International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

Design and Analysis of Two-Seater Go-kart Steering Mechanism.

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Abstract - *The Main Objective of this paper is to detailed design, calculation and analysis of two-seater Go-Kart. As go-kart is usually for the racing purpose which is always a one-seater Go-Kart. Introducing the Two-seater Go-Kart leads to change in the chassis and steering mechanism. This paper gives you an idea and an approach to design, calculation and analysis of the two-seater go-kart steering mechanism by using the Ackerman Principal and Rack and Pinion steering Mechanism. Also, this paper includes the material selection of the two-seater Go-Kart Steering Mechanism.*

Key Words: Go-Kart Steering System, Rack and Pinion, Two stater Go-Kart, Steering Mechanism, Ackerman Geometry.

1.INTRODUCTION

Steering mechanism in vehicle gives direction and corning at required angle. Steering system is a group of linkages which transmit the movement of steering wheel to the front and rear wheels. The primary purpose of the steering system is to allow the driver to guide the vehicle. Vehicle should get proper turn at the turning point without skedding. To avoid the skedding of vehicle, Ackerman Geometry is used to design the steering mechanism. Considering 100% Ackerman geometry so that vehicle will get proper and safe turn. For optimizing the low weight Steering mechanism, Rack and Pinion is used in two-seater Go-Kart which is compact, having less no. of components and high durability.

2. METHODOLOGY

For this paper, we have found the proper approach to calculate, design and analyze the whole Steering Mechanism. In which we have selected the Ackerman Geometry as a steering geometry and Rack and Pinion for the Steering mechanism.

Selection and Calculation of Steering Geometry

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Design and Calculation of Rack and pinion

↓

Design and Calculation of other components of Steering Mechanism

↓

Force Calculation, Material Selection and Analysis.

2.1 Considered parameters of Two-Seater Go-Kart

Table -1: Considered parameters of Two-Seater Go-Kart

Wheelbase (b)	1700 mm
Track Width (c)	1500 mm
Pin to Pin Distance (a)	1280 mm
Total Weight of Vehicle (m)	300 Kg
Weight Distribution	45:55

3. Selection and Calculation of Steering Geometry

For a Go-Kart or any other vehicles, it is very important to take a perfect turn at a turning point to avoid vehicle to skid. As far as the geometry of steering is concerns, Ackerman geometry is selected. The intention of Ackermann geometry is to avoid the tires to slip sideways when turning around a curve. The geometrical solution is for all wheels to have their axles arranged as radii of circles with a common center point with the angles.

To design the geometry of the steering i.e. Ackerman Geometry, we need to consider the minimum turning radius for the Go-Kart. Considering the 300 mm of minimum turning radius (R) which is suitable for all the conditions.

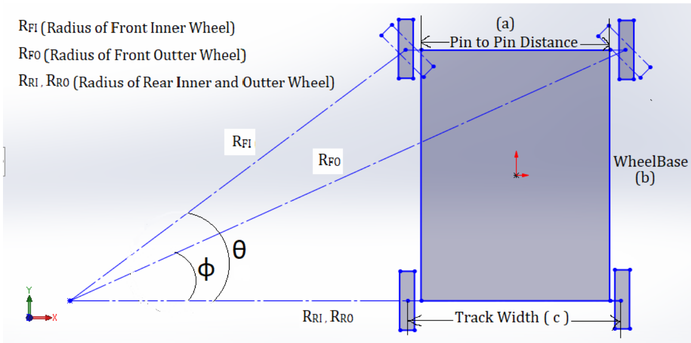

Figure – 1: Ackerman Geometry

Considered Minimum Turning Radius (R) is 300 mm.
The minimum angles of the front wheels are:

$$\text{Front Inner Wheel Angle } (\theta) = \tan^{-1}\frac{(b)}{(R - c/2)}$$

$$= \tan^{-1}\frac{(1700)}{(3000-1450/2)}$$

$$= 36.77^{0}$$

Front Outer Wheel Angle (φ) = $\tan^{-1}\left(\frac{b}{R + c/2}\right)$

= $\tan^{-1}\left(\frac{1700}{3000+1450/2}\right)$

= 24.53^0

Ackerman Angle (β) = $\tan^{-1}\left(\frac{b}{b/\tan(\varphi) - c}\right)$

= $\tan^{-1}\left(\frac{1700}{1700/\tan(24.53) - 1450}\right)$

= 36.77^0

Ackerman geometry should be 100% to avoid the vehicle to skid.
% Ackerman = θ/ β * 100 = 36.77/36.77 * 100
= 100 %
Ackerman Geometry Should satisfy the following condition:
$\cot(\varphi) - \cot(\theta) = c/b$
$\cot(24.53) - \cot(36.77) = 1450/1700$
0.853 = 0.853
The Ackerman Geometry is 100 % Safe and Correct.

