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Design of Precision Steering Mechanism and Motion Study of Ackermann Steering Mechanism for A Four-Wheeler Vehicle with Minimum Error Percentage

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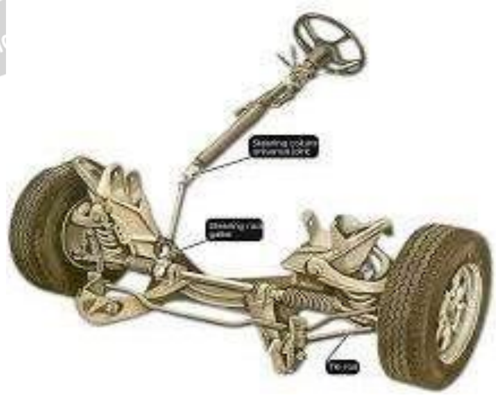
ABSTRACT: Steering systems are used to change the direction of the vehicle. These are essential to provide vehicle safety, steering quality and steering control and used to turn the vehicle without loss of traction and also used to maintain the directional stability of the vehicle. The most commonly used steering geometries are Davis and Ackermann. The types of steering systems are trapezoidal; double trapezoidal and Rack & pinion etc... Direct steering mechanism is rotating the wheel and an indirect steering mechanism is by rotating up and down or pulls and push. Twin lever steering mechanisms is push and pull type and controlled mainly by Bi-articular muscles, making use of advancements in science and technology. The main aim of the paper is to decrease the error percentage associated with the current ackermann steering mechanism. Due to this turning pairs there is an error exist in the mechanism. So by varying the steering arm length and steering arm angle (ackermann angle) we can reduce the error percentage. So by taking different arm angles(ackermann angles),by calculating different error percentages. And consider the angle which produces less error percentage. To perform the analysis on steering arm we choose Ansys software to validate the design of steering arm for applied steering for from the steering wheel. Steering arm is directly connected to wheel hub and rotate the wheel directly.

Key words: Steering Mechanism, Ansys, structural steel, CI

I. INTRODUCTION

More than hundred years that have passed since the introduction of automobile, it can seen that original method of controlling cars pulled by animals such as horses was by reins. Early automobiles had a single push pull bar which is known as tiller steering. Later on it becomes it became a steering wheel.

The most convectional steering arrangement is to turn the front wheel using a hand –operated steering wheel which is positioned in front of a driver, near the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line other arrangements are sometimes found on different types of vehicles for examples, A tiller or rare- wheel steering. Tracked vehicles such as bulldozers and tank usually employ differential steering that is, tracks are made to move at different speeds or even in opposite directions, using clutches and brakes, to bring about a changes of course or direction. To change the vehicle's direction we are using twin lever steering mechanism. Depending on the vehicle's design and construction convenience we choose linkage steering system which four bar mechanism and works on Ackermann's geometry. According to Ackermann's principle the inner wheel turns more than that of the outer wheel



NORMALSTEERING:

- The most conventional steering arrangement is to turn front wheels using a hand operated steering wheel.
- This is positioned in front of the driver , via steering column.
- Other types of steering are Tiller or Rear wheel steering.

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- Tanked vehicles such as tanks and bulldozers usually employ differential steering.
- Many modern cars use rack and pinion steering mechanisms, where the steering wheel turns the pinion gear; the pinion moves the rack, which is a linear gear that meshes with the pinion, converting circular motion into linear motion along the transverse axis of the car (side to side motion.
- The rack and pinion design has the advantages of a large degree of feedback and direct steering "feel". A disadvantage is that it is not adjustable, so that when it does wear and develop lash, the only cure is replacement

ABOUT TWIN LEVER MECHANISM:

Direct steering mechanism is rotating the wheel and an indirect steering mechanism is by rotating up and down or pulls and push. Twin lever steering mechanism is push and pulls type and controlled mainly by Bi-particular muscles, making use of advancements in science and technology.

We have opted this type of steering mechanism because the Twin Lever Steering (TLS) system which mimics the bi-particular muscles and helps in reducing the steering effort of the vehicle, as shown in above Fig. The bioengineering advantages are as follows

(1) Force can be exerted more easily,

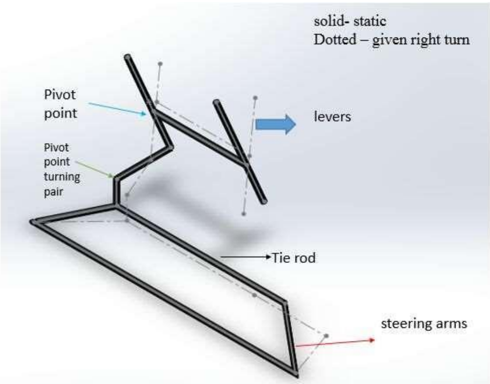
(2) The steering can be accomplished quickly

(3) The positioning can be done accurately, and

(4) The burden on the driver can be reduced (less fatigue)

REASONS FOR SELECTING FOUR BAR MECHANISM FOR TWIN LEVER STEERING MECHANISM

1. Simple mechanism and easy to implement.
2. Simpler in design and construction.
3. The error is constant in Ackermann's principle.
4. Low cost of designed parts.



