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Design and Development of Roll Cage and Steering System of Go-Kart

Adinarayan Dhananjay Kamat[1], Akash Dilip Raval[2], Amol Laxman Dinde[3], Prashant Prakash Kirane[4], Ashish Kumar Parekh[5], Akshay Vishwas Kamble[6], Hamida Shakil Jamadar[7]
[1,2,3,4,6,7]B. Tech Student,[5]proffessor, Department of Mechanical Engineering, NMCOE, Peth, Maharashtra, India

Abstract: Go-kart is a one of the motor sport which is played globally. This racing does not require any professional drivers or greater speed. It is a light weight and cheaper vehicle which does not require suspension and differential. In this paper we are concentrating on Roll cage and steering system of Go-kart. While keeping it light weight, chassis material is selected as AISI 1018 which give more tensile strength, machinability, and can sustain maximum load. For designing and analysis CATIA and ANSYS soft wares were used. Whereas in steering system the Ackermann steering mechanism is used for attaining maximum cornering speed, without the slippage of tires. This also gives us minimum turning radius, helping us to take sharp turns when the driver has to take sharp corners.
Keywords: Roll cage, Racing, Karting, steering system, Ackermann steering mechanism

I. INTRODUCTION

Go-kart may be a simple self-propelled, lightweight and compact vehicle easy for operation. Because of low ground clearance, this sort of vehicles are specifically designed and fabricated for racing. Its main parts are the Roll cage, transmission shaft, steering, engine, wheel, bumpers and tires. Because it is one among the racing vehicles, its ground clearance is low thanks to which no suspension is placed. Its engine might be either two-stroke or four stroke engine. Chassis in one among the most component of this vehicle because the total weight of the vehicle should be beard by it. Chassis should have strength and stability. Go-karting is adventurous and great sporting vehicle for the people that have an interest in racing due to its low cost, simple construction and safer way of racing. Its racing track might be indoor or outdoor. This project is aimed to be model and perform the dynamic analysis of the go-kart chassis which is made with the circular cross section beams. Modelling and analysis are performed on SOLIDWORKS software. The chassis is meant in such how that it requires less pipes and skill to face up to optimum loads applied thereon. Go kart racings are usually raced on almost any plain tracks with no pits and speed breakers. This is often considered because the first vehicle for starting a career in racing field. A driver could easily steel oneself against racing through this vehicle, wheel-to-wheel racing for top speed, precision control, impulsive racing skills and spontaneous decision- making skills. “Go-Karts” had grown into a billions dollars industry within the USA and most of the developed countries within the world. They’re made, sold, and used exclusively as recreational racers. However these vehicles aren’t designed for transportation and are taken into account illegal in most places to drive them on the road.

A. Scope of the project

Go-Karting is initially created in us in 1950s and used as how to pass spare time. Gradually it became an enormous hobby and other countries followed it. In India go-karting is preparing to form waves. A racing track is prepared in Nagpur for go-karting and Chennai is additionally trying to form one.

Indian companies also are producing go-karts in small scale. MRF and Indus motors are the main bodies in karts and that they are offering karts between 1lakh and three lakh. But to form go-karts popular, the worth must come down. For that, many of us try to create one under 1 lakh and that we had also taken up the challenge. A go-kart just under Rs. 25,000/-. So we are sure that our project will have a high demand within the industry and also we hope to urge orders from the racing guns.

B. About go – karts

Kart racing is typically used as a low-cost and comparatively safe thanks to introduce drivers to motor racing. Many people associate it with young people, but adults also are very active in karting. Karting is taken into account because the initiative in any serious racer’s career. It can prepare the driving force for highs-speed wheel-to-wheel racing by helping develop guide reflexes, precision car control and decision-making skills. In addition, it brings an awareness of the varied parameters which will be altered to undertake to enhance the competitiveness of the kart that also exist in other forms of motor racing.

