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Design and Analysis of Components in Off-Road Vehicle

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Abstract: We are going to design and analyze the analysis of roll cage, steering systems, and Engine components. We make the analysis under the rule book of SAE Mechanical Baja. We are going to produce a detailed report about the components and make sure it comes under the rule book. We ensure the safety of the components by conducting various tests. We altered some of the components to increase the performance.
Keywords: Analysis, Design, Performance, roll cage, Steering and Engine.

I. ROLL CAGE

A. Introduction
The design of a roll cage for an off-road vehicle is based on several factors, including the size and shape of the vehicle, expected racing conditions, and safety regulations. A roll cage is usually made of high-strength steel tubes that are welded together to form a strong and durable structure.
Overall, a well-designed and properly installed roll cage can greatly improve the safety of Baja vehicles and protect the driver and passengers in the event of an accident.

B. Roll Cage Elements
The roll cage consists of
1) *Primary Members*
   a) Rear hoop (RRH)
   b) Roll Hoop Overhead Members (RHO)
   c) Front reinforcing members (FBM)
   d) Lateral Cross Member (LCM)
   e) Front side cross member (FLC)

2) *Secondary Members*
   a) Lateral diagonal brace (LCB)
   b) Bottom side of the frame (LFS)
   c) Side Impact Member (SIM)
   d) Front/Rear Stiffeners (FAB)
   e) Under Seat Member (USM)
   f) All other crossbars required
   g) Any pipe that is used to mount a safety feature

C. Design Considerations
The following points were considered for the construction of the Roll cage.
1) Improved ergonomics for better driver comfort.
2) Reduce weight for better acceleration.
3) Improve packaging for subsystems.
4) Security
5) Aesthetic considerations.

D. Material used for the cage:

The material used for the roll cage is AISI 4130. We use twhis material because it is hard enough to withstand the bending, shearing, etc. stress that can be placed on the vehicle.

1) Chemical Compensation of AISI 4130

Table 1.1

Element content (%)	Element content (%)
Iron, Fe 97.03 – 98.22	Iron, Fe 97.03 – 98.22
Chromium, Cr 0.80 – 1.10	Chromium, Cr 0.80 – 1.10
Manganese, Mn 0.40 – 0.60	Manganese, Mn 0.40 – 0.60
Carbon, C 0.280 – 0.330	Carbon, C 0.280 – 0.330
Silicon, Si 0.15 – 0.30	Silicon, Si 0.15 – 0.30
Molybdenum, Mo 0.15 – 0.25	Molybdenum, Mo 0.15 – 0.25
Sulphur, S 0.040	Sulphur, S 0.040
Phosphorus, P 0.035	Phosphorus, P 0.035

2) Physical Properties

AISI 4130 steel is heated to 871oC and then quenched in oil. This steel can be welded, forged, and shaped in the annealed state.

Table1.2

Properties	Metric
Density	7.85 g/cm^3
Melting Point	1432^{o}C
Ultimate strength	936 N/mm^2
Yield Strength	886 N/mm^2
Youngs modulus	210 pas

3) Material Dimensions

Member	Material	Outer Diameter	Inner Diameter	Wall Thickness
Primary Member	AISI 4130	29.2 mm	25.9 mm	1.65 mm
Secondary Member	AISI 4130	25.4 mm	22.1 mm	1.65 mm

Table1.3

E. Bending Strength And Stiffness Calculation

Reference Material : AISI 1018

Yield Strength (S_y) : 370 N/mm^2

Thickness : 3 mm

Outer Diameter (D_O) : 25.4 mm

Inner Diameter (D_I) : 23.9 mm

Modulus of Elasticity (E) : 205 × 10^9 N/m^2

Moment of Inertia (I) $= \frac{\pi}{4}(r_o^4 - r_i^4)$

$= 1.34 \times 10^{-8}$ N/mm

Bending Strength $= \frac{S_y \times I}{c}$

= 392.68 Nm

Bending Stiffness = EI

= 2763.12 N/m^2

Bending Strength $= \frac{S_y \times I}{c}$

= 738.55 Nm

Bending Stiffness = EI

= 2855.50 N/m^2

Required Material : AISI 4130

Yield Strength (S_y) : 793 N/mm^2

Thickness : 1.65 mm

Outer Diameter (D_O) : 29.2 mm

Inner Diameter (D_I) : 25.9 mm

Modulus of Elasticity (E) : 210 × 10^9 N/m^2

Moment of Inertia (I) $= \frac{\pi}{4}(r_o^4 - r_i^4)$ = 1.35 × 10^{-8} N/mm

Since bending stiffness and bending strength of AISI 4130 with outer diameter 29.2 mm and 1.65 mm thickness is greater than that of AISI 1018 with outer diameter 25.4 mm and 3 mm thickness, AISI 4130 is preferred. Moreover, the lesser thickness helps reduce weight of the vehicle substantially. Hence AISI 4130 is chosen for primary member of the roll cage.

F. Chemical Composition

1) Primary Member

Table1.4

Elements	Symbol	Specified Values (%)	Observed Values (%)
Carbon	C	0.28 – 0.33	0.291
Silicon	Si	0.15 – 0.35	0.161
Manganese	Mn	0.40 – 0.60	0.566
Phosphorus	P	0.035 max	0.012
Sulphur	S	0.040 max	0.014
Chromium	Cr	0.80 – 1.10	0.893
Molybdenum	Mo	0.15 – 0.20	0.165

2) Secondary Member

Table1.5

Elements	Symbol	Specified Values (%)	Observed Values (%)
Carbon	C	0.28 – 0.33	0.286
Silicon	Si	0.15 – 0.35	0.188
Manganese	Mn	0.40 – 0.60	0.580
Phosphorus	P	0.035 max	0.017
Sulphur	S	0.040 max	0.010
Chromium	Cr	0.80 – 1.10	0.957
Molybdenum	Mo	0.15 – 0.20	0.166

G. Mechanical Properties

Table1.6

Properties	AISI 4130
Modulus of Elasticity	190-210 GPa
Bulk Modulus (Typical for steel)	140 GPa
Shear Modulus (Typical for steel)	80 GPa
Poisson's Ratio	0.27-0.30
Elongation at break (in 50mm)	21.50%
Reduction of area	59.6
Brinell Hardness	217
Rockwell Hardness B	95
Rockwell Hardness C	17
Vickers Hardness	228
Machinability (Annealed and cold drawn. Based on 100% machinability AISI 1212 steel)	110

1) Mechanical Properties

Table 1.7

Properties	**Metric**
Tensile strength, Ultimate	**560 MPa**
Tensile strength, Yield	**460 MPa**
Modulus of Elasticity	**190-210 GPa**
Bulk Modulus (Typical for steel)	**140 GPa**
Shear Modulus (Typical for steel)	**80 GPa**
Poisson's Ratio	**0.27-0.30**
Elongation at break (in 50mm)	**21.50%**
Reduction of area	**59.6**
Brinell Hardness	**217**
Rockwell Hardness B	**95**
Rockwell Hardness C	**17**
Vickers Hardness	**228**
Machinability (Annealed and cold drawn.Based on 100% machinability AISI 1212 steel)	**110**

H. Modelling

The SAE INDIA Baja rule book was used as a reference to set the dimensions. Dimensions were set with all points in mind and the roll cage model was prepared using Creo 7.0 software. Creo 7.0 was preferred due to its user-friendliness and the availability of the Framework option and various tools.

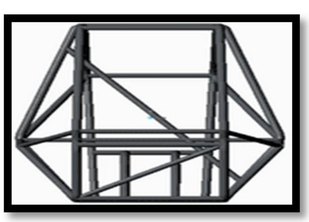

Fig1.1. Roll cage design front view.

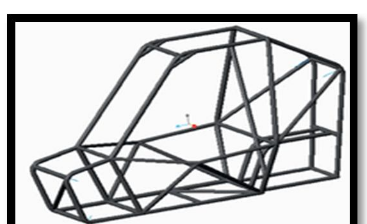

Fig1.2. Roll cage design side view.