In this you can see the movement of the trapezoidal steering mechanism to turn the vehicle from one direction to another by revolving at a revolving joint

1.1. WHAT IS STEERING

The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear–wheel steering. Tracked vehicles such as bulldozers and tanks usually employ differential steering that is, the tracks are made to move at different speeds or even in opposite directions, usingclutches and brakes, to bring about a change of course or direction. The direction of motion of a motor vehicle is controlled by a steering system. A basic steering system has 3 main parts: A steering box connected to the steering wheel, the linkage connecting the steering box to the wheel assemblies at the front wheels.

When the driver turns the steering wheel, a shaft from the steering column turns a steering gear. The steering gear moves tie rods that connect to the front wheels. The tie rods move the front wheels to turn the vehicle right or left.

The primary purpose of the steering system is to allow the driver to guide the vehicle. Early vehicles used manual steering linkage system manual steering boxes or manual racks. Later systems used the benefits of hydraulic fluid systems to greatly improve the steering performance. Today, we now have fully electronically controlled steering systems for greater and smoother performance and maneuverability.

1.2. STEERING GEAR BOXES

The steering box is commonly used in larger vehicles, such as commercial-type vehicles. Although some manufacturers of four-wheel drive vehicles use this system due to its strength. All of the steering boxes are identified by their internal mechanical design. All of them operate by either their mechanical structure or are supported by the means of a hydraulic fluid system to enhance their performance.

Steering Box Operation

The steering box converts rotation of the steering shaft into angular movement of the Pitman arm as shown in fig.1.2. The box is partially filled with oil to lubricate the steering mechanism inside. The steering shaft turns a worm shaft that runs through a threaded nut. The nut has teeth that engage with the teeth on a sector gear. The steering gearbox provides the driver with a lever system to enable them to exert a large force at the road wheel with the minimum effort, and to control the direction of vehicle motion accurately. The overall ratio between the steering wheel and the road wheel varies from about 18:1 to 35 :1, depending on the load on the road wheels and the type of steering. As the ratio is raised, a large number of turns are required to

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move the wheel from lock to lock. This makes it difficult to make a rapid change in vehicle direction. By varying the efficiency, the degree of reversibility can be controlled. This then enable the driver to 'feel' the wheels, yet not be subjected to major road shocks.

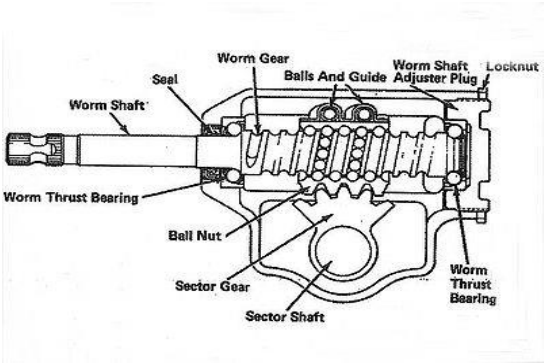

Fig1.1 steering gear

Worm & Sector Steering Box

In this type of steering box as shown in fig.1.3, the end of the shaft from the steering wheel has a worm gear attached to it. It meshes directly with a sector gear (so called, because it's a section of a full gear wheel). When the steering wheel is turned, the shaft turns the worm gear, and the sector gear pivots around its axis as its teeth are moved along the worm gear. In this type of steering box, the end of the shaft from the steering wheel has a worm gear attached to it. It meshes directly with a sector gear (so called, because it's a section of a full gear wheel). When the steering wheel is turned, the shaft turns the worm gear, and the sector gear pivots around its axis as its teeth are moved along the worm gear.

Fig.1.2 Worm and sector box

Screw and Nut Steering Box

The screw and nut type mechanism is possibly the basic form for all the other types of steering gear box mechanisms. A nut is screwed on a multi-start thread formed on the inner column. This design gives much more strength to the main shaft. When the steering wheel is turned, the splinted end rotates causing the thread section to rotate too, but because the nut is prevented from turning the ball joint has to move up and down with the thread instead. This movement then causes the rocker shaft to eventually transmit movement to the steering linkage and onto the road wheels.

Recirculating Ball Steering Box

In a recirculating ball steering box, the worm drive has many more turns on it with a finer pitch. A box or nut is clamped over the worm drive that contains dozens of ball bearings. These loop around the worm drive and then out into a recirculating channel within the nut where they are fed back into the worm drive again.