C. Departments in go – kart

In a Go-Kart, there are mainly five departments. They are,

1) *Chassis:* Chassis is a particularly important element of the kart. Generally it's made from square steel tubes of various grades. But strong hollow circular SAE rated pipes has been used from economic and light weight perspective. Size of the chassis developed is 67"*48"(length*breadth).

Following components are mounted on chassis –

a) Engine having 190cc developing 4.5bhp.
b) Transmission consisting of chain, sprocket and rear axle with axle hangers.
c) Tires.
d) Brakes.
e) Steering assembly.

2) *Engine:* An engine of go-kart is typically a little around 100-200cc. Since there is only requirement of power and not the mileage, Briggs and Stratton 190cc, two stroke engine developing 4.5bhp is used.
3) *Steering Assembly:* Go-kart steering are often complex, overwhelming and a source of major problems within the complex design of go-kart. There are some ways of creating a steering assembly in go kart like Ackermann and Bogie steering mechanism. The simplest, easiest go-kart steering system of 1:1 ratio has been used.
4) *Transmission:* Transmission means the entire of the mechanism that transmits the facility from the engine crank- shaft to real wheels. During this vehicle the facility from the engine is transmitted to rear wheels using chain and sprocket mechanism. The driving force sprocket has 12 teeth and driven sprocket has 44 teeth. Usually go-karts don't have differential. Chain drive has been used be-cause it's capable of taking shock loads. Centrifugal clutch has been utilized in the kart to avoid direct acceleration after starting the engine.
5) *Tires:* For go-karts, wheels and tyres are much smaller than those used on a traditional car. The tyres will have increased grip and may withstand high temperature. In this kart, two tires having 5.5" diameter for front and seven .5" diameters for rear are used. The tyres must have pressure of a minimum of 16 psi
6) *Brake:* On the rear axis drum brakes are mounted. The brake are going to be capable of stopping the kart running in 40 kmph. For this purpose, single disc brake directly attached to rear axle has been used.
7) *Kill Switch:* Kill switch may be a device used for stopping the ignition. Electric kill switch is used to connect engine.

D. Precaution

1) After ever 500 km. engine oil must be changed
2) The nuts and bolts should be properly fixed and tightened.
3) The air filter should be replaced after some time.
4) Corrosion paints are applied to protect Kart.
5) Overweight should be avoided.
6) Fix and tighten all the parts.

II. METHODOLOGY FOR PROPOSED WORK

The SMITSONICS started with the method of brainstorming; literature review and continued with designing; design analysis; fabrication; assembly and documentation consistent with the quality specification of Go-kart. Our design is approached by considering all possible alternatives for a system and modelling them in CATIA V5. The model was then modified and retested for the last word design. The design process of the vehicle is iterative and is predicated on various engineering and reverse engineering processes depending upon the supply, cost and other such factors. The design objectives, began to be achieved were three simple goals applied to each component of the vehicle: durable, light-weight and high performance, to optimize the planning by avoiding over designing, which might also help in reducing the value, with this we had a view of our kart. This started our goal and that we found out some parameters for our work

Designing is one among the foremost important necessity considering the various factors like its aesthetic, functional and economic dimensions. Research should be made before modelling any vehicle in order that the vehicle meets the human needs. Meanwhile, the various sorts of objects may designed, including cloths, graphical user interfaces, skyscrapers, corporate identities, business processes, and method or processes of designing. The design was made supported the driver ergonomics

A material of less weight without compensating the strength was taken into consideration to form the vehicle lesser in weight and optimizing the overall performance.

III.CHASSIS

The chassis is a particularly imported element of the kart, because it must provide, via flex, the equivalent of suspension to offer good grip at the front. Karts haven't any suspension, and are usually no bigger than is required to mount a seat for the driving force and a little engine. Chassis construction is generally of a square tube construction, typically MS with different grades. In this Go-Kart, we have used Mild Steel tube with 1 inch diameter. The chassis support the facility unit, gearing, the running system etc.