4. Design and Calculation of Rack and pinion

Steering Mechanism are of two types Mechanical Linkage and Rack and Pinion steering Mechanism. By comparing both the Steering Mechanism we selected the Rack and Pinion Steering Mechanism for the Go-Kart. As it is compacted and having a less number of components as compared to the Mechanical Linkages. It has high durability and required very less steering efforts to turn the steering wheel. Therefore, the steering ratio or pinion and rack gear ratio is considered as 1:1.
For the selected gear ratio of 1:1, the Pitch circle diameter (PCD) of pinion and No. of teeth (Tn) of pinion and rack is given by the following calculation.
Taking Module (m) = 1.5

Module (m) = $\frac{\text{PCD of pinion}}{\text{No. of Teeth}} = \frac{40.5}{27} = 1.5$

Since, PCD of pinion and no. of teeth of pinion has taken in such a way that their ratio will become 1.5 with the pitch of 20 mm and Rack rod diameter as 20 mm and Pressure angle 20 degree
.
Since, Ratio of pinion to rack is 1

Gear Ratio = $\frac{\text{No. of Teeth of pinion}}{\text{No. of Teeth of rack}}$

$1 = \frac{27}{\text{No. of Teeth of rack}}$

Therefore, no. of teeth of rack = no. of teeth of pinion = 27

Rack Travel(X) or Rack length is Calculated as

Module (m) = $\frac{\text{Rack Travel or Rack length}}{\text{Pai * no. of Teeth of rack}}$

$1.5 = \frac{\text{Rack Travel or Rack length}}{3.14 * 27}$

Therefore, Rack Travel or Rack length is 127.25 mm.

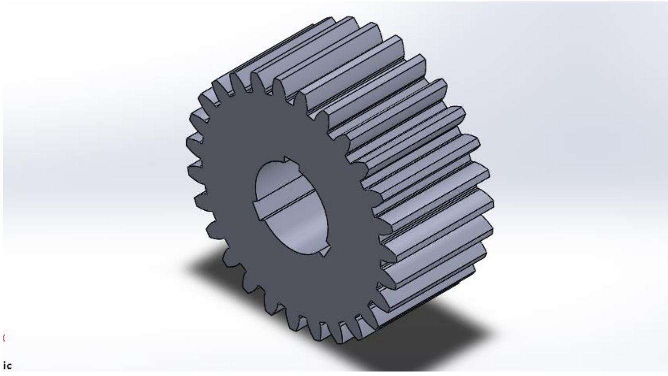

Figure – 2: CAD Model of Pinion

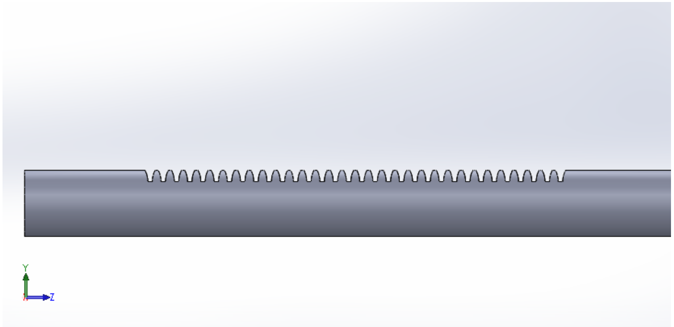

Figure – 3: CAD Model of Rack

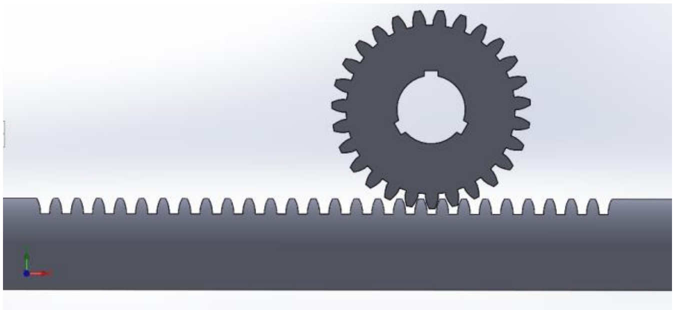

Figure – 4: Rack and Pinion Assembly

5. Design and Calculation of other components of Steering Mechanism

The main components of the steering mechanism are:
Steering Wheel → Steering Column → Rack and Pinion → Tie Rod → Stub axel and bracket → Wheel.