Cam & Peg Ball Steering Box

A tapered peg in the rocker arm engages with a special cam formed on the inner column. The end-float of the column is controlled by shims, and an adjusting screw on the side cover governs the backlash and end-float of the rocker shaft. A modified form, known as the high efficiency cam and peg gear, uses a peg, which is allowed to rotate in bearings in the rocker arm

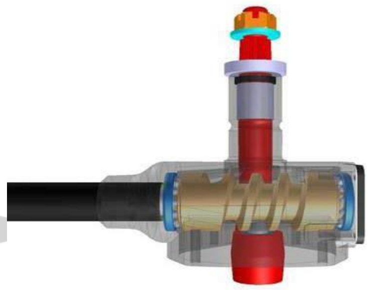

Fig.1.3 Cam and peg box

Fig.1.4 worm and roller

TYPES OF STEERING MECHANISM

- Power Rack-And-Pinion Steering
- Re-Circulating-Ball Steering
- Power Steering

2.1. POWER RACK-AND-PINION:-

When the rack-and-pinion is in a power-steering system, the rack has a slightly different design.

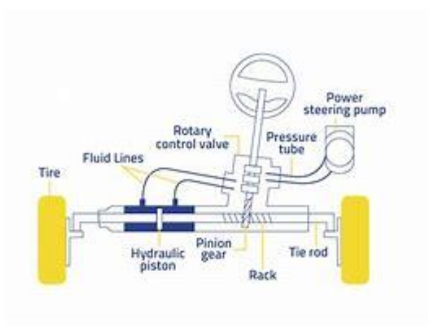

Fig.2.1 Rack and pinion system with power steering

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Part of the rack contains a cylinder with a piston in the middle. The piston is connected to the rack. There are two fluid ports, one on either side of the piston. Supplying higher-pressure fluid to one side of the piston forces the piston to move, which in turn moves the rack, providing the power assist.

We'll check out the components that provide the high-pressure fluid, as well as decide which side of the rack to supply it to, later in the article. First, let's take a look at another type of steering

2.2. RE-CIRCULATING-BALL STEERING:-

Re-circulating-ball steering is used on many trucks and SUVs today. The linkage that turns the wheels is slightly different than on a rack-and-pinion system.

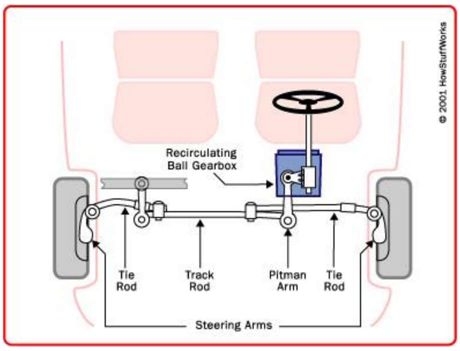

Fig.2.2(a) Recirculating Ball Steering

The re-circulating-ball steering gear contains a worm gear. You can image the gear in two parts. The first part is a block of metal with a threaded hole in it. This block has gear teeth cut into the outside of it, which engage a gear that moves the pitman arm (see diagram above). The steering wheel connects to a threaded rod, similar to a bolt that sticks into the hole in the block. When the steering wheel turns, it turns the bolt. Instead of twisting further into the block the way a regular bolt would, this bolt is held fixed so that when it spins, it moves the block, which moves the gear that turns the wheels.

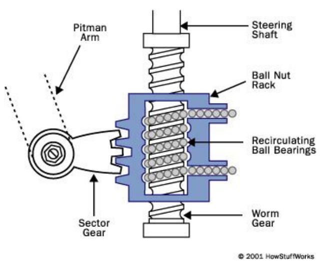

Fig.2.2(b).Recirculating Ball Steering

Instead of the bolt directly engaging the threads in the block, all of the threads are filled with ball bearings that recirculation through the gear as it turns. The balls actually serve two purposes: First, they reduce friction and wear in the gear; second, they reduce slop in the gear.

Slop would be felt when you change the direction of the steering wheel -- without the balls in the steering gear, the teeth would come out of contact with each other for a moment, making the steering wheel feel loose. Power steering in a re-circulating-ball system works similarly to a rack-and-pinion system. Assist is provided by supplying higher-pressure fluid to one side of the block.

2.3. POWER STEERING

There are a couple of key components in power steering in addition to the rack-and-pinion or recirculation-ball mechanism.

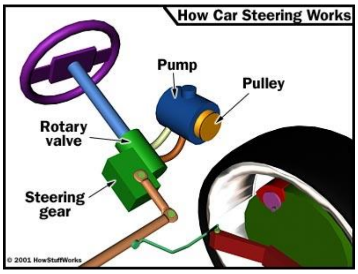

Fig 2.3 Power Steering

Step by step procedure for design methodology:-

Track width and wheel base selection
⇩
Turning radius
⇩
Ackermann condition
⇩
Turning angles
⇩
Wheel geometry
⇩
Selection of linkage design
⇩
Error calculation
⇩
Design and CAE of steering parts
⇩
Fabrication

. SELECTION OF TRACK WIDTH & WHEEL BASE:

As per our design requirement for the design vehicle, we selected suitable parameters of track width and wheelbasefor grey cast iron and structural steel.

