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Hydro-Electronically Toe Adjustable Steering (HETAS)

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Abstract— **The purpose of this paper is to develop a new steering system, which can add a new dimensional control over the vehicle. In the traditional steering systems, the wheel can be operated as left-right turning directions by rotating the steering wheel. But in the HETAS the front wheel can be tilted inward and the outwards toe-in and toe-out respectively by using the electronically controlled hydraulic tie rods. Instead of using traditional fixed sized tie-rods we are going to use the electronically controllable hydraulics tie-rods in the Pitman steering mechanism which can increase and decrease their length according to the vehicle performance requirement. The actual aim of this system to enhance the performance of the high-speed vehicles by adding an additional toe angle adjustment for improved vehicle cornering ability and the stable straight drive performance at the high speed and in less time period. Also, to improve the tires heat distribution and decrease the un-even wearing of tires and to increase their durations, which can save lots of efforts at the pitstop and the money over tire.**

Keywords— **Steering system, Toe angles, Toe-in, Toe-Out, Ackerman, Pitman, Hydraulic, Electronics.**

I. Introduction

The main function of steering system is to convert the rotary motion of steering handle into angular displacement of front wheels. The steering mechanism must also maintain the straight-ahead motion of vehicle while it encounters road bumps and pot-holes and must operate with minimum effort during operating vehicle. The purpose of the steering system is to provide directional control of the vehicle with minimum input. The steering is designed to withstand the stress of the vehicle through any type of possible condition at the time of driving. The main concern about steering is, that it should be according to "Ackermann" condition of correct steering. Steering system is affected by many factors like toe of steering, caster angle, camber angle, king pin inclination. Our project is a new kind of initiative and will play around with toe of the steering. Components required in steering systems are: 1. Steering wheel

2. Steering column
3. Rack& pinion / Pitman
4. Tierod
5. Steering Arm
6. Stub axle

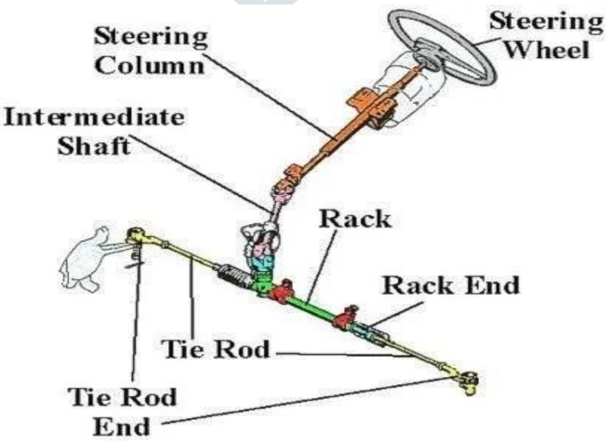

Fig. 1: Steering system

- Steering wheel - Direct the vehicle and is connected to steering column
- Steering column - To transfer the motion from steering wheel.
- Rack & pinion / Pitman - Convert the angular motion in liner motion.
- Tie Rod – Use to move steering arm
- Steering arm - Help to transmit the force from tie rods to make turn angle.
- Stub axle - Mounting of wheel.

In order to make adjustment in toe angles as it affects the stability and cornering ability of the vehicle, vehicle needs to be in static position. Our projects over come this problem and can help toe adjustment in dynamic condition. Such condition is used in fast cars such as Formula-1, Formula-E. In present world, Go-Kart driving is more essential to become a F1 driver. Karting is a form of racing in a small Four-wheel vehicle is known as Go-Kart. In the beginning, the first ever Go-Kart was created in Los Angeles by Art angels in 1956. The first official organized race took place with several dozen home-built machines in1957inthe parking lot of the Famed Rose Bowl in Pasadena, California. We will implement our project in steering system of Go-Kart

II. TOE ANGLES

Toe in and toe out have an effect on the car's stability and handling. It is rarely seen a toe out setup on a road going car, maybe a bit on the driven axle, but it is due to the stability issues it brings (road cars tend to be set up very conservatively, giving generally safer and less eventful under-steer). Toe out, at least in the front, causes the car to want to be 'all over the place', it won't be good at holding the line, and it will wallow across the road and need constant adjusting. Since this instability gives you a sharper turn-in response, the car will be easier to turn into the corner. Toe-out in the rear would give similar results, but with the rear end being the more unstable part of the car, which would be even worse on the road.