5.1 Steering Wheel

Considering the standard steering wheel is of 30mm in diameter for our Go-Kart with the material of Al 6061.

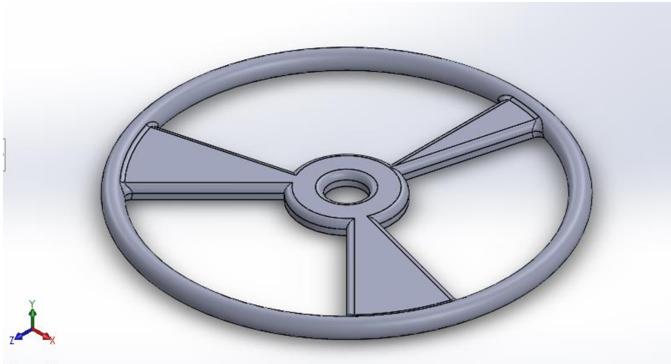

Figure – 5: CAD Model of Steering Wheel

5.2 Steering Column

A single rod Steering Column is going to be used as at the one end steering column will be there and at the other end pinion of the steering mechanism will get attached through shaft key.

As the Go-Kart is two-seater, the position of the steering mechanism should be shifted on the right side. It does not affect the length of the steering column. Considering the dimensions of our vehicles and the driver the dimensions of steering columns should be:

Steering column length = 300mm
Inner diameter of pipe = 8mm
Outer diameter of pipe = 15mm

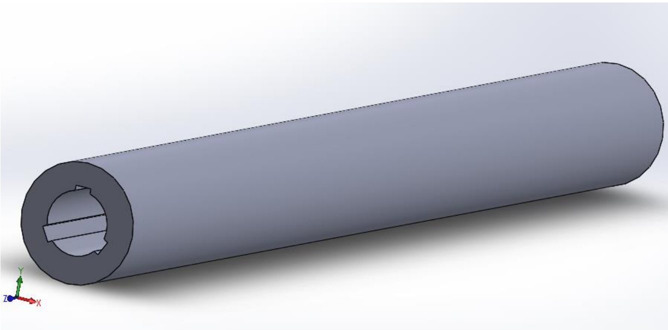

Figure – 6: CAD Model of Steering Column

5.3 Tie Rod

The length of tie rod is considered on the basis of Ackerman geometry and the dimensions of the go-kart. Two tie rods are used at both the end of the rack with the rose joint.

M8 rose joint is selected with the tube dimensions as follows

Table -2: Parameters of Tie Rod

Tie rod length	170.4 mm
Inner diameter of tube	8 mm
Outer diameter of tube	12 mm
Rose joint specification	M8

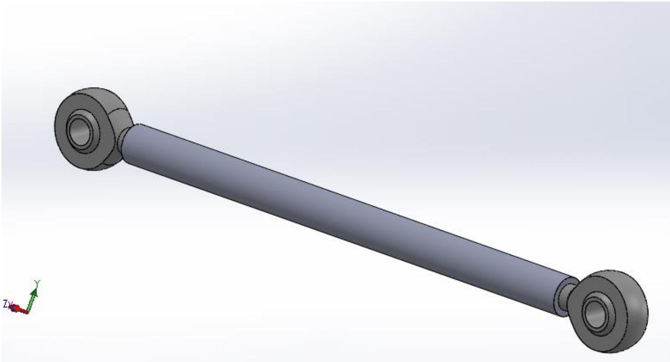

Figure – 7: CAD Model of Tie Rod

5.4 Stub Axel and Bracket

The axle design was decided on the basis of Ackerman geometry and tire size. The bracket used is an OEM part.