The chassis of go-kart may be a skeleton frame made from pipes and other materials of varied cross sections. The chassis of go-kart must contain stability, torsional rigidity, also because it should have relatively high degree of flexibility as there's no suspension. It also can adequate strength to sustain load of operator and other accessories. We have designed chassis considering n the convenience and safety for operator. The chassis was designed for a secure ride and therefore the load is applied thereon without compromising the structural strength.

Be aware that you simply need a strong but light frame. We suggest 2.7mm thick tubing, either square or round (or both) counting on preference. The bending operation of the fabric used should be easier. By adding filler material to the notched area during welding operation strength of frame are often increase. Circular cross-section is used for the chassis development because it helps to beat difficulties as increment in dimension, rise within the overall weight and reduce in performance thanks to reduction in acceleration. Circular section is usually a preferred over other cross section become it resist the twisting effects. Circular section is selected for torsional rigidity.

A. Chassis Dimensions

Overall length of vehicle 1803.4 mm= 71 inches

Track Width :-Front :-1080mm, Rear :-910mm

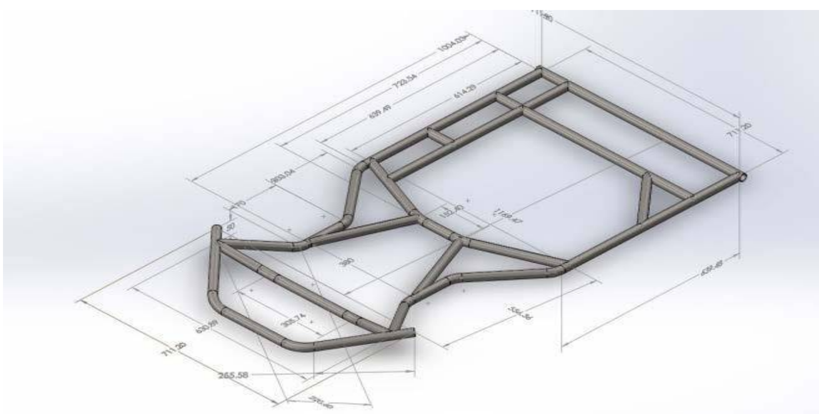

Fig.1 Chassis Dimensions

B. Material and Methodology

The selection of fabric was a tedious task for us because it had many constraints of weight, structural resilience towards various sorts of forces, torsional rigidity, factor of safety under application of varied loads and also market availability with pricing and price constraints.

The roll cage that was designed by the planning team was analyzed after application of varied loads as calculated by the legitimate procedures and mathematical calculations supported physical theories The amount of carbon in steel is vital to work out the strength, hardness, and providing desired strength, endurance, safety and reliability of the vehicle. The material used for chassis is various aluminum alloys. The main component of steel is carbon which increases the hardness of fabric of chassis. Aluminum alloy is dear than steel so mainly steel is employed to constructs the chassis.

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IV. CONSTRUCTION

A. The chassis of a Go-Kart consists of following components suitably mounted:

1) Engine
2) Transmission system, consisting of the chain sprocket, rear axle.
3) Road wheels.
4) Steering system.
5) Brake.
6) Fuel tank.

All the components listed above are mounted on the conventional construction, in which a separate frame is used and the frameless or unitary construction in which no separate frame is employed.

Roll Cage is a skeleton of any vehicle which is used to provide support and mounting points for primary and secondary systems of vehicles. [1]For go kart the main consideration in design of roll cage is that due to no suspension it should have flexibility which will be act as suspension while in motion. For that the cross section of material chosen is of pipe cross-section which will have high strength with flexibility also [5]; so from survey we got 3 materials as per the requirements which are AISI 1018, AISI 1022 and AISI 4130. Every material having own specifications and properties which are making it proper to use but we chose AISI 1018 as having good strength with flexible in nature against the load.

