DESIGN AND ANALYSIS OF GO-KART STEERING SYSTEM

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Abstract - This study includes theory, design, and analysis of go-kart steering systems. Usually, owners who want to improve the handling of their go-kart or vehicle will need to buy the latest wheels, tires, and other equipment, only to eventually realize that these things make it worse to drive. The first step to a kart with good handling and maximum energy efficiency is to focus on what is essential. The most common steering arrangement is to rotate the front wheels using a manual steering wheel placed in front of the driver via a steering column. The steering column may contain universal joints (sometimes part of a collapsible steering column design), which can cause slight deviations from a straight line, the Ackerman angle is 12.43°, and the turning radius is 1.7m, resulting in a high steering effect.

Key Words: Go-Kart, Steering, Tripod, Solid works (2022), Ansys student version.

1. INTRODUCTION

The steering system, which determines the direction of the vehicle, is an important system because it is the system without which the destination of the vehicle cannot be determined. The steering system converts the rotational motion of the steering wheel into the rotational motion of the wheels in contact with the road surface, and the steering wheel rotates inward to provide more rotation and change to the wheels with a shorter radius. The steering system is a critical component of any vehicle, providing a direct link between the driver and the direction of travel.

Translates the driver's steering wheel rotation into precise movement of the front wheels, allowing for control and maneuverability. At the heart of a steering system is a network of interconnected parts. The driver starts the process by turning the steering wheel, and the rotational movement is transmitted to the steering column.

This rotation reaches the steering gear. Steering gear is the unsung hero responsible for converting rotational motion into linear (lateral) motion. Common steering gear mechanisms include rack and pinion, known for their precision and efficiency, and ball screws, which provide excellent feedback in a compact design.

The most common steering arrangement is to rotate the front wheels using a manual steering wheel placed in front of the driver via the steering column. The steering column may include a universal joint (which may also be part of the collapsible steering column design), which may deviate slightly from a straight line.

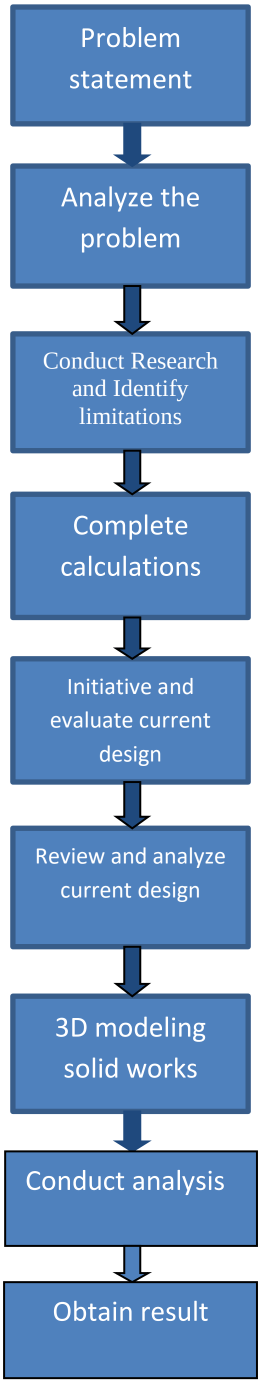
Tracked vehicles such as bulldozers and tanks typically have differential steering. This means using clutches and brakes to move the chain at different speeds or in opposite directions to change course or direction. This system allows the driver to maneuver a heavy vehicle with minimal effort.

The steering system is the central interface between the driver and the vehicle. Steering is a set of mechanisms used to control the trajectory (path) of a vehicle. The main purpose of steering is to ensure that the wheels point in the desired direction and give the driver control of the vehicle. The most common steering arrangement is to use a manual steering wheel in front of the driver to rotate the front wheels.

The mechanism is of vital a part of the dynamic style of any automobile to facilitate a swish amendment of directions and build use of the tires ability to get lateral forces to the very best extent. An athletics driver’s sensory inputs provide visual, tactile, and mechanical phenomenon data utilized in developing a “feel” for automotive handling and performance.

This feedback is critical in sanctimonies the driving force to extract most performance from the automobile. thence the steering is a crucial feedback mechanism giving the driving force data on stability and directional management.