I. *Analysis*

1) *Methodology*

- CAD model structure is created using Creo 3.0 software.
- Generation of mesh
- Application of loads and constraints as per requirement
- Obtaining stress value and deflection for respective deformation tests
- Modification of CAD design
- Process repeated until safe design is obtained.

2) *Analysis Impact*

a) *Front Impact*

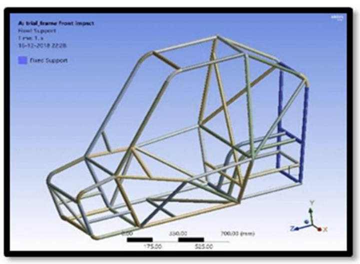

Fig1.3. Fixed Support

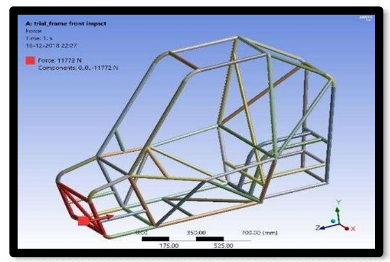

Fig1.4. Force

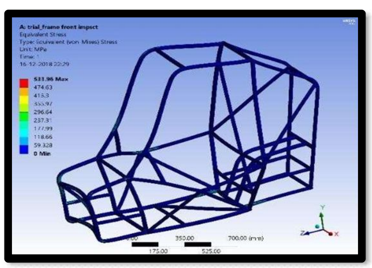

Fig1.5. Equivalent stress

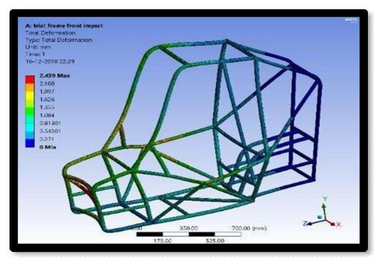

Fig1.6. Total Deformation

The front crash safety factor is **1.6.**

b) *Rear Impact*

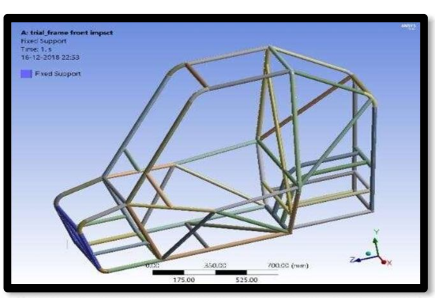

Fig1.7. Fixed Support

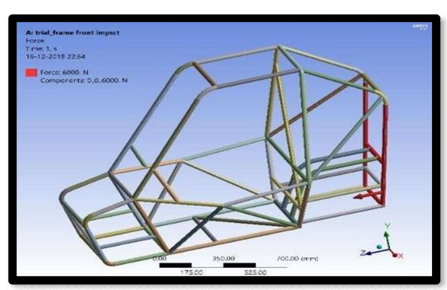

Fig1.8. Force

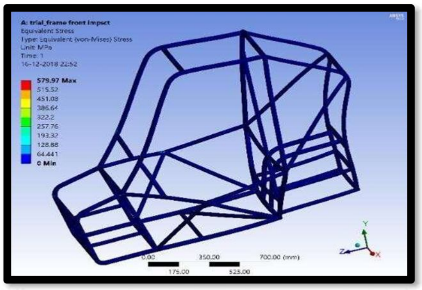

Fig1.9. Equivalent stress

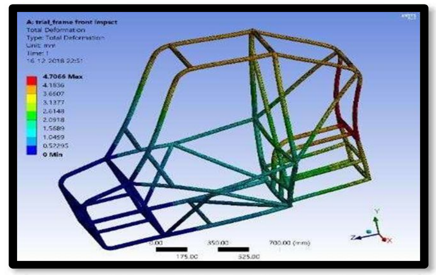

Fig1.10. Total Deformation

The rear impact safety factor is **1.4**.

c) Side Impact

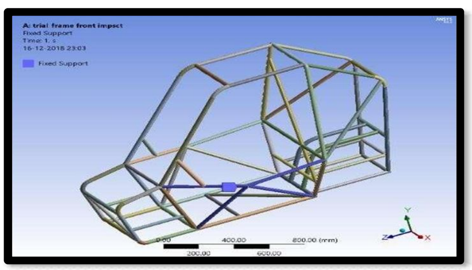

Fig1.11. Fixed Support

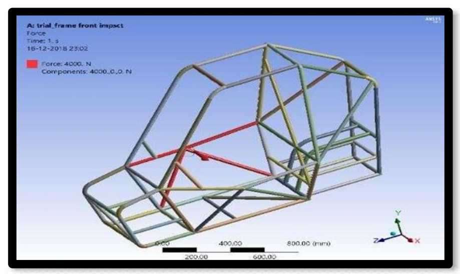

Fig1.12. Force

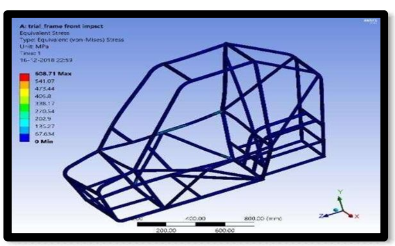

Fig1.13. Equivalent stress

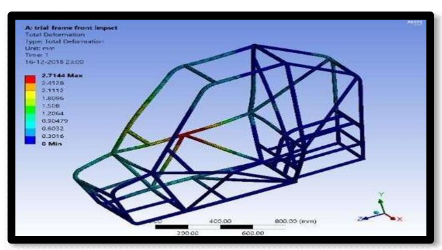

Fig1.14. Total Deformation

Factor of Safety for Side Impact is **1.2**

3) Result

Table1.8

Impacting Place	Factor of Safety
Front Impact	1.6
Rear Impact	1.4
Side Impact	1.2

J. Welding

1) Welding Process

The recommended material for the roll cage is AISI 4130 (chromium alloy), a low alloy steel with molybdenum and chromium as reinforcement. The nominal carbon content is 0.30%. This relatively low carbon content makes this alloy superior in fusion weldability. This alloy can also be hardened by heat treatment.

Due to the low carbon content and low melting point of AISI 4130, electric arc welding cannot be used. However, it can also be welded using TIG or MIG. TIG welding was preferred after ensuring its availability in our university. TIG welding is much more complicated than arc welding because it requires adjusting the filler rod and electrode, but it produces high quality welds with the necessary penetration.
The filler rod selected for the TIG welding process is the ER70S-2

2) Description and use of alloys

ER70S-2 is a composite deoxidizing wire that contains small amounts of zirconium, titanium, and aluminum in addition to manganese and silicon oxidizing agents that are characteristic of the steel wire group. This wire can be used for MIG or TIG welding of all mild and carbon steel grades and produces high quality welds with minimal porosity.
The ER70S-2 is ideal for TIG welding of rusted plates and tubes and root penetration welding of tubes. It has excellent mechanical properties and toughness even at low temperatures.
Uses Alloy is a declarative modeling language and analyzer that is used for software engineering and formal methods. It allows you to define abstract models of systems or software components and analyze them for various properties.

K. Wire

1) Wire Chemistry

1. Element	AWS Specification (%)	70S-2 (%)
Carbon	Max	0.05
Manganese	0.90– 1.40	1.15
Silicon	0.40 – 0.70	0.50
Phosphorus	0.025 max	0.012
Sulphur	0.035 max	0.012
Aluminium	0.05 – 0.15	0.011
Zirconium	0.02 – 0.12	0.09
Titanium	0.05 – 0.15	0.10

Table 1.9 Wire Specification

2) Weld Metal Properties

Properties	AWS Specification	Typical
Tensile Strength	70,000 psi (min)	83,000 psi
Yield Strength	58,000 psi (min)	71,000 psi
Elongation in 50.8 mm	% (min)	27 %
Charpy V-notch at -20 ˚F	m.kg (min)	4.14 m.kg
Reduction of area	n/a	58%
Average Brinell Hardness	n/a	140

Table 1.9 Metal Properties

L. Conclusion

In cage analysis, the safety factor should be greater than 1.0. In this analysis, the safety factor is greater than 1.0, and the roll cage will be strong and stable under impact from all sides.
In conclusion, the design and analysis of a roll cage for an off-road vehicle is a key aspect of ensuring the safety of the driver and passengers during extreme off-road conditions. The roll cage must be designed to withstand the various forces and impacts that may occur during off-road driving, such as rollovers, collisions and uneven terrain.