A. TOE Angles

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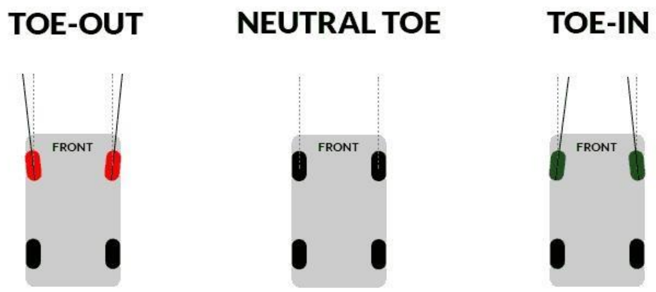


Fig.2: Toe angles

B. What is turn radius and how it affects our mechanism

The turning radius or turning circle of a vehicle is the diameter of the smallest circular turn (i.e. U-turn) that the vehicle is capable of making. Turning radius, is the length of a car(or other vehicle) and how sharply it cornering arc. Since it is not a complete circle, it is called a turning radius. Figure 3:Turning Radius Change in toe angle affects the turning radius as: Toe out : Turning radius is reduced. Toe in : Turning radius is increased. Toe 0 : Turning radius is in between best and worst.

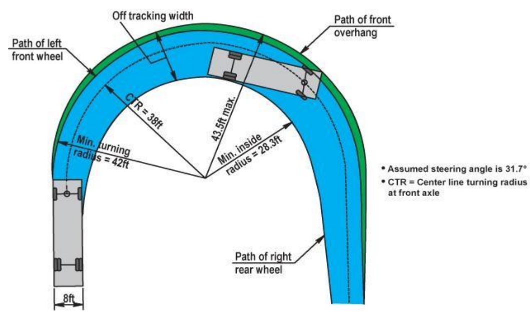


Fig.3:Turning Radius

III. Objective

Easy way to steer a vehicle.

- To develop a physical prototype of toe adjustable steering system open head.
- To develop a tie rod with ability to change the toe angles as well as trackwidth. Steering is one of the crucial part of any vehicle

when it comes to turning the vehicle or changing the direction of it. The most difficult part of optimizing the steering system is adjusting toe that suits best for the vehicle by adjusting the length of the tie rods. This happen to be the most difficult phase while installing the steering system to the vehicle. Our project helps to overcome this problem as its main function is to adjust the length of the tie rod hence eliminating the most crucial step. The Tie rod will include a hydraulic cylinder on each rod which will help the tie rod to change the length.

A. Problem Statement

Basically, F1 cars often run with a little toe-out to help with cornering. This is because with some toe out up front, the tires better approximate the arc of the curve in a turn. But while toe out makes for better steering response and better cornering, it's a literal drag on the straights. Because the tires are sliding crabwise against the direction of travel (if only very slightly). The ETAS system pulls those tires straight for better straight line speed and less tire wear, using some sort of Hydraulic mechanism to move the inboard portion of the steering arms back or inwards, in effect, "steering" the front tires into a straighter alignment.

B. Proposed Work

Present work includes adjustment of toe in and toe out using hydraulics system. Project work includes:

1.To study the basic of steering system.
2.To study tracking and wheel alignment.
3.To Study Hydraulic system
4.Selection of suitable hydraulic pump.
5.Selection of suitable hydraulic circuit.

C. Methodology

Steps to be followed

1. Formation of group
2. Topic selection
3. Future scope of found solution
4. Calculations
5. CAD model
6. Market survey
7. Manufacturing
8. Optimization
9. Report making
10. Final product

The commencement of the project started in the month of July in mid month time. Right after the formation of the group we decided to choose the topic. Having some experience in the steering we chose this topic. There is already a system developed by Mercedes AMG F1 team. The main difference between our innovation and theirs is that theirs is dependent on rack and pinion steering system. Rack and pinion is a heavy and costly system than that of the pitman steering system. So we thought of bringing this mechanism to the cheaper system and this system has has proven efficient in F1 trials. We further performed calculations did some research & read some papers and started to design CAD model for this system. After CAD model was developed we made our required optimization and will start our manufacturing

IV. Calculation

The purpose of the steering system is to provide direction to the vehicle as per driver's requirement. In order to achieve better performance, Toe of the steering system is adjusted.