2. METHODOLOGY:



Material Selection:

Mild steel was used for all steering components except the steering column. That's because structural steel is a popular choice for many applications due to its versatility, availability, and cost-effectiveness, as well as other benefits such as:

1. Strength-to-weight ratio.
2. Ductile.
3. Weldable.
4. Ideal mechanical properties.

Table 2.1: 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

Table 2.2: Physical properties of mild steel

Properties	value
Melting Point	1520 °C
Modulus of Elasticity	190-210Gpa
Electrical Resistivity	1.71 μΩm
Thermal Conductivity	50.7 W/m°k
Thermal Expansion	11.3 μm/m-k

3. JUSTIFICATION

CASTER ANGLE:

The front wheel caster is set to 6 degrees for reasons such as good centering force, less wobbling, high straight-line stability, and improved handling during cornering.

TOE ANGLE:

By comparing the effects of toe-in and toe-out, we decided not to maintain toe-in and toe-out on our car. Driving on the Zero Track, the car feels relatively stable in a straight line at high speeds. It also makes the car feel more neutral when taking long corners or tight corners at low speeds. Zero toe on the rear wheels reduces the vehicle's ability to accelerate, but increases the vehicle's top speed because the tires rotate in the most efficient direction. This also means your tires will last longer, but they will take longer to heat up to operating temperature.

KING PIN INCLINATION :

KPI was taken as 3 degrees in the front to increase the aligning torque in the wheels and reduce torque steer.

SCRUB RADIUS :

As our king pin inclination is 3 degrees we got 55 mm of positive scrub radius.

CAMBER ANGLE :

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).

3.1. COMPARISON:

t3.1 Comparison between 2023 go-kart steering system and 2024 go-kart steering system

GEOMETRY	2023 GO-KART	2024 GO-KART
Caster Angle	5deg	6deg
Camber Angle	1.5dg	-1.5deg
Toe in	2 m	0 mm
King pin inclination	5 deg	3deg
Scrub Radius	13.mm	+55mm

4.DIMENSIONS OF THE KART:

Wheelbase [l]: 1.27m

front track width [ft]: 0.83 m

rear track width [rt]: 0.99m

stub axle length [c]: 0.56m

Fig 4.1: Dimensions of the kart

1. Inner wheel angle $(\theta) = 2*\tan^{-1}(ft/2l)$
   $(\theta) = 2*\tan^{-1}(0.83/2*1.27)$
   $(\theta) = 36.19°$
2. Outer wheel angle $(\phi) = \cot\phi - \cot\theta = c/l$
   $(\phi) = \cot\phi - \cot(36.19)$
   $(\phi) = (0.56/1.27)$
   $(\phi) = 28.94°$
3. Ackerman angle $(\alpha) = \tan-1\ (c/2l)$
   $(\alpha) = \tan-1\ (0.56/2*1.27)$
   $(\alpha) = 12.43°$
4. Turning radius $(r) = l/2\sin\alpha$
   $(r) = 1.27/2*\sin(12.43)$
   $(r) = 1.07m$
5. Ackerman value $= \tan^{-1}(l/(l/(\tan\phi)\text{-}ft))$
   $= \tan^{-1}(1.27/(1.27/\tan(28.94)0.83))$
   $=40.88$
6. Ackerman percentage $= \theta/(\text{Ackerman value})\times 100$
   $= 36.19/40.88\times 100$
   $=88\%$

5. STEERING EFFORT:

Steering force varies with the speed of the go-kart. H. The coefficient of friction continues to decrease with increasing speed, so it is higher at low speeds and lower at high speeds. Steering force depends on many factors of the steering geometry.