Overall, the design and analysis of a roll cage for an off-road vehicle requires a thorough understanding of the vehicle's specifications and intended use, as well as a focus on safety, strength, and durability. With proper design and analysis, a roll cage can provide essential protection to vehicle occupants during extreme off-road conditions.

II. STEERING

A. Introduction

A crucial function of the Off-Road vehicle is steering. To prevent understeer and oversteer and to raise the calibrate of the steering mechanism, the steering must not be calibrated wrongly. In the Off-Road vehicle, it is utilized to steer left and right.

1) Type Of Steering System Used

Rack and pinion steering is the type of steering system employed.

Its use has the benefit of requiring the least amount of steering effort while offering less mechanical advantage than other methods like recirculating balls, but less backlash and better feedback.

2) Basic Design Of Our Steering System

The center-mounted Rack and Pinion system is the foundation of the Off-Road steering system.

The inside front tyre may steer up to 43 degrees from straight ahead using rack extensions and track rods fitted to the front uprights.

B. Rack Selection

1) A desirable quality of the perfect Off-Road vehicle is maneuverability.
2) A OFF Road vehicle is therefore anticipated to have a small turning circle radius. Therefore, we tried to research TCR and racks of vehicles with compact wheelbases.
3) In addition to this, much effort was made to create a rack of our own.
4) The rack from the steering gearbox of a desert cart was finally chosen because it was lightweight, offered the necessary lock-to-lock angle, and required a manageable amount of steering effort (to be explained later).
5) As a result, most of the steering system and components from the desert cart are still in use.
6) The team's tight ergonomic standards must be reached, and more crucially, the Ackermann geometry must be satisfied, which is why the steering adjustments aim to make the steering compact.

C. Ackermann Steering Mechanism

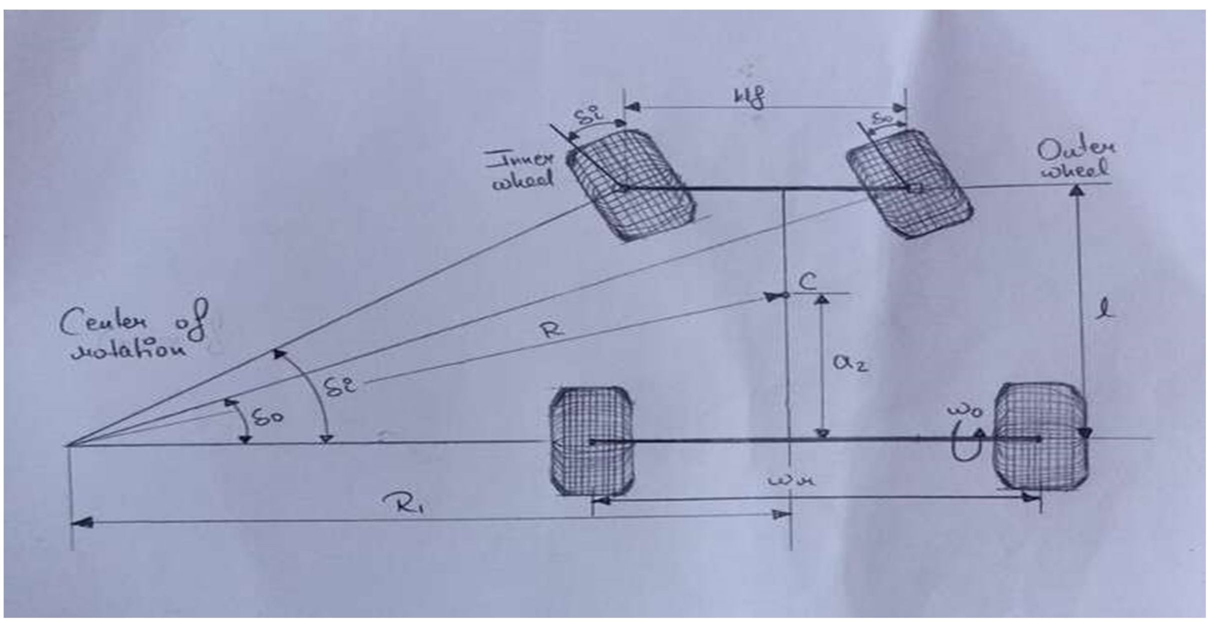

Fig 2.1

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The Ackermann Steering Mechanism is a four-bar linkage mechanism that has been modified.
The movement of the links and the angle to which the wheels are turned define the Ackermann steering kinematics.

1) Working Of Ackermann Steering Mechanism

When the steering wheel is turned, it causes the steering axis to move. The steering axis is linked to the central moving link of the steering mechanism. The moving link then directs the wheels to turn by transmitting its motion to the link that connects to the wheels. This is the basic principle behind the functioning of the Ackermann Steering mechanism.
By adjusting the angles of the steering links, the Ackermann Steering mechanism ensures that all the wheels follow their respective turning radii, which results in a smooth and stable turning of the vehicle.

2) Applications Of Ackermann Steering Mechanism

The Ackermann Steering mechanism is commonly utilized in passenger cars. Additionally, the mechanism is employed in some robotic materials for experimental purposes.
Off-road vehicles such as all-terrain vehicles (ATVs) and utility terrain vehicles (UTVs) require a steering system that can handle the demands of rough terrain. The Ackermann Steering mechanism has been adapted for use in these types of vehicles to provide precise steering and stability.
The Ackermann Steering geometry ensures that the wheels turn at different angles, which allows the vehicle to make tighter turns while maintaining stability on uneven terrain.
The Ackermann Steering mechanism in off-road vehicles is the use of a fully articulated steering system. In this system, each wheel is connected to a separate linkage that is attached to the chassis of the vehicle.
The linkages are then connected to a central pivot point that allows the wheels to move independently of each other. This type of steering system allows the vehicle to navigate through extreme terrain and obstacles with ease.
Overall, the Ackermann Steering mechanism has proven to be a reliable and effective steering system for off-road vehicles, providing drivers with precise control and stability in challenging environments.

3) Radius Of Turn Of Vehicle

The condition for true rolling is

c = 860 mm
b = 1500 mm
a =1125 mm

The maximum angle of turn of the inner front wheel is **43 °**

- Angle of inner and outer wheel:

$$\cot \theta i - \cot \theta o = c / b \qquad \text{-------Equation 2.1}$$

The maximum angle of the inner front wheel = **31.19 °**

- Steering ratio

For inner wheel =360×0.75/43˚
=8.5:1
For outer wheel =360×0.75/31.42˚
=6.2:1

- Radius of the front and rear wheels

The turning circle radii for different wheels can be written.

$$\mathbf{R}IF = b/\sin\theta - ((a - c)/2) \qquad \text{-------Equation 2.2}$$
$$\mathbf{R}IR = b/\tan\theta - ((a - c)/2) \qquad \text{-------Equation 2.3}$$
$$\mathbf{R}OF = b/\sin\varphi + ((a - c)/2) \qquad \text{-------Equation 2.4}$$
$$\mathbf{R}OR = b/\tan\varphi + ((a - c)/2) \qquad \text{-------Equation 2.5}$$