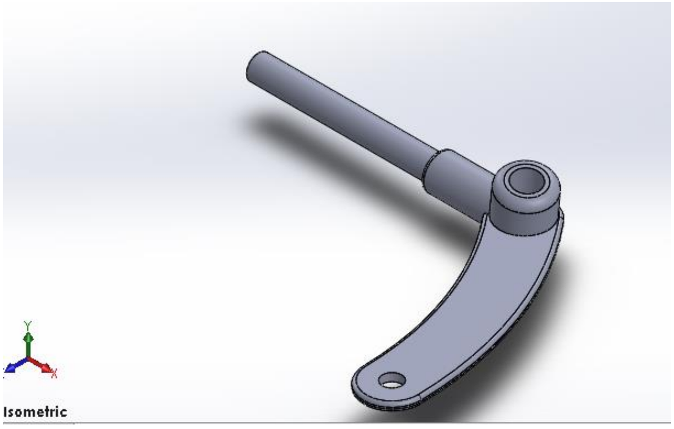

Figure – 8: CAD Model of Stub Axel

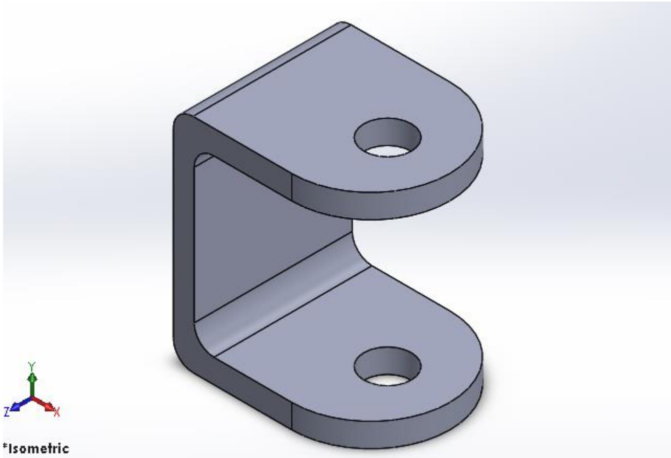

Figure – 9: CAD Model of Bracket

6. Force Calculation, Material Selection and Analysis.

Analysis has to be done for each and every component to determine the factor of safety and total deformation for the selected materials to know whether the Design is safe or not in the Ansys Workbench.

The Material section has done in such a way that all the components can carry maximum load on it and the weight of the mechanism should be reduced.

6.1. Rack and Pinion

Torque on a pinion (T) = 1000*Radius of Pinion
= 1000*0.02025
= 20.25 N-m

a) Tangential Force (F_t):

$$Ft = \frac{2000 * T}{PCD} = \frac{2000 * 20.25}{40.5} = 1000 \text{ N}$$

b) Radial Force (F_r):

Fr = Ft * tan (Pressure angle) = 1000 * tan (20)
= 363.97 N

Selected Material AISI 4130 for both Rack and Pinion.

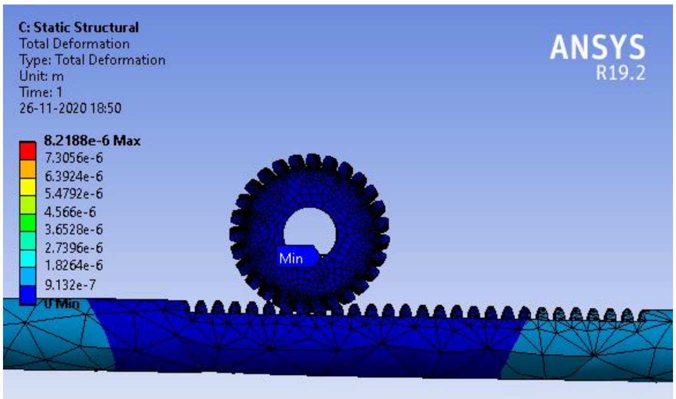

Figure – 10: Total Deformation of Rack and Pinion Assembly

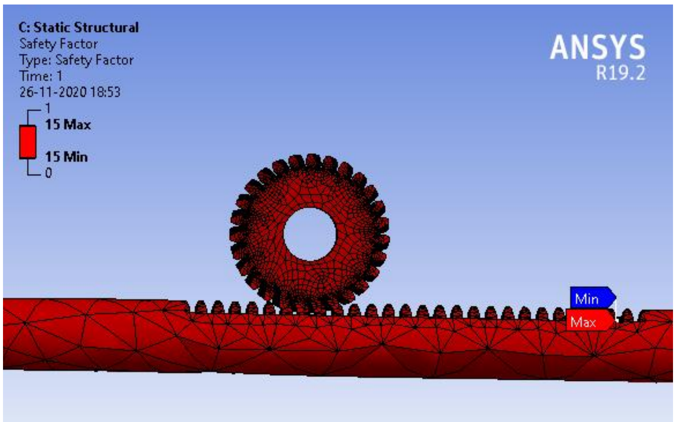

Figure – 11: FOS of Rack and Pinion Assembly

6.2. Steering Wheel and Steering Column

Torque on a steering wheel = Torque on a pinion (T)
= 20.25 N-m
Torque on Steering column is same as torque applied on pinion = 20.5 N-m