Table.1. Composition of AISI 1018

Properties Material	AISI 1018	AISI 1022	AISI4130
Modulus of Elasticity (Gpa)	205	200	210
Caron Content %	0.15-20	0.20-23	0.28-33
Yield Strength (Mpa)	370	375	435
Ultimate Strength (Mpa)	440	400	560
Density (kg/m^3)	7.87x10^3	7.70x10^3	7.85x10^3

Design of any component is consists of three major principles:

a) Optimization
b) Safety
c) Comfort

The primary objective of the roll cage is to provide a 3-dimensional protected space around the driver that will keep the driver safe. Its secondary objectives are to provide reliable mounting locations for components, be appealing, low in cost, and low in weight. These objectives were met by choosing a roll cage material that has good strength and also weighs less giving us an advantage in weight reduction. A low cost roll cage was provided through material selection and incorporating more continuous members with bends rather than a collection of members welded together to reduce manufacturing costs. The modelling of the roll cage structure is done by using CATIA V-5 software.

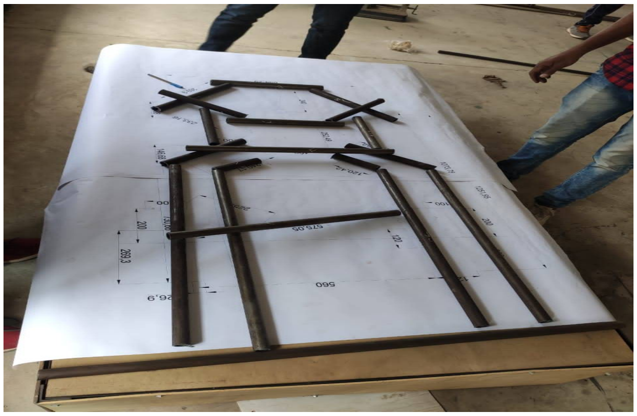

Fig. 2 Chassis construction

i) Function of the frame

- To support the chassis components and body.
- To withstand static and dynamic loads without undue deflection or distortion.

ii) Loads on the Frame

- Weight of the vehicle and the passenger, which causes vertical bending of the side members
- Vertical loads when the vehicle comes across a bump or hollow, which results in longitudinal torsion due to one wheel lifted (or lowered) with other wheels at the usual road level.
- Loads due to road chamber, side wind and cornering force while taking a turn, which results in lateral bending of side members.
- Load due to wheel impact with road obstacles may cause that particular wheel to remain obstructed while the other wheel tends to move forward, distorting the frame to parallelogram shape.
- Engine torque and braking torque tending to bend the side members in the vertical plane.
- Sudden impact loads during a collision, which may result in a general collapse.

B. Frame Design

1) *Objective:* The frame 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. Principal aspects of the chassis focused on during the design and implementation included driver safety, drive train integration, and structural weight, and operator ergonomic. The number one priority in the chassis design was driver safety. By the competition rules and Finite Element Analysis (FEA), the design assured.