- Given

θ =43 degree
Ψ=**31.19 degree**
Now,

R_{IF} = **1500**/sin 43° (1125-860/2)
= 2066.5 mm

R_{IR} = 1500/tan 43° (1125-860/2)
=1480.40 mm

R_{OF} = 1500/sin 31.19° (1125-860/2)
=3028.93mm

R_{OR} = 1500/tan 31.19° (1125-860/2)
=2610.27 mm

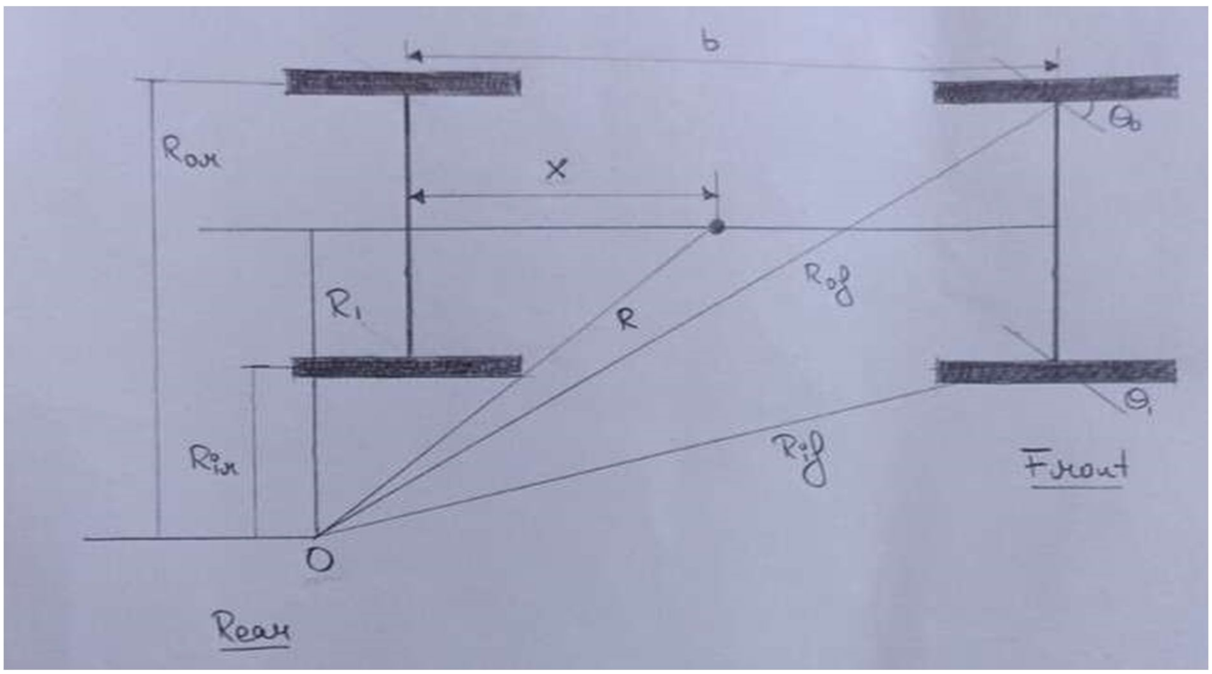

Fig 2.2

D. *Static Torque Calculation*

(From Autonomous Steering For An Sae Vehicle Department Of Mechanical Engineering The University Of Michigan-Dearborn)

1) *Torque On Road Wheel*

Certainly! When a wheel is in motion, it experiences a force of resistance due to friction between the surface it is in contact with and the wheel. This frictional resistance generates a torque that must be overcome in order to keep the wheel moving. The magnitude of this torque is influenced by several factors, such as the type of materials in contact, the amount of force exerted on the wheel, and the speed at which the wheel is rotating.

$$Tr = (2 * \mu * W * R) \div 3 \qquad \text{-------Equation 2.6}$$

Tr = the torque required to turn the wheel about the steering axis,
R = radius of the tire patch
μ = coefficient of friction
W= weight supported by one wheel
Tr = 15.54N-m

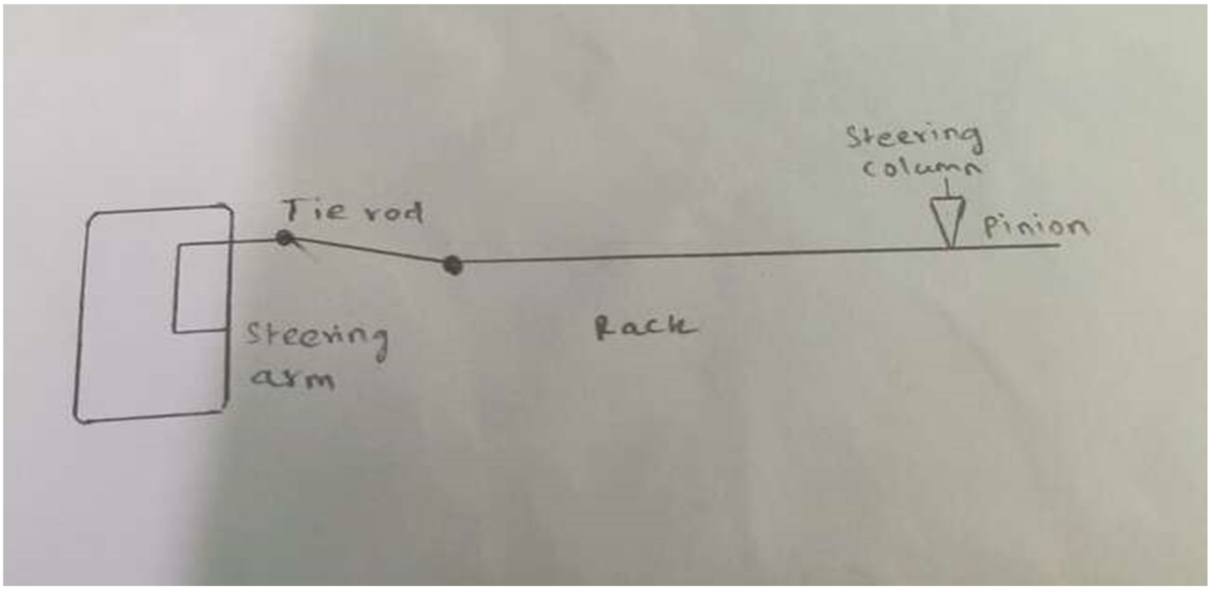

Fig 2.3

As the steering arm is perpendicular to the rack, the force of the rack exerted onto the steering arm is described as:

Tr = F * L -------Equation 2.7

F = force exerted onto steering arm by rack
L = length of steering arm
T = total torque required
Fr = 155.4N

2) Torque On Steering Wheel

The total torque required to be applied by steering columns to overcome the resistance of the wheel is

T = $(4 * \mu * r * \left(W^3 \div 2\right)) \div (3 * L * \sqrt{(P * \pi)})$-------Equation 2.8

W = weight supported by one Front Wheel
r = radius of the pinion gear
P = pressure of the tire
L = length of the steering arm / Tie rod
Ts = 3.46 N-m.
Fs = **T**s÷L -------Equation 2.9
Ts = torque on steering wheel
Fs = steering wheel input effort
L = length of the steering wheel
Fs = 11.53 N-m.

The obtained value is less than the assumed value (20N), hence the input value is sufficient for steering operation.

It is important to acknowledge that the final value obtained from the equation mentioned earlier does not account for any potential losses in the steering system. These losses may result from various sources, such as the pinion rack gear mesh or steering column deflection, and they could lead to a reduction in the overall efficiency of the system.

One factor that may contribute to these losses is the force exerted on the steering arm by the rack. Although this force does not affect the rotation of the steering arm or the wheel, it may still cause energy to be lost through friction or other means.

Therefore, when designing a steering system, it is important to consider all possible sources of losses and to take steps to minimize them wherever possible.

3) Rack Output Load

Radius of steering wheel, R = 150 mm
Radius of pinion gear, r = 11.46 mm
Steering wheel effort, f = 20 N Rack output
Load, w = ?