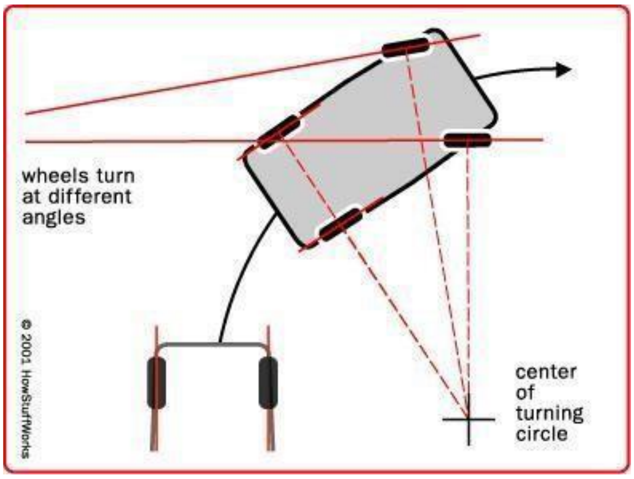


Fig 5.1: Turning radius

1.Weight of the vehicle =180 kg =1765.197 N
2.Weight on front wheels (40% of total weightage on front side) =1765.197*0.40 =72kg =706.07N
3. Sliding friction between tyre and road(μ)=0.8
4.Friction force to overcome = Friction coefficient*Weight =0.8*706.07 = 564.856N
5.Force at Knuckle =((Frictional Force*Scrub Radius))/(Steering arm length)= =((564.856*55mm))/120mm =258.892 N
6.Radius of steering wheel = 5 inch = 12.7 cm= 127mm
7.Torque at the tripod = tripod length*force to overcome at knuckle = 130mm*258.892N
=33655.7 N.mm =33.655 N m
8.Steering effort = Torque/steering wheel radius =33655.7 /127=265.005N =27.02kg

6 .HORIZONTAL CENTER OF GRAVITY: -

CG is the point on which the entire weight of the car appears to act. A car's center of gravity is where mass is most concentrated, and in racing cars it is usually around the engine and associated drivetrain components. Also, all acceleration forces experienced by a vehicle are expected to act through its center of gravity. It is recommended to keep the vehicle's center of gravity as low as possible to reduce the moments created by the vehicle's lateral acceleration.

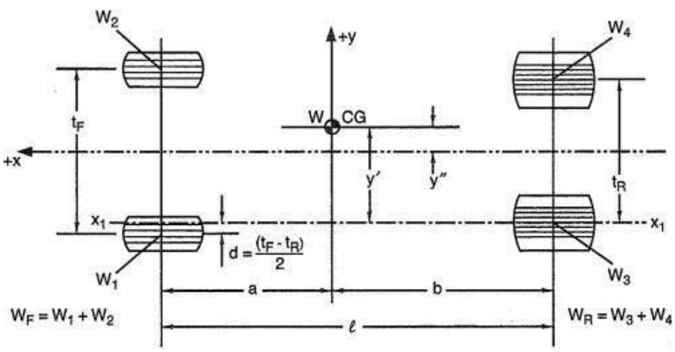


Fig 6.1: Horizontal location of center of gravity

Calculation: -
Total weight of the vehicle with driver(W) = 180 kg
Rear track width (Tr) = 0.99m
Front track width (Tf)= 0.83m
Wheelbase(l) = 1.27m
Mass on front axle =40 % of total weight = 40 % of 180
= 72kg
Mass on rear axle = 60% of total weight = 60 % of 180
= 108 kg

Weight on front wheels (W_f) $=\frac{\text{mass of front axle}}{2} = \frac{72}{2}$ = 36kg
W1=W2=36kg
Weight on rear wheels (Wr) $= \frac{108}{2}$ =54kg
W3=W4= 54kg

7. LATERAL LOAD TRANSFER:

7.1. Cornering Force: -

As the name suggests, lateral force is the lateral force that a tire generates every time it turns. This force is equivalent to centrifugal force that, if left unchecked, will cause the vehicle to veer off course.

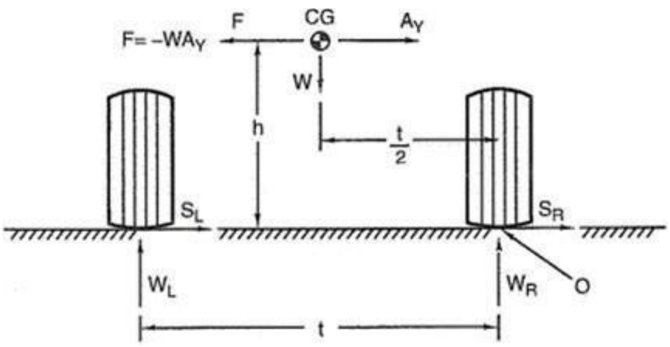


Fig 7.1: Lateral load transfer

Cornering force (F)= 〖M*V〗^2/R
Mass of the vehicle (M) = 180 kg

Velocity of the vehicle (V) = as assuming vehicle speed kmph =12.Ms

Radius of turn ® = 12 m

F = 〚180*12.5〛^2/12

F = 2343.75 N

Lateral acceleration (ay) = FL+FR

As load transfer on both sides are same, = FL+FR

ay = 2343.7 + 2343.7

ay = 4687.4

A_y = ay/32.2= 4687.4/32.3 = 145.5

Now taking the moments of O (the right side of track), we have $W_{Lt} = W\,(t)$ + Way (h = height of CG = 0.12m)

$W_L = W + W_{Ay}h\ /\ t$ (t = track width of front = 0.83m)

W_L = (180/2) + (180 ×145.5×0.12)/0.83

W_L = 3876.5

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

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

ΔW = 3876.5 – 180 = 180×145.5×0.12/0.83

ΔW = 3786.5 =3786.5.