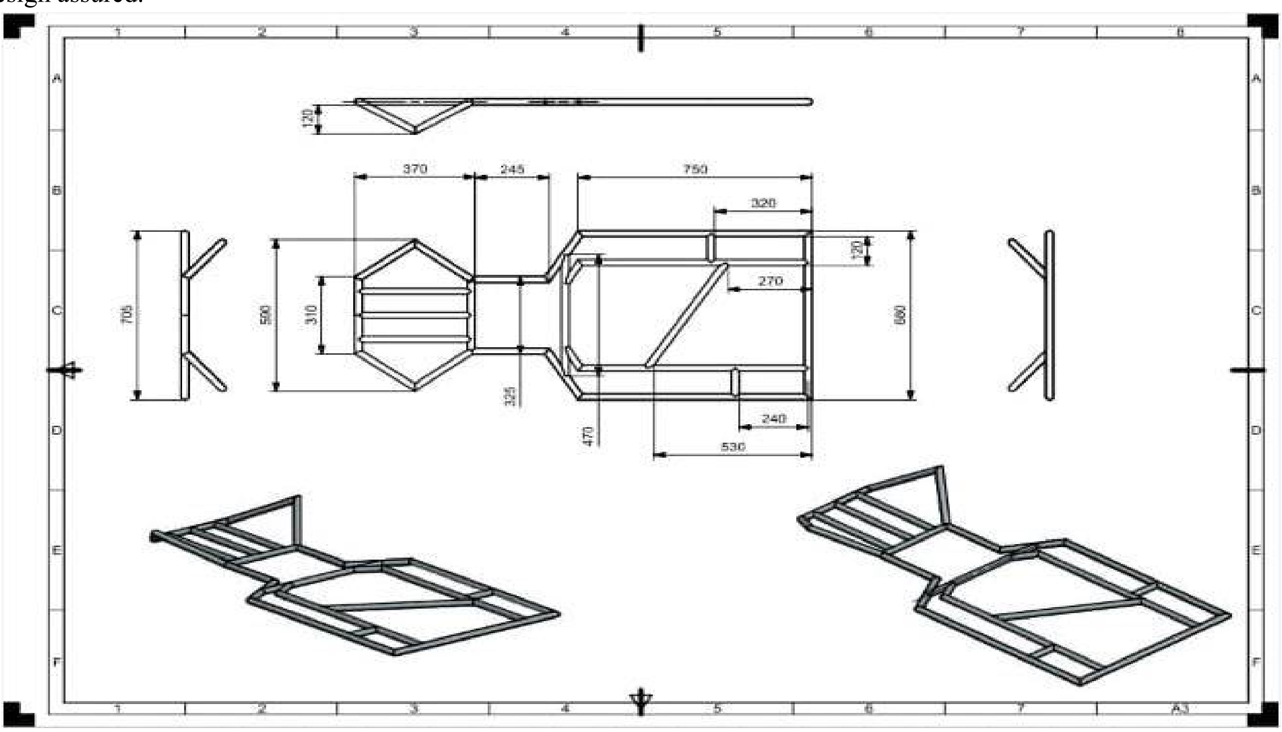

Fig.3. CAD model

2) *Safety:* Roll cage feature were first implemented by keeping on mind the safety requirement of the event .The first primary safety standard focused on during design was maintaining the proper clearance of the driver's body rest to the other rigid parts like engine compartment, firewall structure, and panel bracing of the vehicle. Once the basic requirements fulfilled the other safety design were implemented. The chassis was designed to give occupant extra space to operate the vehicle easily. The place of the fire extinguisher is designed in the easily accessible point and also the ethane foam padding is provided over the pipes adjacent to driver.

3) *Structural Rigidity:* Overall frame structural rigidity is important to enhance the capabilities of a 4-wheeler vehicle. To measure the overall frame rigidity, tensional rigidity analysis was conducted through CAD. The objective of the tensional rigidity analysis was to manipulate the chassis design within the CAD software to increase the amount of torque per degree of chassis deflection. By theoretically increasing this value, the actual vehicle could have the ability to be more torsion-ally rigid, making it able to withstand more intensive without failure. Which is equivalent to the gross weight is calculated i.e Gross weight = 120kg and the equivalent force that is

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F = M × g F = 120 × 9.81 F = 1177.2 N

The calculated force is placed on one of the corner of the frame while other three corners were kept fixed by constraining.
Hence according to the result obtained, the frame would be torsion-ally rigid.