We know, movement ratio

$$M.R = 2\pi * R \div 2\pi * r \quad \text{-------Equation 2.10}$$
$$= 2\pi * R \div t * p$$
$$= 13.08$$

$$M.R = W \div f \quad \text{-------Equation 2.11}$$

Rack output load, W = 261.8N

Tie rod length (From Manual Drawing), L = 470.2mm
FOS, n = 3
Modulus of elasticity, E = 200 Gpa
Inner diameter, di = 22.4mm
Outer diameter, do = 25.4mm

Moment of inertia:

$$I = \pi \div 64 * (do^4 - di^4) \quad \text{-------Equation 2.12}$$
$$I = 8.0733 * 10^{-9} m^4$$

Then by EULER'S formula:

(One end fixed, another end free)

$$W = (\pi^2 * E * I) \div (L * n) \quad \text{-------Equation 2.13}$$

$$= (\pi^2 * 200 * 10^9 * 8.0733 * 10^{-9}) \div (0.4702^2 * 3)$$

$$W = 24002.35631 \text{ N}$$

The load on the Tie rod in our application is only 261.6N. Based on this, we can determine that the inner and outer diameter of the Tie rod are adequate to withstand this load, thus ensuring that the design is safe.

E. Steering Knuckle

The steering knuckles are a crucial component of the steering system in off-road vehicles, connecting the wheels to the suspension and enabling them to turn. As these vehicles navigate rugged terrain, the steering knuckles must be able to withstand high levels of stress and impact.

Off-road vehicles commonly utilize a solid axle design, which requires a steering knuckle that can pivot around the axle housing. This design is preferred for its strength and simplicity, and steering knuckles can be made from materials like steel, aluminum, and composites, depending on the vehicle's specific needs and requirements.

Regular maintenance of steering knuckles is important to ensure they continue to perform reliably, and this may involve inspections, lubrication, and replacing worn or damaged components. Steel alloy is often used for steering knuckles in off-road vehicles due to its durability. In summary, steering knuckles are a critical component for the performance of off-road vehicles, and selecting the appropriate type of knuckle is crucial for achieving optimal performance and reliability in harsh environments.

We have created a 3D model of a steering knuckle using Creo software, keeping in mind the working principles of this component. Since off-road vehicles face high levels of stress and impact while driving on rough terrain, sturdy and durable steering knuckles are crucial.

Many off-road vehicles use a solid axle design, which requires a steering knuckle that can pivot around the axle housing. This design is preferred for its strength and simplicity. Steering knuckles can be made from various materials, such as steel, aluminum, and composites, depending on the specific needs and requirements of the vehicle. For high-performance applications, some off-road vehicles may use aftermarket steering knuckles that have upgraded materials, larger bearings, and other modifications to improve strength and durability. Proper maintenance of steering knuckles is essential to ensure reliable steering performance. This includes regular inspections, lubrication, and replacement of any worn or damaged components.

F. Steering Knuckle Design

Steering knuckle mesh design is crucial in the automotive industry. It transmits steering and suspension forces from the wheels to the vehicle frame. This is a basic design of steering knuckle which is used in off road vehicles. A well-designed steering knuckle mesh ensures the vehicle handles well and remains safe on the road.

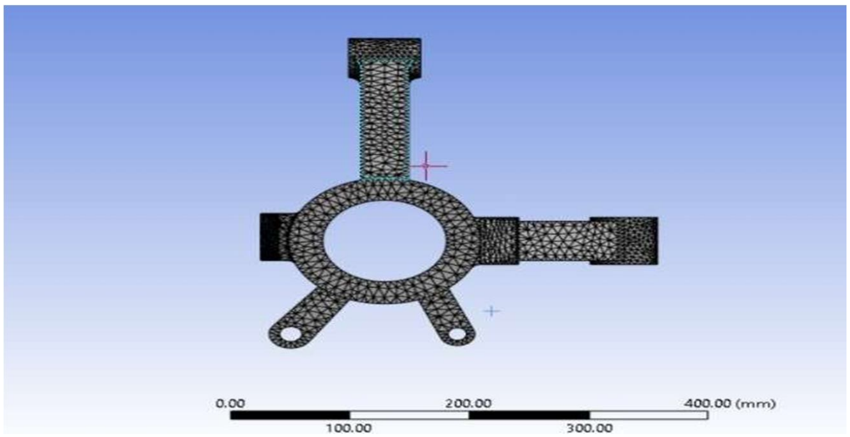

Fig 2.4 Mesh model of steering knuckle

G. Steering Knuckle Metal Properties

We take Mild Steel for the steering knuckle and the properties of the mild steel given below in the following tables. Mild steel steering knuckles offer several advantages, including high strength and durability, making them ideal for withstanding the harsh conditions of the road. Mild steel is also relatively inexpensive compared to other materials, making it a cost-effective choice for manufacturers. Additionally, mild steel is easy to weld and machine, allowing for greater flexibility in the design process. However, mild steel does have some drawbacks, such as its susceptibility to corrosion, which can be mitigated through coatings or plating. Overall, mild steel steering knuckles are a reliable and practical choice for many automotive applications due to their strength, durability, and cost-effectiveness.

MECHANICAL PROPERTIES	
Ultimate Tensile Strength	400 – 550 MPa
Yield Strength	250 MPa
Young’s Modulus of Elasticity	200GPa
Thermal Conductivity	50 W/mK
Density	7850 kg / m3

Table 2.1

CHEMICAL PROPERTIES	
Carbon	0.16 - 0.18 %
Silicon	0.40% Max
Manganese	0.70 – 0.90 %
Sulphur	0.40% Max
Phosphorous	0.40% Max

Table 2.2

H. Steering Knuckle Analysis

This analysis of steering knuckle is done in ANSYS R22. The normal weight of the off-road vehicle which participates in the competition weighs around 210 kg. We researched through many papers and found these results.

The table down below with all dimensions given which is the force applied during ansys.

PARAMETER	LOAD
Moment due to Braking force	159025 N-mm
Moment due to Steering force	50682.72 N-mm
Longitudinal force	2118.96 N
Lateral force	2812.50 N
Vertical force due to weight	706.32 N
Vertical force due to Longitudinal Weight Transfer	1032.38 N
Vertical force due to Lateral Weight Transfer	3195.80 N
Vertical force due to Bump	2540.00 N

Table 2.3

The following are different types of analysis done in order to get accurate results.