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

Expressed as total weight this becomes.

Lateral Load Transfer = (A_y h)/t

LLT = 145.5×0.12/0.83

= 21.036 kg

= 206.292 newtons

8. SOLIDWORKS

SolidWorks is a solid modeling application for computer-aided design (CAD) and computer-aided engineering (CAE) published by Dassault Systems. According to the publisher, in 2013 more than 2 million engineers and designers in more than 165,000 companies were using SolidWorks.[21] SOLIDWORKS 3D CAD software is the recommended tool for engineers and designers in the design development stage. Engineers can simulate conceptual designs in different scenarios and easily make optimizations in the process. SOLIDWORKS 3D CAD software allows designers to import, save, and save data between different projects. You can import 2D data in various formats, including DXF and DWG formats. SOLIDWORKS helps you quickly generate 3D models from your 2D data as part of product development or mechanical design. DWG files can be imported into SOLIDWORKS 3D CAD software, and View Folding can automate 3D model development by adjusting imported 2D drawings.

8.1. STEERING WHEEL:

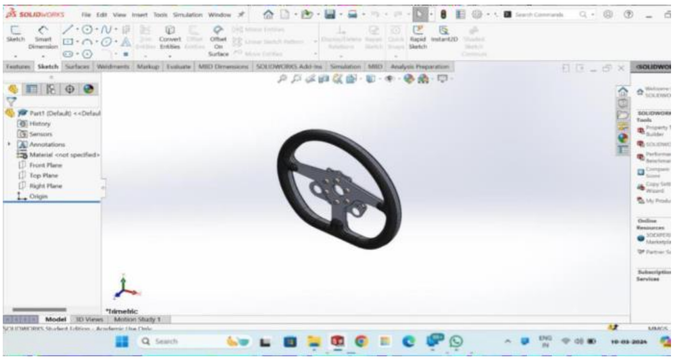


Fig 8.1: Steering wheel

8.2 TRIPOD:

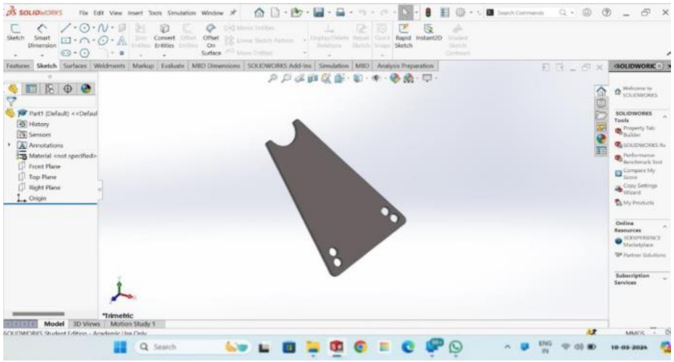


Fig 8.2: Tripod

8.3 STUB AXLE:

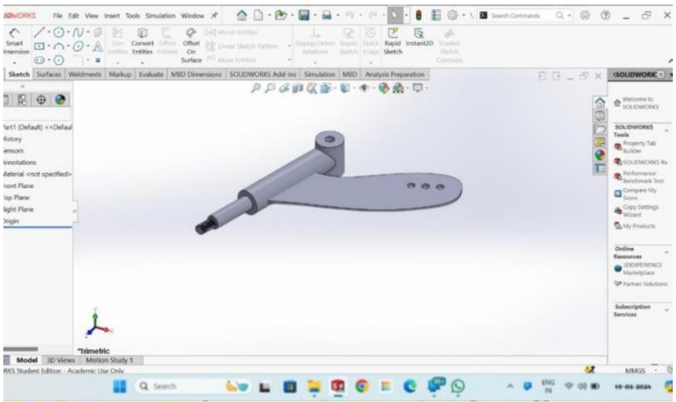


Fig 8.3: Stub Axle

8.4 QUICK RELEASE:

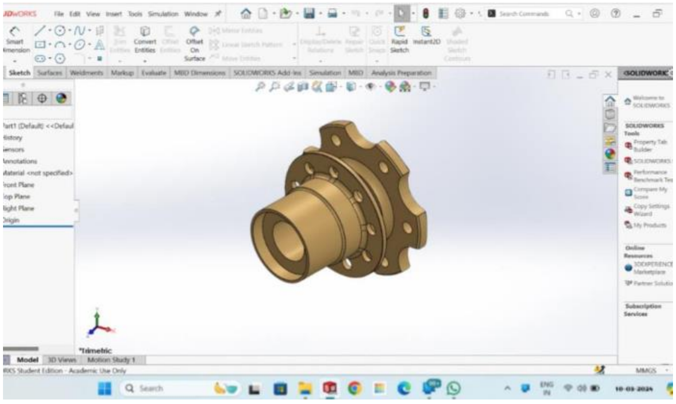


Fig 8.4: Quick Release

8.5 STEERING COLOUMN:

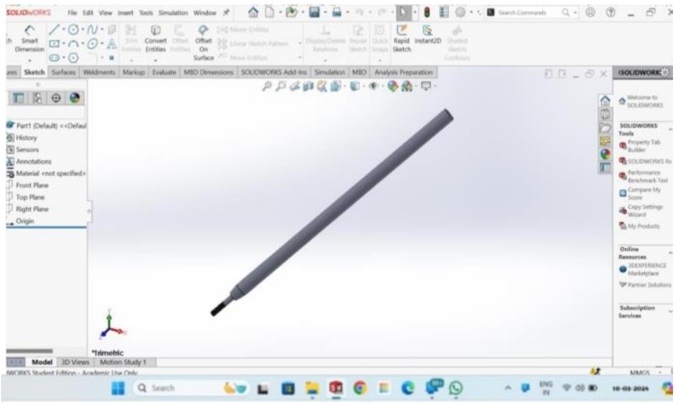


Fig 8.5: Steering Column

8.6 STEERING HOOP:

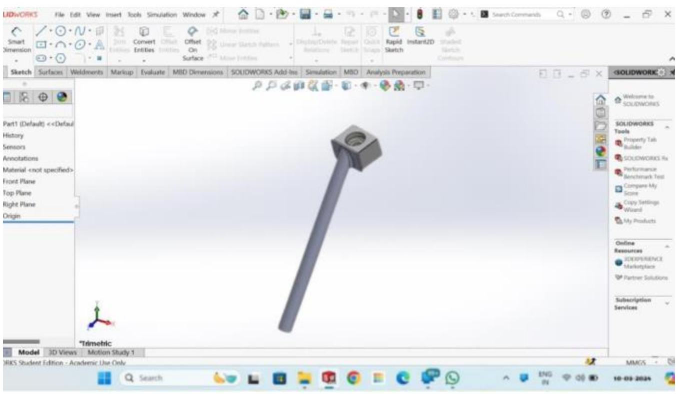


Fig 8.6: Steering Hoop

8.7. C-MOUNT:

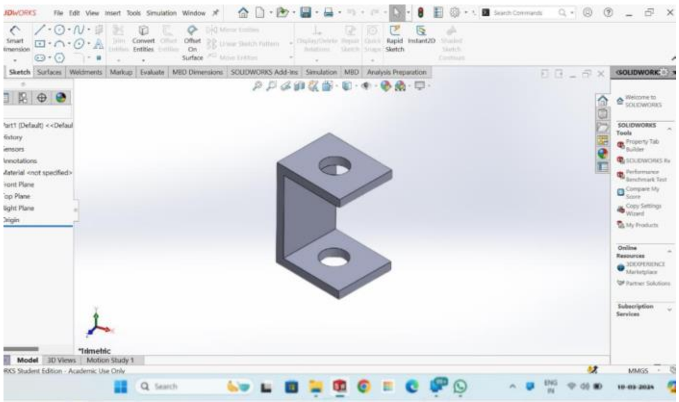
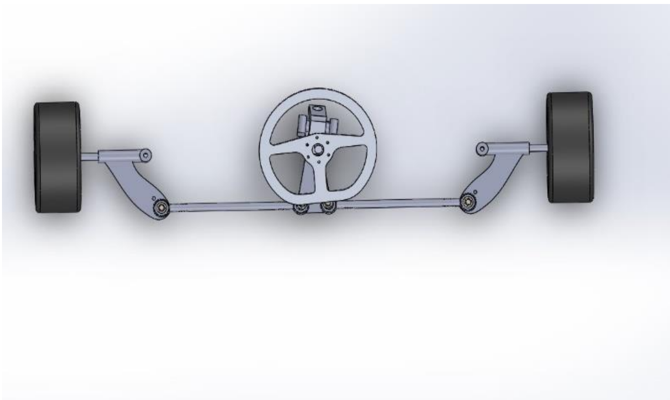