4) *Weight:* Keeping the frame as light as possible was a top priority. When power is limited, vehicle weight is a large factor in vehicle performance. The frame is one of the large stand heaviest components of the car, and which is why special attention was given to it. The strategy utilized to minimize weight consisted of determining defined goals for the chassis and employing the correct material in the best places to accomplish those goals. Once baseline safety design requirements were met, CAD aided the material decision making process. CAD specifically helped to determine whether a member was under high or low stresses, in the scenarios discussed previously, making the chassis design process efficient and effective. Chassis members were made out of inch (2mm) wall thinness and 1inch (25.4mm) outer diameter AISI 1018, this material was chosen because of its weight reduction capability and beneficial material properties, as was stated previously. Through accurately determining stresses on the chassis in different scenarios, weight reduction was able to be maximized through material selection and placement. Also the simplicity of the frame design that is used for less number of members tends to the reduction in the weight. The final weight of the chassis was measured in software as 22kg and the gross (final)

V. DESIGN

We have selected the material as AISI 1018 for chassis pipes.
Yield Strength = 370 MPa
Taking, factor of safety = 2
σpermissible = 230 MPa.
Tesnsile strength = 440 mpa
The point loads of 98.06N, 490N, 14N, 637N, 1470N and 117N are acting on beam at points C, D, E, F, G and H due to the steering, fuel tank, chassis, engine, driver and battery, respectively as shown below.

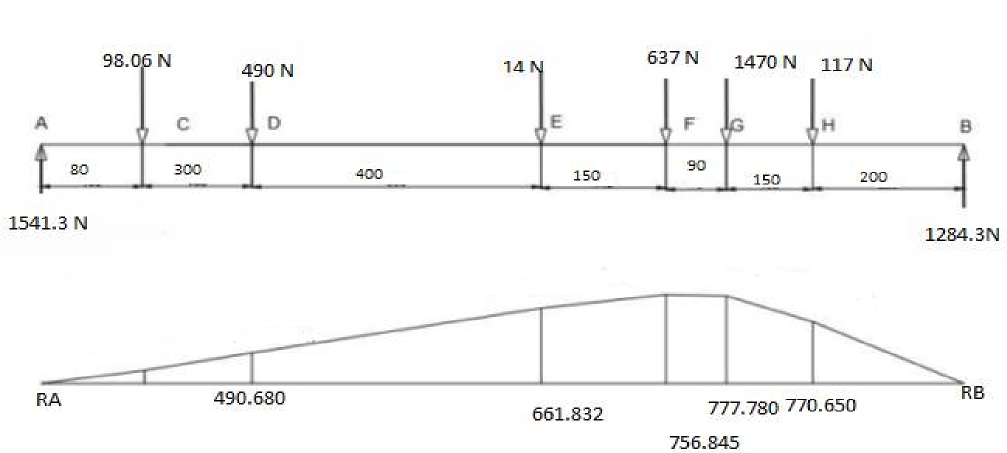

Fig.4. BMD for chassis

A. BMD Calculations

RA and RB are the reactions at point A and point B respectively.
ΣFY =0
RA + RB = 550N
Moment at point A:
ΣMA =0
10 × 100+20 × 200+50 × 535+140 × 680+300 × 750+30 × 850-1070 × RB =0
RB = 352.757N
Therefore, RA = 197.243N
Now,
For bending moment diagram,
Bending moment at point A (MA) = 197.243 × 0 = 0
Bending moment at point C (MC) = 197.243 × 100 = 19724.3N-mm = 19.7243N-m
Bending moment at point D (MD) = 197.243 × 200-10 × (200-100) = 38448.6N-mm = 38.4486 Nm
Bending moment at point E (ME) =197.243 × 535-10 × (535-100)-20 × (535 -200) = 94475N-mm = 94.475N-m
Bending moment at point F (MF) =197.243 × 680-10 × (680-100)-20 × (680-200)-50 × (680-535) = 111475.2N-mm = 111.4752N-m
Bending moment at point G (MG) =197.243 × 750-10 × (750-100)-20 × (750-200)-50 × (750-535)-140 × (750-680) = 109882.3N-mm = 109.8823N-m
Bending moment at point H (MH) =197.243 × 850-10 × (850-100)-20 × (850-200)-50 × (850-535)-140 × (850-680)-300 × (850-750) = 77606.6N-mm= 77.6066N-m
Bending moment at point B (MB) = 197.243 × 1070-10 × (1070-100)-20 × (1070-200)-50 × (1070-535)-140 × (1070-680)-300 × (1070-750)-30 × (1070-850) = 0
From above, the maximum bending moment (Mmax) is at point F.
Therefore,
Mmax = 111.4752N-m
We take, fixed outer diameter of pipe (D) = 25.4mm
Y= D/2 = 12.7mm
Moment of inertia (I) = (π/64) × (D4-d4) = (π/64) × ((25.4)4-d4)
We know that,
Mmax / I = σ permissible / Y
111475.2 / I = 230 / 12.7
I = 6155.3697mm4
6155.3697 = (π/64) × ((25.4)4-d4)
From these we get,
d = 23.2226mm
t = (D-d)/2 =1.0887mm
Therefore, For pipe of Outer Diameter 25.4 mm, 1.0887mm thickness is required in order to prevent bending of chassis due to point loads. But by taking into consideration the constraint given in rulebook and results of analysis of chassis in ANSYS16.0, We have selected cross section of 1.8mm thickness.