Formulas that we used for calculation of various steering parameters are:

- $\cot\alpha - \cot\beta = c/\text{wheelbase}$.

Where,

c= Distance between KPI to KPI.

α= Front outer turning angle.

β= Front inner turning angle

Turning radius:

Where,

R1 = inner front wheel turning radius

R1= (wheelbase/sinβ) - (track width-c/2)

R1 = (1066.8/sin53.10) - (959.8 – 609.8/2) R1 = 679.12 mm

Where,

R2 = front outer turning radius

R2 = (wheelbase / sinα) + (track width-c/2)

R2 = (1066.8/sin53.10) + ((959.8 - 609.8)/2)

R2 = 2423.44 mm

Where,
R3 = Inner rear wheel turning radius
R3 = (Wheel base/Tanβ) - (track width-c/2)
R3 = (1066.8/Tan53.10) + ((959.8 - 609.8)/2)
R3 = 450.97 mm
Where,
R4 = Outer rear wheel turning radius
R4 = (Wheel base/Tanα) + (track width-c/2)
R4 = (1066.8/Tan37.10) + ((959.8-609.8)/2)
R4 = 2370.36 mm
R mean = (R1 + R2 + R3 + R4) / 4
= (679.12+2423.44+450.97+2370.36) / 4
R mean = 1480.97 mm
β for 100% Ackermann = Tan-1 (wheel base / (wheel base/Tanα-track width))
= Tan-1 (1066.8/((1066.8/Tan37.10)- 609.8))
β for 100% Ackermann = 53.10 % Ackermann
= β / (βfor 100 %Ackermann)
= (53.10 / 53.10) *100
=100% (theoretically).

M = 60 kg
V = 4.722 m/s
R = 1.48 m
Height of C.G = 0.232 m
Track width = 0.959 m
F static = M * u * g
= (60 * 0.8 * 9.81)
= 470.88 N.
Load transfer = (mv2/r * ht.cg) / track width
= (60 * (4.722) 2 / 1.48 * 0.232) / 0.959)
= 218.68 N
Torque at left king pin = F static * stub axel
= 470.88 * 175 = 82404 Nmm^2
F castor (5°) = cos (53.10) * sin (5) * 218.68
= 11.44 °
F scrub radius = 470.88 * cos (95) * sin (53.10)
= - 32.81
Total Torque at king pin
= Torque at left king pin + castor + scrub radius
= 82404 + 10.71 + (-32.81)
= 82382.63 N. mm
Perpendicular force at c (Fc) = Torque at kp / steering arm
= 82404 / 135 = 610.4 N
Force on the Tie rod = Fc * cos (15.11) = 610.4*cos (15.11)
= 589.29 N
Torque at king pin (Ʈe) = Fcd * cos (15.11) * Steering arm
= 589.29 * cos (15.11) * 135
= 76803.73 N.mm
Force on steering arm (Feg) = Ʈe / steering arm
= 76803.73 / 135 = 568.91 N
Force on pitman = Feg* sin (15.11) = 568.91 * sin (15.11)
= 148.29 N.
Cornering force = Load transfer = 218.68 N
Total force at point H (Fh) = Force on pitman + cornering force
= 148.29 + 218.68
= 367.13 N
Force on steering = (Fh * pitman dist.) / Distance of steering handle
= (367.13 * 110) / 310
= 130.27 N
Force on R = Force on steering / 2 = 130.27 / 2
= 65.13 N
Force per hand = Force on R / 9.81
= 65.13 / 9.81
= 6.63 Kg

