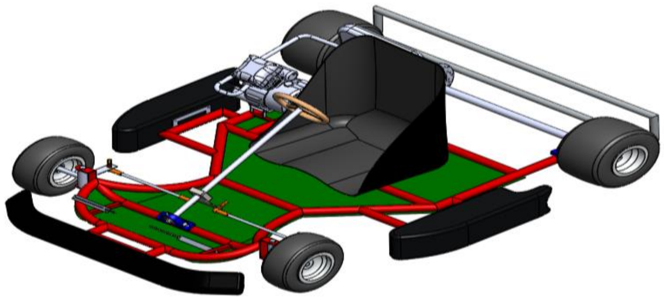

Figure-15: Isometric View

9. CONCLUSIONS

Result concluded that the AISI 1010 material used is more economic and gives better performance of kart. Static analysis was successfully carried out on chassis CAD model to determine equivalent stresses, maximum deformations, Factor of Safety on chassis model. The factor of safety calculated is found to be greater than 1. Hence the chassis design is safe.

The Engine selected and Power train designed can easily propel the Go-kart at higher speed. The Brake system is also designed so as to lock the rear wheels and stop the kart safely even at higher speeds. Also the Steering system designed for the kart gives the turning radius which satisfies the minimum condition of turning the go-kart on racing tracks.

This paper gives us the adequate idea and design guidelines about modeling and designing of Go-Kart. Thus after all the analysis and design calculation, It concluded that our design of Go-kart is safe for fabrication.

Figure-16: Fabricated Model

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