B. Calculations for Torsional Stiffness

Torsional Stiffness = G * J / L
Where,
G -Modulus of Rigidity
J - Polar moment of Inertia
L- Length
Modulus of rigidity for given material is 80GPa
For D = 25.4mm, t = 1.8mm

The polar moment of Inertia (J) = (π/32) × (D4-d4)
= (π/32) × ((25.4)4-(21.8/4)
= 18690.3525mm4
Length (L) = 1070mm

Torsional stiffness = T/θ = (G× J)/L
= ((80×103) × 18690.3525)/1070
= 1.3974×106N-mm/rad
= 1397.4N-m/rad
Similarly, we have calculated the torsional stiffness values for different cross sections that are easily available in market. Therefore, we get following result
Calculations for Bending Stiffness:
Bending Stiffness = E * I
Where,
E – Young's Modulus
I – Moment of Inertia
Young's modulus of given material (E) = 210GPa
Moment of inertia (I) = (π/64) × (D4-d4)
= (π/64) × ((25.4)4-(21.8/4)
= 9345.1763 mm4
Bending Stiffness = (210 × 103) × 9345.1763
= 1.9625× 109 N-mm2
= 1962.5N-m2
Therefore, the torsional stiffness and bending stiffness for a given cross section are 1397.4N-m/rad and 1962.5N-m2 respectively. Similarly, we have calculated torsional stiffness and bending stiffness for some other cross sections that are easily available in market.

VI. CONCLUSION

The basic need of Go-kart vehicle is a smaller amount weight to strength ratio and fewer clearance also satisfied by the roll cage. Keeping fabrication in the mind, we tried to make the design optimum and simple with high in strength and stability. Thus roll cage is demonstrating good strength against collisions from the front, rear as well as side.
From the above calculation we can conclude that AISI 1018 is one of the materials that could be used for fabrication of go-kart chassis as it gives better performance. Static analysis is performed in Solid works software using FEA technique on the chassis CAD model successfully. Maximum stress, deformation, displacement and factor of safety are determined from it. The factor of safety is calculated and it is found to be greater than 1.
Factor of safety is under the safe limit and may be wont to make a Go- kart. Hence we will conclude that the chassis design is safe and stable. The design of the chassis for Go-Kart helps to finding the strength and weakness of the planning and fabrication. With the assistance of the analyses, it's easy to spot the chassis to rectify the weak points and therefore the strength it with slight modifications.
The designing of the chassis for Go-Kart helps in identifying the strength and weakness of the build and style. With the assistance of the analyses, it'll be easy to switch the chassis to rectify the weak points and to strengthen it with slight modifications. It will be able to carry all the components such as power train, power unit, wheels, tires and also it must have the capacity to carry a human weighing more than 70kg. On adding all the weights, it crosses quite 150kgs.