Materials selected:
Steering Wheel: Al6061
Steering Column: Stainless Steel

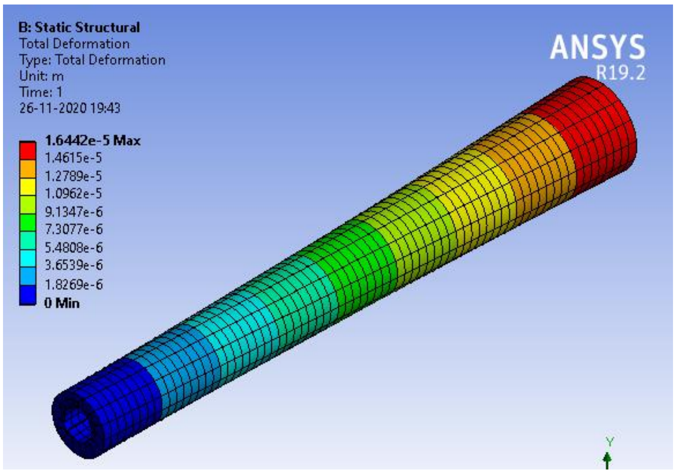

Figure – 12: Total Deformation of Steering Column

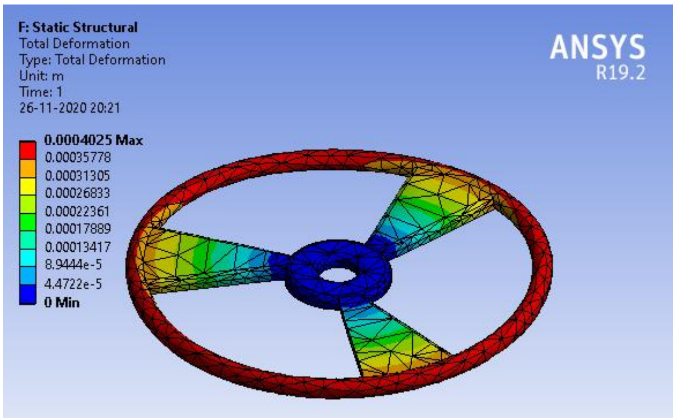

Figure – 13: Total Deformation of Steering Wheel

6.3. Tie Rod

Tyer Specification:
Width of the Tyer = 114.40 mm
Radius = 129.80 mm
Force of rock acting on wheel (Frock) = m*a = 300*16
= 4800 N
(Taking average Acceleration (a) = 16 m/s²)

Moment of kingpin ($M_{kingpin}$) = Frock*(Width of front wheel)/2
= 4800*0.0572
= 274.32 N-m

Force acting on Tie Rod = $\frac{M_{kingpin}}{\text{Radius of Wheel}} = \frac{274.32}{0.1298}$
= 2113.405 N

Material Selected is Mild Steel for Tie Rod.