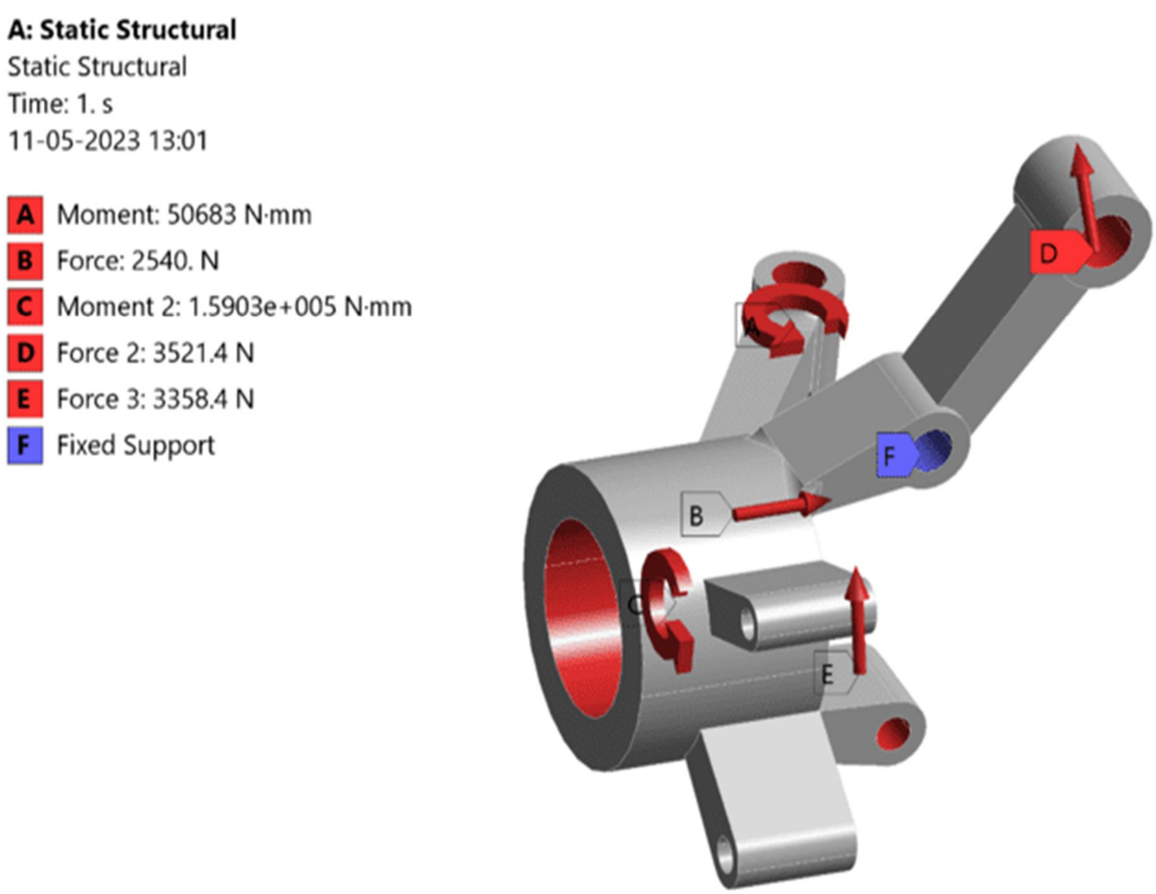

Fig 2.5 Boundary condition

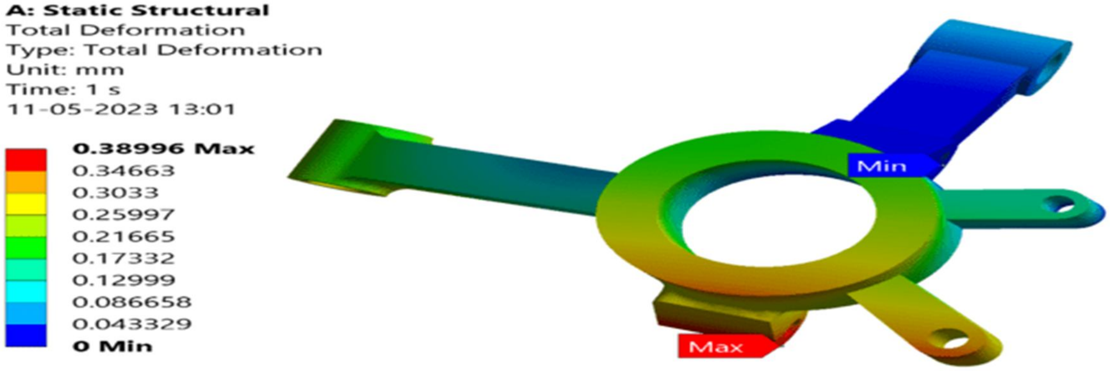

Fig 2.6 Knuckle Total deformation

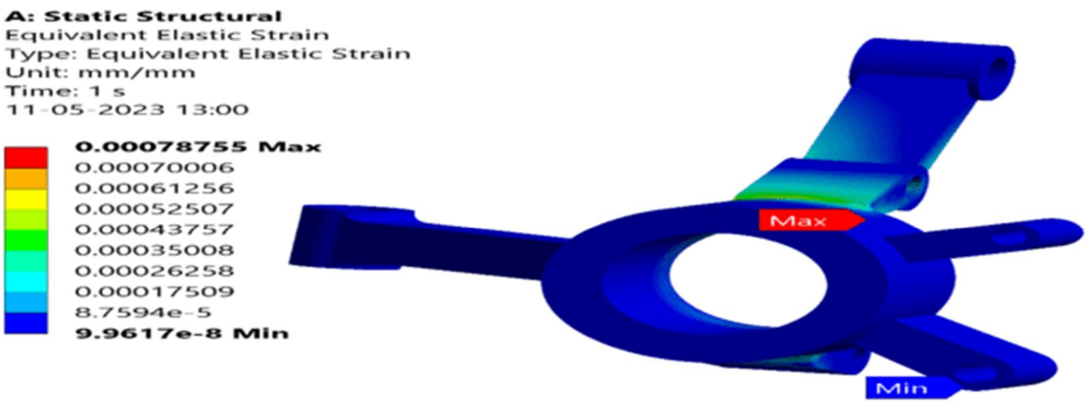

Fig 2.7 Strain

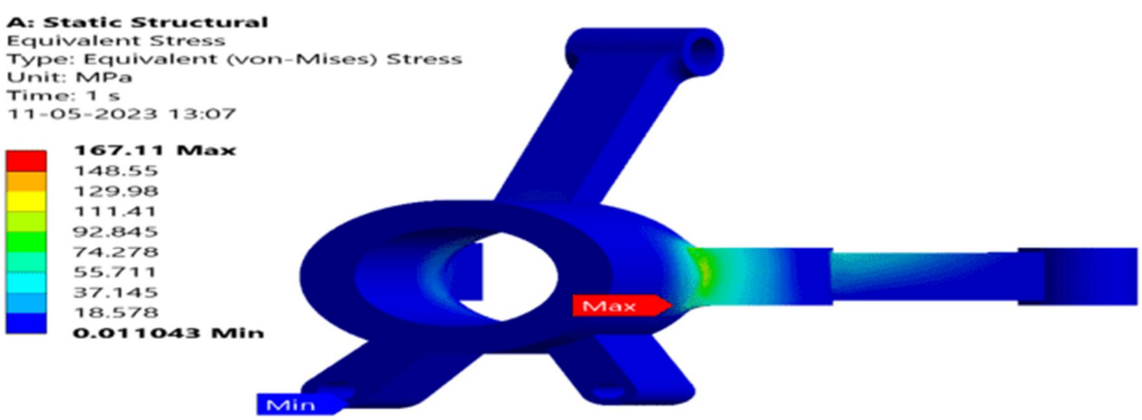

Fig 2.8 Stress

I. Result

The maximum stress acting at a point is 167.11 MPa. The tensile strength of the mild steel is 400MPa.The obtained value is half less than the tensile value of the material. So, it is safer to use and withstand the loads.

III. TRANSMISSION

A. Introduction

In the context of vehicles, the term "transmission" is defined as the mechanical component responsible for transmitting power from the engine to the wheels, enabling the vehicle to move from one place to another. There are two main types of transmissions.
They are,

1) Manual Transmission
2) Automatic Transmission

B. Manual Transmission (or "Stick Shift")

In a manual transmission, the driver manually selects the gears using a gear shifter and a clutch pedal. By engaging and disengaging the clutch, the driver can control the transfer of power from the engine to the transmission, and subsequently to the wheels. Manual transmissions provide the driver with more control over gear selection but require manual shifting.

C. Automatic Transmission

An automatic transmission, as the name suggests, automatically changes gears based on various factors such as vehicle speed, engine RPM, and throttle input. It uses a torque converter or a dual-clutch system to transmit power from the engine to the transmission. The driver does not need to manually shift gears but can select between different driving modes (such as Drive, Park, Reverse) using a gear selector.
So, for the better results we chosen the automatic transmission i.e., CVT for our vehicle.
The transmission plays a major’s role in determining the vehicle's performance, efficiency, and driving experience. It allows the engine to operate within its optimal power range while providing torque multiplication and gear ratios suited for different driving conditions.
For transmission we use Continuous Variable Transmission (CVT). CVT is defined as the Continuously Variable Transmission, which is a type of automatic transmission used in vehicles. Unlike traditional automatic transmissions that have a fixed number of gears, a CVT uses a pulley system to provide a various number of gear ratios between the lowest and highest angle.