Fig 8.7: C-Mount

8.8 STEERING SYSTEM :



9.ANSYS:

9.1 STATIC ANALYSIS OF STEERING PARTS

Static analysis of mechanical components aims to calculate the effects of constant loads on a structure, ignoring the effects of inertia and shock, which often occur when the applied loads change rapidly. Nevertheless, while a static analysis may include constant inertial loads such as gravity or time-varying loads, the static equivalent It can be approximated to objects.

Linear stress analysis: This analysis allows engineers to verify design quality, performance, and safety in a highly efficient and accurate manner. This static analysis calculates the stresses and displacements experienced by the geometry. Additionally, this calculation helps determine how the part will react to the effects of different forces, temperatures, and contact between different components.

9.2 C-MOUNT ANALYSIS:

9.2.1. C-MOUNT MESH QUALITY ANALYSIS

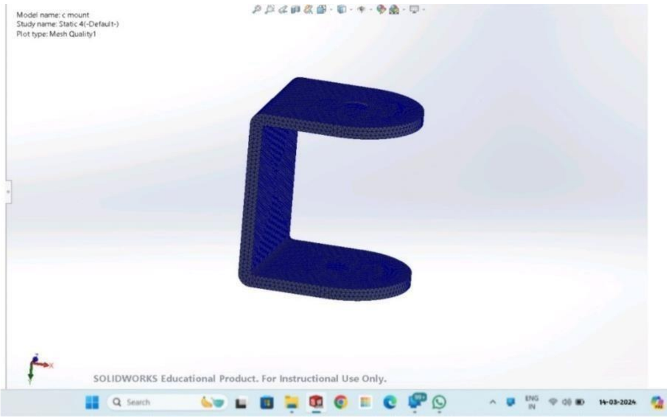


Fig 9.1: C-mount mesh quality analysis

9.2.2. C-MOUNT STATIC STRAIN ANALYSIS

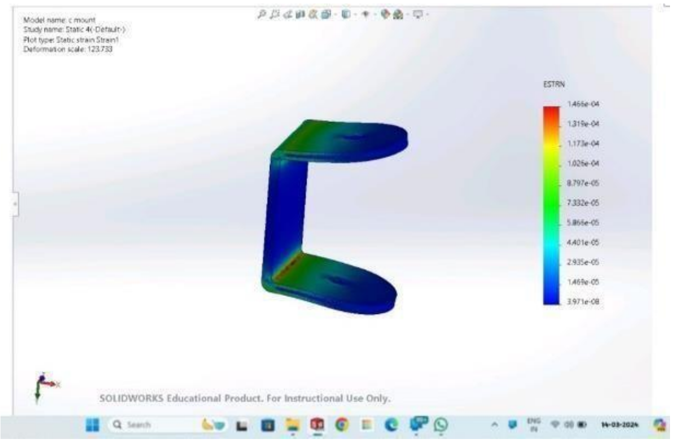


Fig 9.2: C-mount static strain analysis

9.2.3. C-MOUNT STATIC DISPLACEMENT ANALYSIS

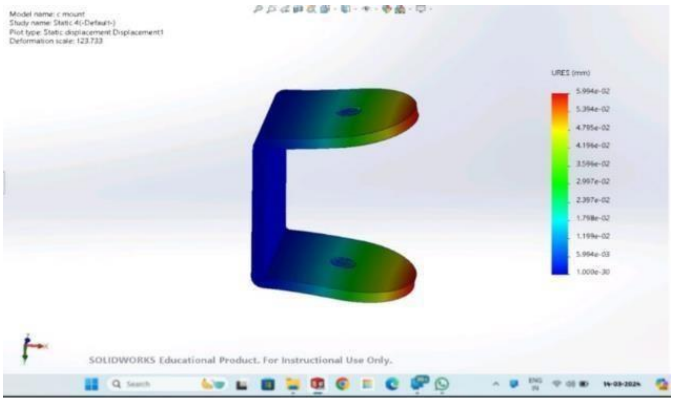


Fig 9.3: C-mount static displacement analysis

9.2.4. STATIC DISPLACEMENT ANALYSIS :

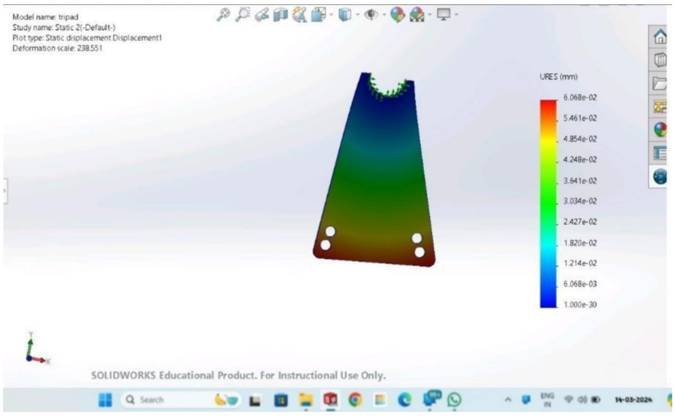


Fig 9.4: C-Mount Static Displacement Analysis

9.2.5. STATIC NODAL STRESS ANALYSIS :

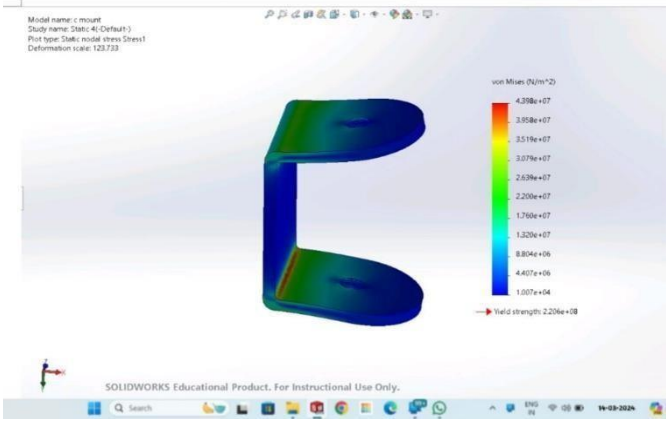


Fig 9.5: C-Mount Static Nodal Stress Analysis

9.3 BELL CRANK ANALYSIS :