V. DESIGN

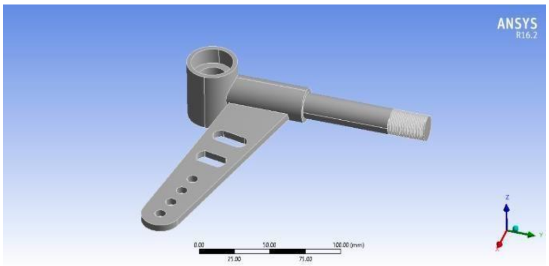


Fig.4:Knuckle

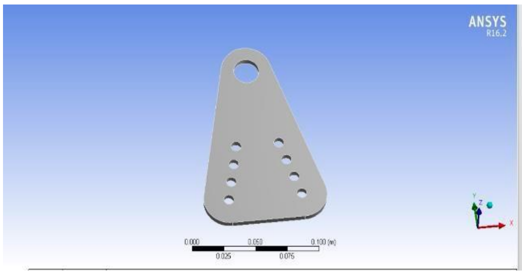


Fig.5:Pitman

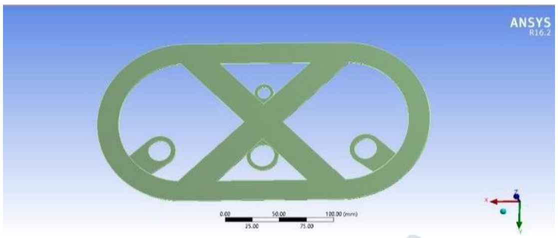


Fig.6: Steering Wheel

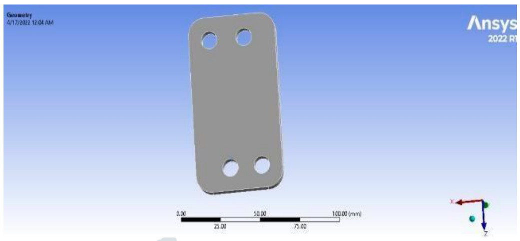


Fig.7: Steering Plate

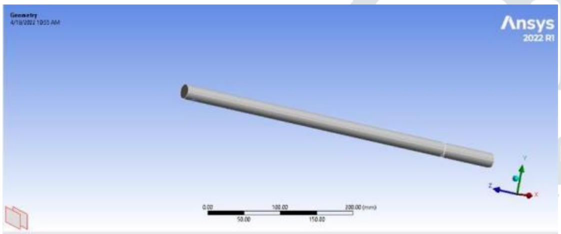


Fig.8: Steering Column

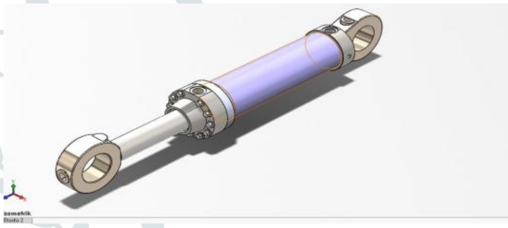


Fig.9: Hydraulic Pitman

VI. ANALYSIS

a) Stub :

Material Data:
Mild Steel
Density – 7.85 g/cc
Modulus of Elasticity – 210 Gpa
Poisson's Ratio – 0.29
Tensile Stress – 370 Mpa Ultimate Tensile Stress – 420 Mpa

Model:

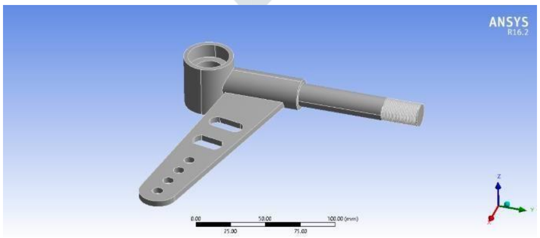


Fig.10: Knuckle

Model Mesh Details:
Advanced Size Function: Proximity and Curvature on.
Min Size -1 mm
Max size- 4 mm
No of nodes: 478152
Number of elements: 308543 Types of elements: Tetrahedron.
Mesh Quality Jacobian Ratio: 1.01