D. Record of CVT

In 1910, Apex Cruisers built a V2 motor bike with the Gradua- Gear, which was CVT. This Zenith-Gradua was so fruitful in slope climbing occasions, that it was inevitably banished, so that other producers had a chance to win.
In 1912, the British cruiser producer Rudge-Whitworth built the Rude Numerous equip. The Multi was a much-progressed form of Zenith's Gradua-Gear. In 1922, Browne advertised a cruiser with variable-stroke ratchet drive employing a confront ratchet.In early the application of VT was within the British Clyno car, presented in 1923.A CVT, called Variomatic, was planned and built by Center van Doorne, co-founder of Van Doorne's Automobiel Fabriek (DAF), within the late 1950s, particularly to create an programmed transmission for a little, reasonable car..
The first DAF car using van Doorne's CVT, the DAF 600, was produced in 1958. Van Doorne's patents were later transferred to a company called VDT (Van Doorne Transmissie B.V.) when the passenger car division was sold to Volvo in 1975.

E. Working of CVT

A CVT works with a belt that rotates between two main pulleys with adjustable parameters. As the vehicle accelerates, the pulleys adjust to change the gear ratio and maintain the optimal engine speed for the vehicle's speed and load. This allows for a smoother and more efficient driving experience, as the engine can operate at its most efficient speed for longer periods of time.
CVTs have become increasingly popular in recent years due to their ability to improve fuel efficiency and provide a smoother driving experience. They are commonly found in small cars, hybrids, and electric vehicles.
However, CVTs can also have some disadvantages. Some drivers find the lack of traditional shifting to be less engaging and less satisfying. Additionally,most CVTs only have three basic components.

1) A high-power metal or rubber belt.
2) A variable-input drive pulley.
3) An output driven pulley

- CVT with customized gear box was preferred since the output of the CVT gives high torque only at low speed of the engine.
- As the speed increases, the torque decreases. So, the vehicle will have less pulling capacity.
- So, to increase the pulling capacity of the vehicle, we use a gear box. The analysis of various gear boxes for ATV were done.
- To eliminate the usage of the clutch while the vehicle is moving, a customized gear box is used.
- The main advantage of the this gear box is to eliminate the usage of clutch because the transmission using clutch is difficult to handle during the endurance race and the gear ratio of the gear box matches with requiredgear ratio. Hence the usage of CVT with gear box is preferred.
- And another advantage of using the CVT is we have customized ratio for each gear which more useful to the vehicle

.

F. Disadvantages

- CVT torque-handling capability is restricted by the quality of their transmission medium (as a rule a belt or chain), and by their capacity to resist grinding wear between torque source and transmission medium (in friction-driven CVTs). CVTs in generation earlier to 2005 are predominantly belt- or chain-driven and so ordinarily constrained to low-powered cars and other light-duty applications. Units utilizing progressed greases, in any case, have been demonstrated to bolster a run of torques in generation vehicles, counting that utilized for buses, overwhelming trucks, and earth-moving power vehicles.
- Some CVTs in brand new vehicles have seen premature failures.

1) Drive Line Calculations

The CVT's are directly fixed with engine output shaft so the the maximum amount of power deleivered to the CVT mat be differ based on engine used in vehicle.

- Max. Torque = 19.65 N-m at 1800rpm (14.5 lbft.)
- Max. rpm3800
- Engine power = 10 hp.

2) CVT Polaris Made

- Starting ratio – 3.90:1
- Ending ratio – 0.5:1 (nominal)
- C-C Distance – 215mm

3) Design of the CVT

The CVT is designed by the designing software named CREO version 7.0. The exact design of the CVT is attached below:

Fig 3.1 The assembly of CVT

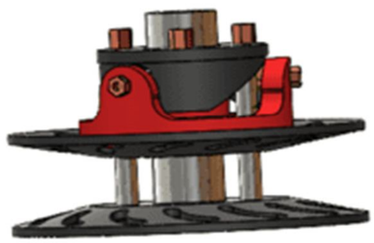

Fig 3.2 Expansion of the secondary

Fig 3.4 Compression of the Primary pulley

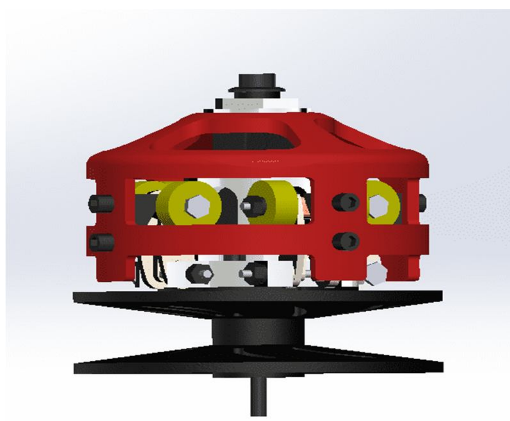

Fig 3.5 Expansion of the pulley in idle

Fig 3.6 Copression of the pulley in running

Fig 3.7 Primary pulley

G. Driveshaft

1) Purpose of the Driveshaft

A driveshaft, has a another tream called propeller shaft, is a mechanical component of a vehicle that transmits torque fom the transmission to the differential, which in turn rotates the wheels. It is usually a tubular metal shaft that is supported by bearings and connects the transmission output shaft to the differential input shaft.

2) Functions of Driveshaft

Driveshafts are commonly used in rear-wheel drive and four-wheel drive vehicles, where the engine is located in the front and the wheels are located in the back or all four corners of the vehicle. The driveshaft allows power to be transmitted to the wheels through the differential, which splits the torque between the left and right wheels to allow for smooth and stable driving.

Driveshafts are designed to be strong and durable, as they must withstand the stresses of high torque and rotational speeds. They are typically made from steel or aluminum, and are often balanced to reduce vibration and ensure smooth operation.Overall, the driveshaft is an essential component of a vehicle's drivetrain system, allowing power to be transmitted from the engine to the wheels efficiently and effectively.

3) Designing Of Driveshaft

The material which we have choosen is C45 metal.The driveshaft is designed by the help the designing software named solidworks. and analysed in the Ansys 7.0.And the images are attached below.And ii has factory of safety 1.3 which is beeter ans safe to use.