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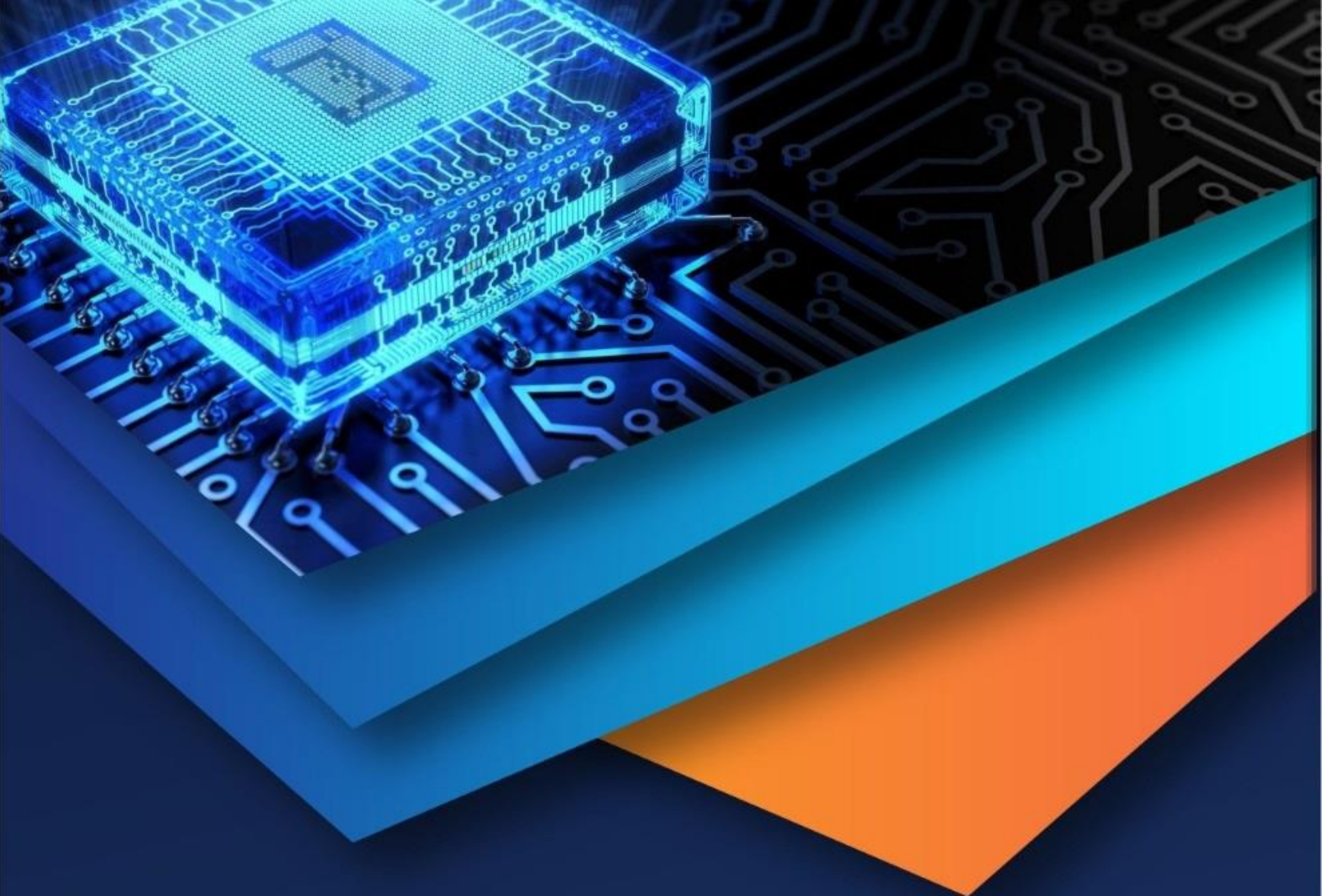

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