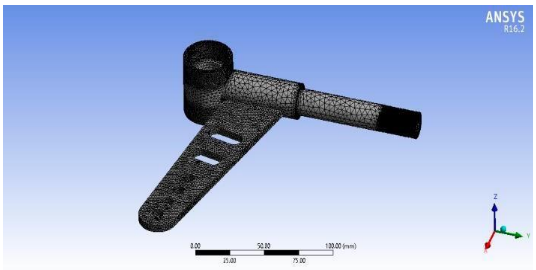


Fig.11: Mesh on Knuckle

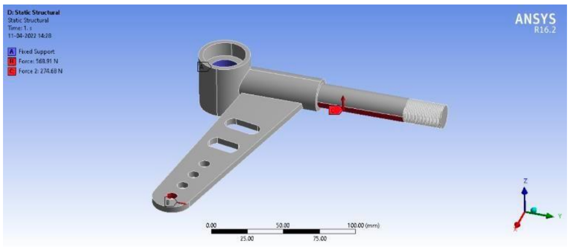


Fig.12: Boundary conditions

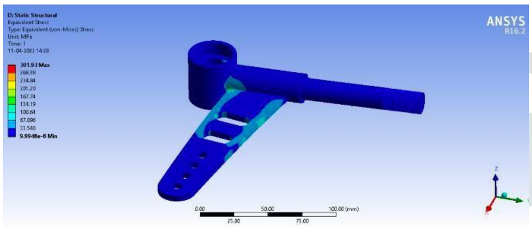


Fig.13: Stress in Knuckle

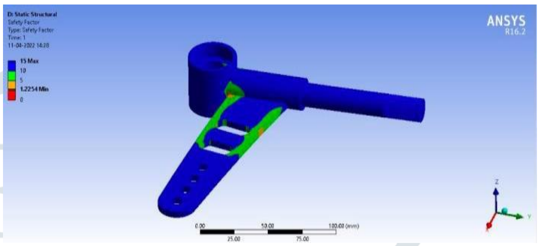


Fig.14: Safety Factor

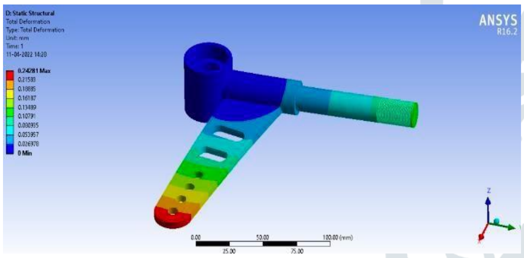


Fig.15: Deformation in Knuckle

b) Pitman :

Material Data:

Mild Steel
Density – 7.85 g/cc
Modulus of Elasticity – 210 Gpa
Poisson’s Ratio – 0.29
Tensile Stress – 270 Mpa Ultimate Tensile Stress – 320 Mpa Model:

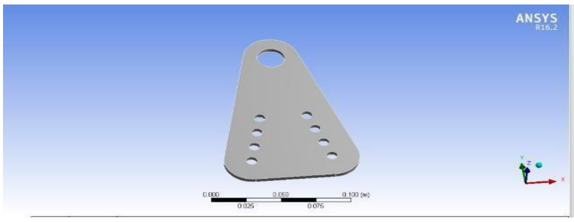


Fig.16: Pitman

Model Mesh
Details:
Advanced Size Function: Proximity and Curvature on.
Min Size 0.6 mm
Max size- 1.0 mm
No of nodes: 86945
Number of elements: 16881
Types of elements: Quadrilateral.
Jacobian Ratio: 1.2