Fig 3.8 Driveshaft design

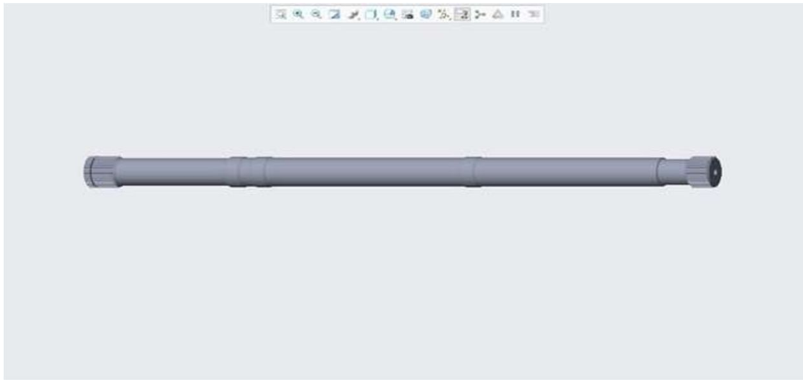

Fig 3.9 Driveshaft design in top view

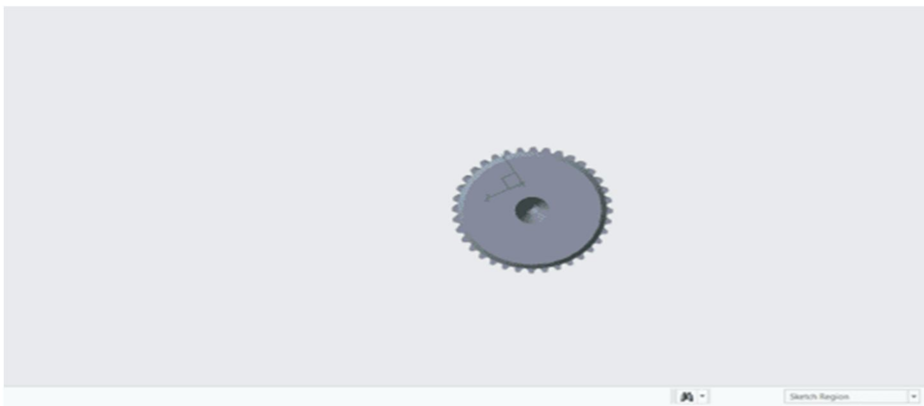

Fig 3.10 Driveshaft design inside

H. Analysis Of The Driveshaft

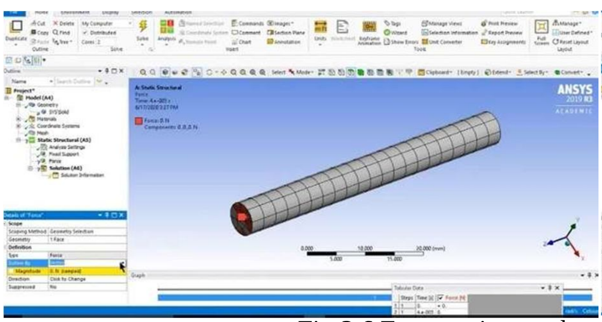

Fig 3.6 Force acting on the shaft

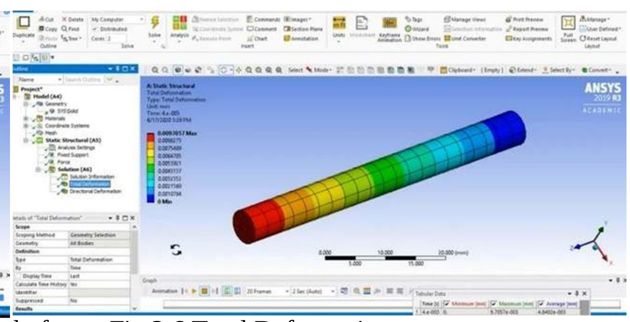

Fig 3.6 Total Deformation

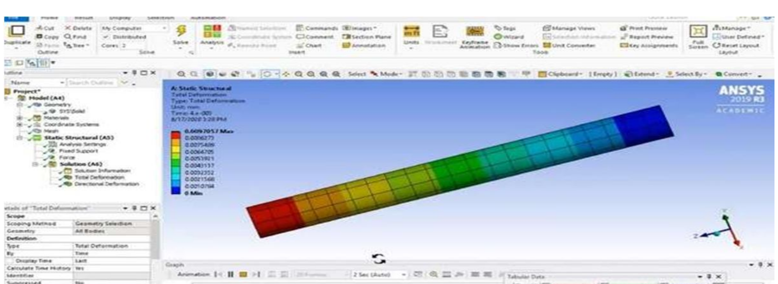

Fig 3.6 Side view of the shaft

IV. CONCLUSION

To sum up, the report has presented a detailed analysis of the design and functionality of essential components crucial for ensuring the safety and performance of off-road or ATV vehicles. Through finite element analysis (FEA), the roll cage has been designed to provide optimal protection to the occupants in case of a rollover, and its structural strength and rigidity have been verified. The steering system has been engineered to ensure precise control and stability. Moreover, the engine has been designed to deliver maximum power and efficiency while guaranteeing durability and reliability.

The outcomes of the report demonstrate that the design and analysis of the roll cage, steering, and engine components have met the mandatory safety requirements and standards. The roll cage provides adequate protection to the occupants in the event of a rollover, the steering system guarantees stable and precise control, and the engine delivers optimal power and efficiency.

Overall, the report has offered a comprehensive examination of the design and functionality of critical components for off-road or ATV vehicles. The results underscore the significance of precise design and analysis to ensure the safety and performance of these vehicles in harsh terrain and conditions.

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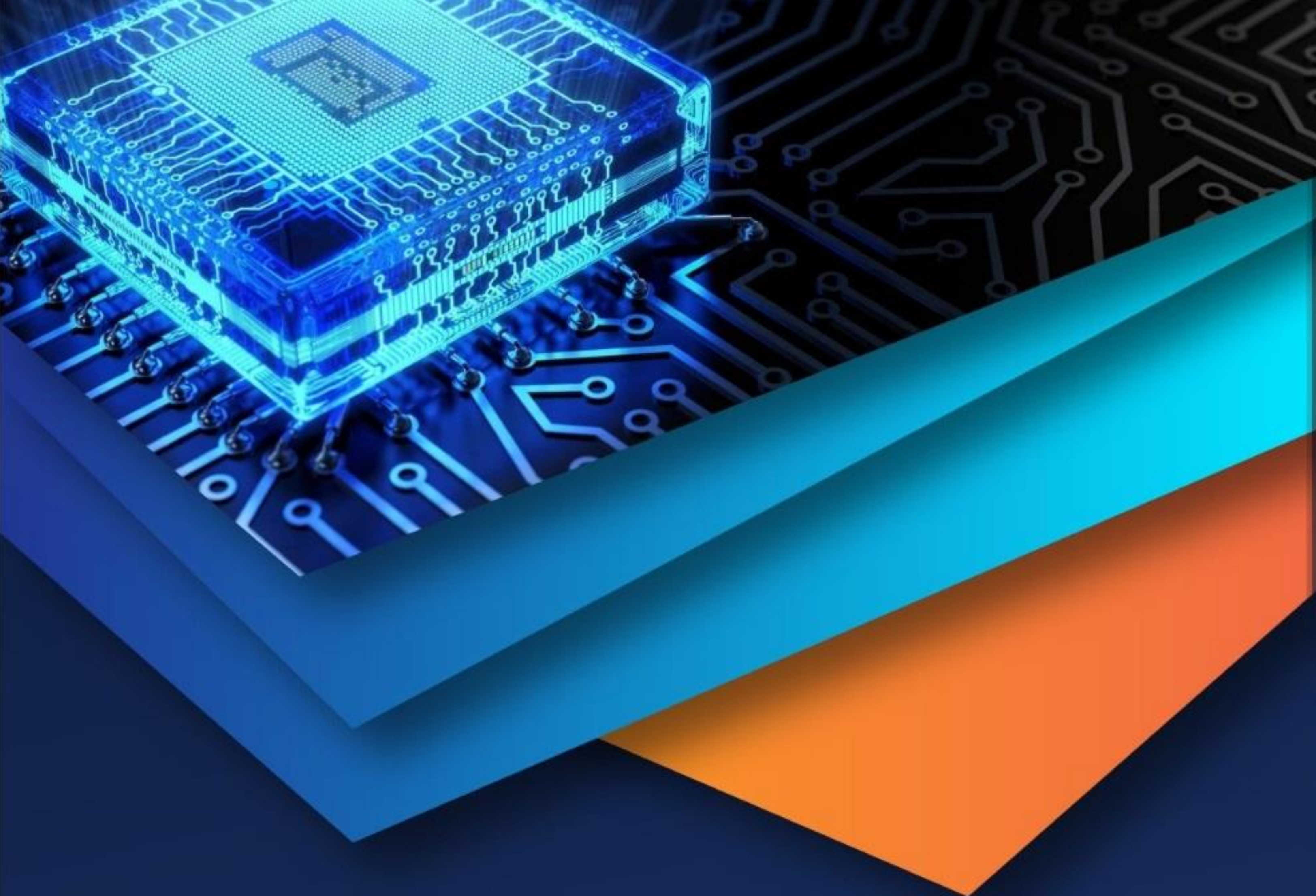

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