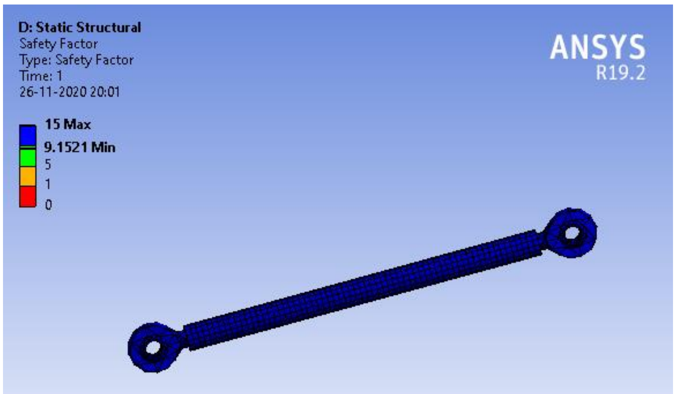

Figure – 14: FOS of Tie Rod

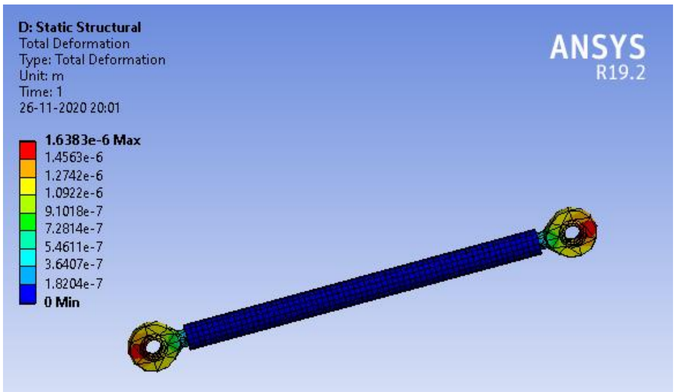

Figure – 15: Total Deformation of Tie Rod

6.4. Stub Axel and Bracket

Mass of front tires (m) = 67.5 kg
Average velocity (v) = 30 km/hr = 8.33 m/s
Coefficient of Friction (μ) = 0.6

i) Normal Force on Stub Axle:
N = m*g = 67.5 * 9.81 = 662.175 N
ii) Lateral force on Stub Axle:
Lateral force = $\frac{mv^2}{R} = \frac{67.5*(30)^2}{21.96}$ = 2766.39 N
iii) Tractive Force:
Force due to Traction = μ*Normal force = 0.6*662.175
= 397.305 N
Materials selected as AISI 1045 for both Stub Axel and Bracket.

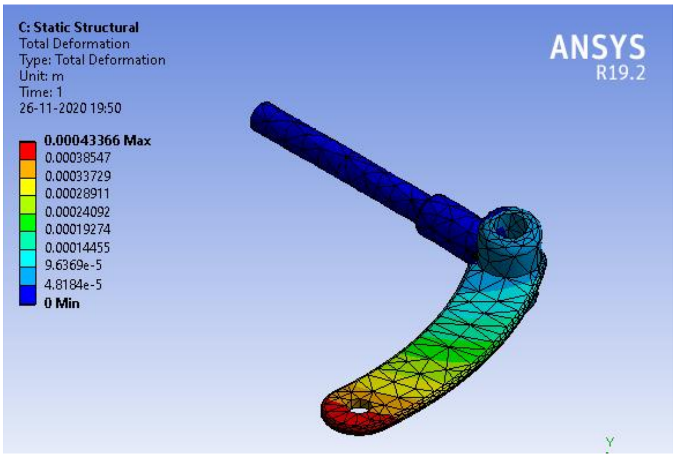

Figure – 16: Total Deformation of Stub Axel

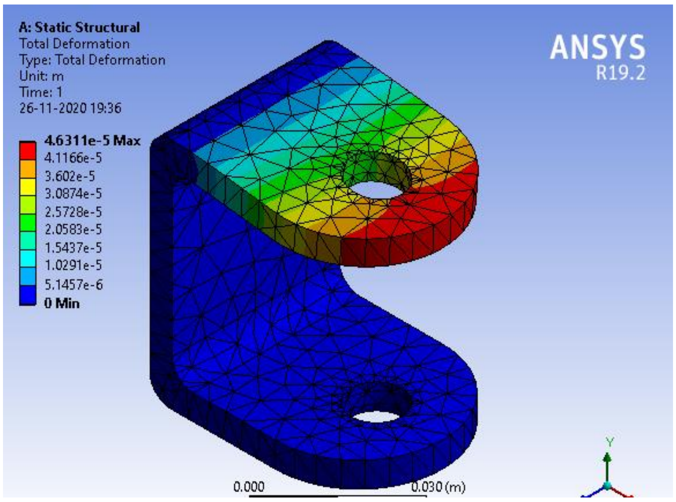

Figure – 12: Total Deformation of Bracket

7. RESULT

The result of Steering mechanism is divided into two parts, Design part and Analysis part with materials.
The resultant design are as follows:

Wheelbase (b)	1700 mm
Track Width (c)	1500 mm
Pin to Pin Distance (a)	1280 mm
Total Weight of Vehicle (m)	300 Kg
Weight Distribution	45:55
Minimum Turning Radius (R)	300 mm
Front Inner Wheel Angle (θ)	36.77°
Front Outer Wheel Angle (φ)	24.53°
Ackerman Angle (β)	36.77°
Module (m)	1.5
PCD of Pinion	40.5 mm
No. on teeth on pinion & Rack	27
Rack Travel / Rack Length	127.25 mm
Face Width	20 mm
Pressure angle	20°

3. CONCLUSIONS

This paper gives you a theoretical idea about the Designing and Force Analysis of the Two-seater Go-kart Steering Mechanisms with all the Data, Calculation, Design and Analysis.

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