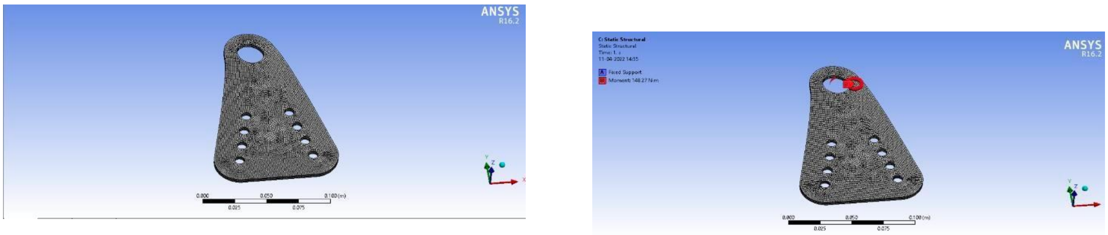


Fig.17: Meshing in Pitman

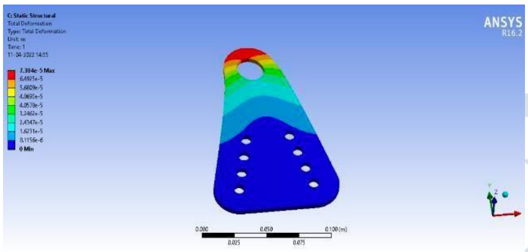


Fig. 19: Deformation in Pitman

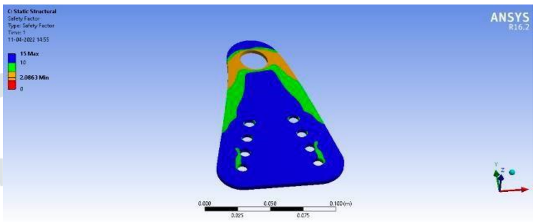


Fig.20: Safety Factor

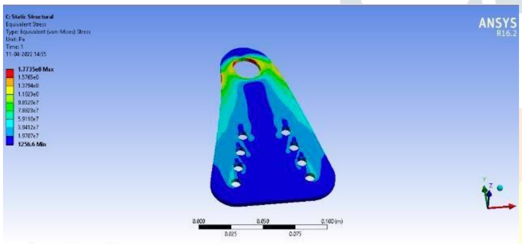


Fig.21: Stress in Pitman

c) Steering wheel :

Material Data:

Mild Steel
Density – 7.85 g/cc
Modulus of Elasticity – 210 Gpa
Poisson's Ratio – 0.29
Tensile Stress – 370 Mpa Ultimate Tensile Stress – 420 Mpa Model

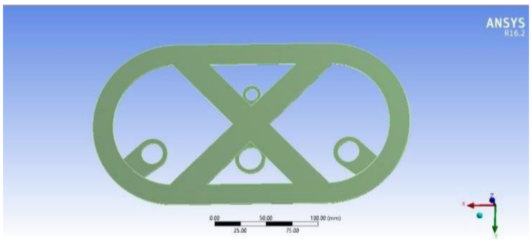


Fig.22: Steering Wheel

Model Mesh Details:
Advanced Size Function: Proximity and Curvature on
Mesh Element size: 2.0 mm
No of nodes: 975593
Number of elements: 635771
Types of elements: Tetrahedron
Mesh Quality Jacobian Ratio: 1.003

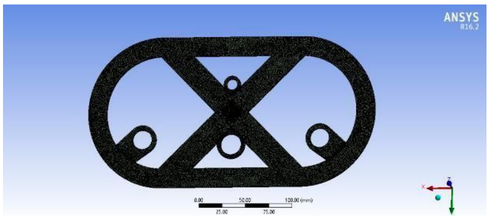


Fig.23: Steering Wheel

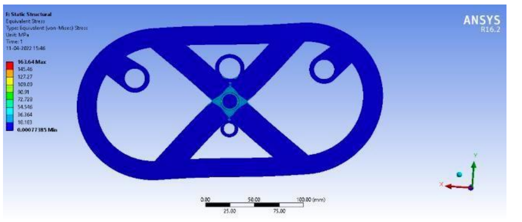


Fig.24:Stress in Steering Wheel

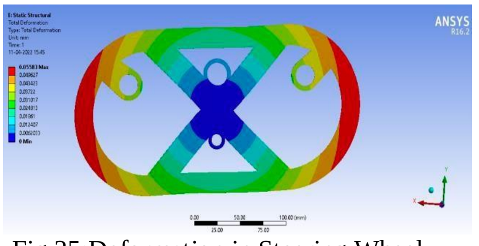


Fig.25:Deformation in Steering Wheel

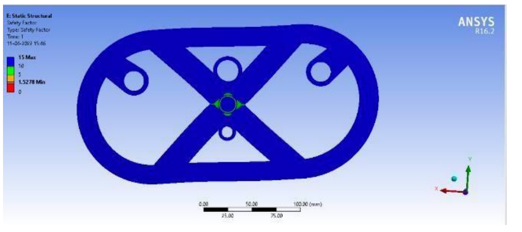


Fig.26:Safety Factor

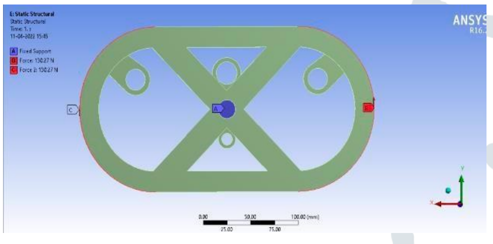


Fig.27:Boundary Conditions

d) Plate:

Material Data:

Mild Steel
Density – 7.85 g/cc
Modulus of Elasticity – 210 Gpa
Poisson's Ratio – 0.29
Tensile Stress – 370 Mpa Ultimate Tensile Stress – 420 Mpa Model:

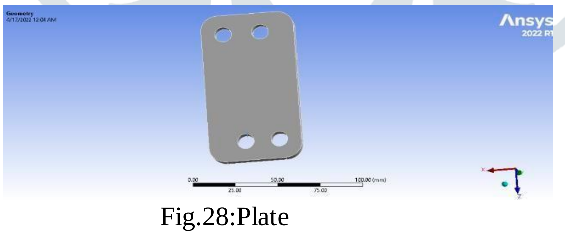


Fig.28:Plate

Mesh Details:
Advanced Size Function: Proximity and Curvature on.
Min Size 0.6 mm
Max size- 1.0 mm
No of nodes: 21280
Number of elements: 10718
Types of elements: Quadrilateral.
Jacobian Ratio: 1.2

Fig.29: Meshing On Plate

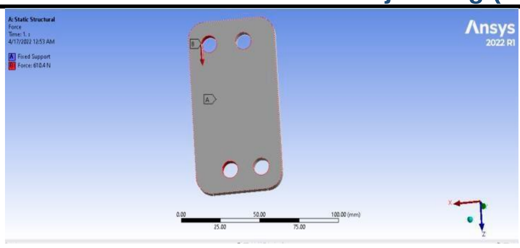


Fig.30:Boundary conditions

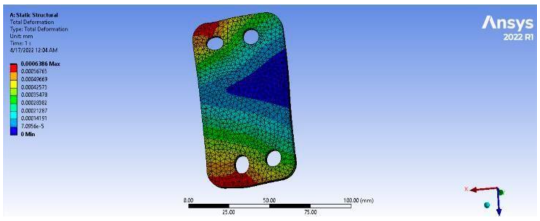


Fig.31:Deformation

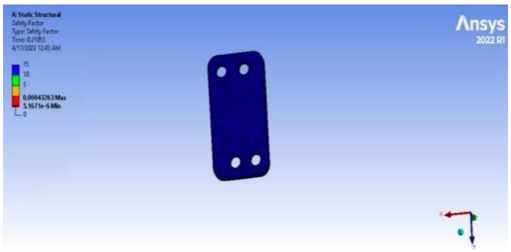
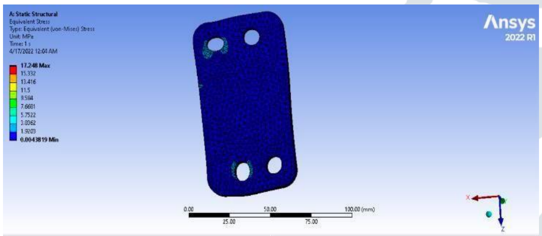


Fig.32:Safety Factor



e) Column :

Material Data:

Mild Steel
Density – 7.85 g/cc
Modulus of Elasticity – 210 Gpa
Poisson's Ratio – 0.29
Tensile Stress – 370 Mpa Ultimate Tensile Stress – 420 Mpa Model:

Fig.34: Column

Mesh Details:
Advanced Size Function: Proximity and Curvature on.
Min Size 0.6 mm
Max size- 1.0 mm
No of nodes: 93230
Number of elements: 52890
Types of elements: Quadrilateral.
Jacobian Ratio: 1.2