9.3.1. STATIC STRAIN ANALYSIS :

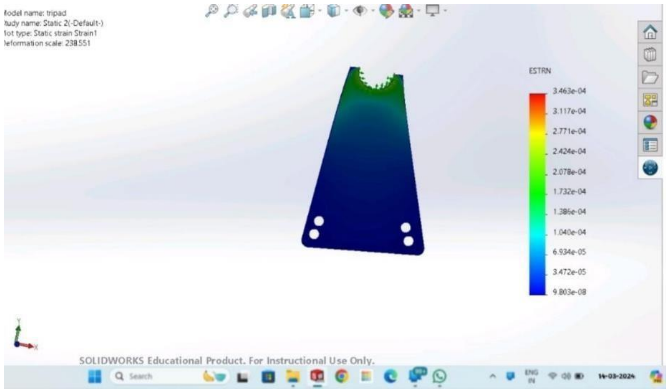


Fig 9.6: Bell Crank Static Strain Analysis

9.3.2. STATIC NODAL STRESS ANALYSIS :

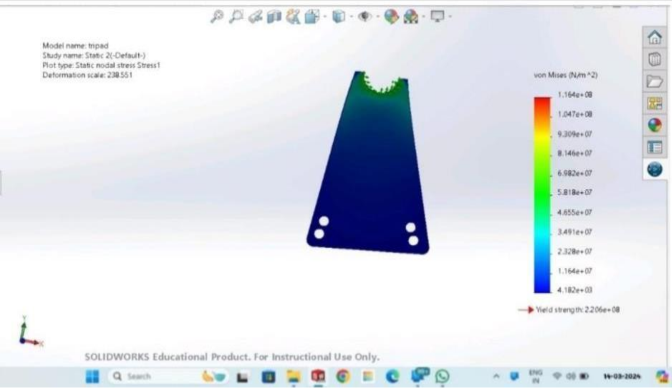


Fig 9.7: Bell Crank Static Nodal Stress Analysis

9.3.3. MESH QUALITY ANALYSIS :

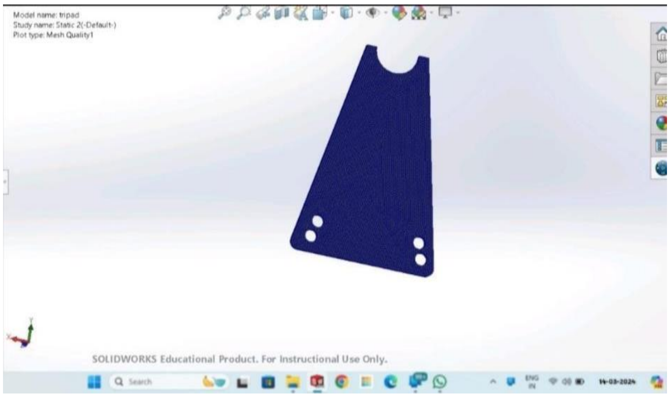


Fig 9.8: Bell Crank Mesh Quality Analysis

9.3.4. STATIC DISPLACEMENT ANALYSIS :

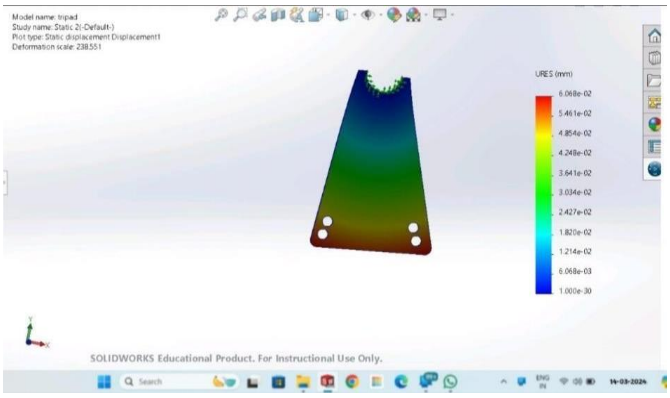


Fig 9.7: Bell Crank Static Displacement Analysis

6. RESULTS:

In this project, we designed and analyzed a go-kart steering system with a Bell crank mechanism. The analysis showed that the angle crank system has several advantages over traditional go-kart steering mechanisms, including:

Improved Mechanical Benefits: Angle cranks can be designed to provide mechanical benefits and reduce the steering effort required by the driver. This is especially advantageous for young drivers driving high-performance go-karts.

Compact Design: The Bell crank system can be more compact than traditional steering linkages, creating valuable space within the go-kart chassis. This is very important in optimizing the cart's weight distribution and overall performance.

Adjustable Steering Ratio: By adjusting the rocker arm dimensions, the steering ratio can be fine-tuned to achieve the desired handling characteristics for a particular go-kart application.

CONCLUSION:

The chosen design is a tripod mechanism with Ackermann steering for precise control, efficient rotation, and reduced friction.

This project investigated the possibility of using a tripod mechanism for steering a go-kart. Our results show that the tripod steering system has several advantages over traditional designs, including:

Simplified Design: Tripod mechanism eliminates the need for complex connections and bearings, reducing manufacturing complexity and maintenance requirements.

Increased Strength: The tripod design effectively distributes force across three contact points, increasing the strength and stiffness of the entire steering system.

Improved Responsiveness: Tripod configuration allows for a more direct and responsive steering feel compared to traditional systems.

ACKNOWLEDGMENT:

We wish to convey our sincere thanks to our internal guide **Mr. S. MADHU** Assistant Professor, Department of Mechanical Engineering, for his professional advice, encouragement in starting this project, and academic guidance during this project. We wish to convey our sincere thanks to **Dr. B. VIJAYA KUMAR**, Professor & Head of Department & COE, Department of Mechanical Engineering for his masterly supervision and valuable suggestions for the successful completion of our project.

We wish to express our candid gratitude to Principal **Dr. S. SREENATH REDDY**, and the management for providing the requirement facilities to complete our project successfully.

We convey our sincere thanks to the staff of the mechanical engineering department and the lab technicians for providing enough stuff which helped us taking up the project successfully.

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