Fig.35:Meshing on Column

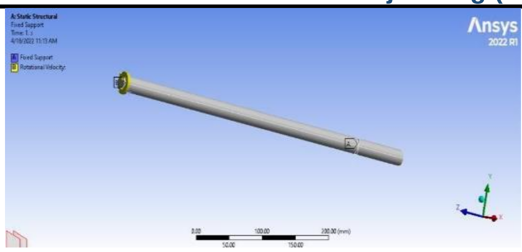


Fig.35:Boundary condition

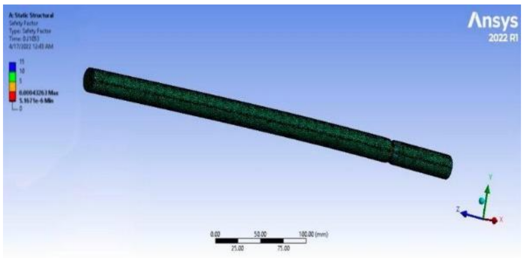


Fig.36:Deformation in Column

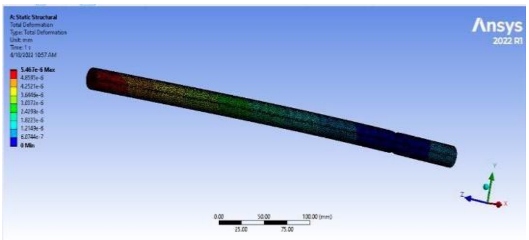
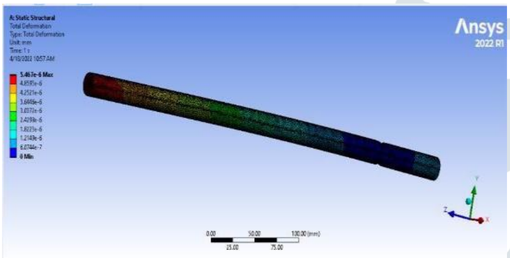


Fig.37:Stress in Column



VII. Conclusion

On the basis of the above work, we have concluded that this model is unique and new to industry and simple to assemble. The fabricated prototype gives satisfactory results with around 75-80% of accuracy. The prototype model has some in accuracy which are expected to be solved in future and are considered under future scope of the project. With further optimizations and effective implementation of solution the product can achieve the required accuracy.

VIII.Future Scope

As of now we have two options to play with regarding toe of the vehicle. This limitation is caused by single side actuating cylinder. As of our future plan we plan to procure a dual side acting cylinder so that we can reach the condition of neutral toe. This will require a little optimization for length of Tie Rod and the condition will be full filled. Our current design being in early stage can be buggy. Problems like unequal toe at different tires, wobble on tire etc. In order to fix such problems we will consider optimizations to overcome such problems it will also increase the control over vehicle. Steering being very crucial component of the vehicle it needs to be precise with angles to achieve best result possible, to achieve inch correct perfection. Project being in premature stage there is always a chance of leakage with cylinder. Leakage in cylinder would affect length of tie rod hence toe angle causing vehicle to dis balance and be out of control of the driver. This steering mechanism would best fit high speed cars which cannot be driven by anyone. One needs to have quick reflexes and a habit to use it at such a great speed, we plan to bring this to basic level slower speed (comparatively) vehicle like go-kart and could be accessible to more amount of people.

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References

[1] Wang B L, Zhou J S, Zhao B et al. 1995 Trans. Chinese Soc. Agric. Eng. 11(1)89-94.
[2] Pan H D, Su J, Jia Z R et al. 1998 Chinese J. Highways, 11(suppl.) 116-21.
[3] Wei D G, Chen X Q, Hu N J et al. 2003 Trans. Chinese Soc. Agric. Eng. 19(6)139-42.
[4] Wei D G 2004 J. Hefei Univ. Technol. (Natural Sci.) 27(6) 1594-8.
[5] Ma J, Qian L J 2012 J. Hefei Univ. Technol. (Natural Sci.) 35(1) 25-8.
[6] Dixon J C 1996 Tire, suspension and Handing 2nd ed. Warrendal, PA: SAE81-109.
[7] Zhuang J 1995 Automotive Tire Science Beijing: Beijing Inst. Technol. Publishing 127-9.