PARAMETERS	VALUES
Track width	1060 mm
Wheel base	1162 mm
Max. inner angle (δi)	34.01°
Max. outer angle (δo)	22.672°

TURNING RADIUS CALCULATIONS:

As per driver ergonomics and driver comfort while driving the vehicle we have selected the track width and wheelbase of the vehicle. Turning radius is fixed as 2.3 meters for the vehicle taken on the basis of track width and wheel base.

Where T = (pivot - pivot distance) T= 1060mm

R_1 = 2260.566 mm

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A = 424mm

Tan δ_i = wheel base/(R_1-T/2)

Tan δ_i = 1060/ (2260.5-1060/2)

Tan δ_i = 34.01^0

Tan δ_o = wheel base/(R_1+T/2)

Tan δ_o = 1060/(2260.5+1060/2)

Tan δ_o = 22.67^0

ACKERMANN'S CONDITION:

Cotδ_o –cotδ_i = (Distance between pivots)/ (wheel base)

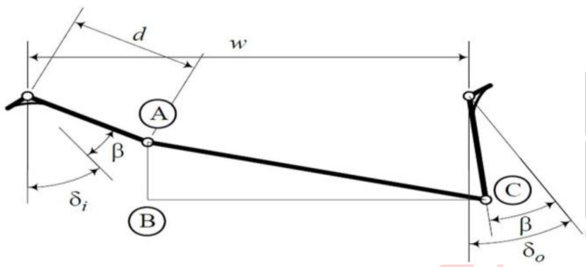
Cot (22.67)-cot (34.01) = 1060/1162 0.9120=0.9125

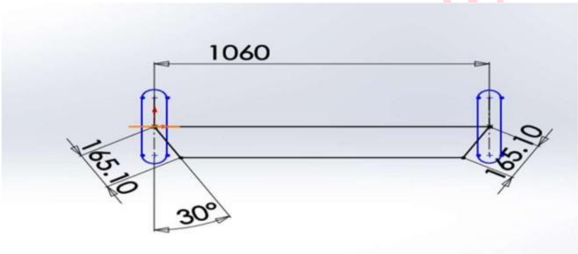
Thus Ackermann condition is approximate

Above dimensions are in mm

CALCULATION OF ACKERMANN ANGLE AND STEERING ARM LENGTH FOR MINIMUMERROR:

Derivation:





From the above figure

AB = dcos (β−δo) − dcos (β + δi)

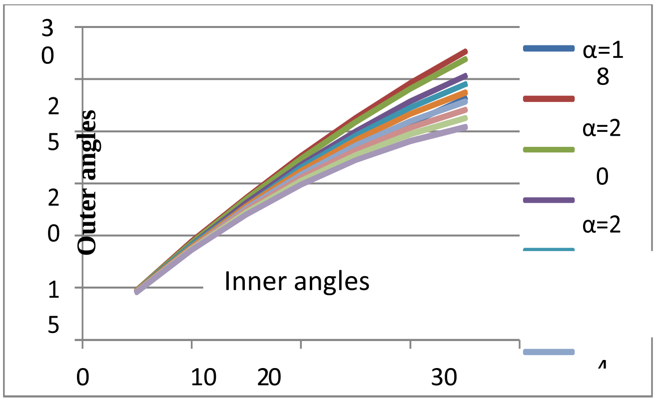
BC = w − dsin (β + δi) + dsin (β−δo)

AC= w − 2dsinβ

Applying Pythagoras theorem:

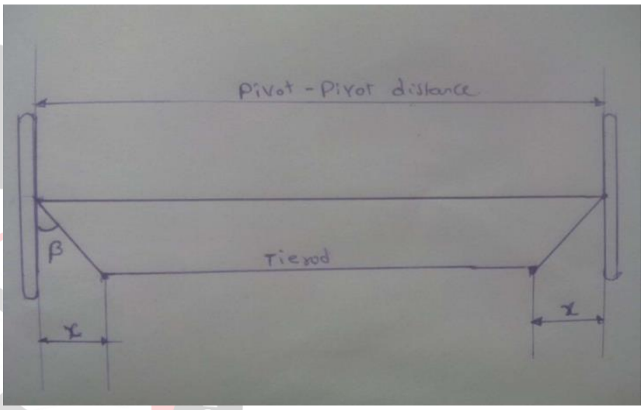
$AC^2 = AB^2 + BC^2$

$(w - 2d\sin\beta)^2 = (w - d\sin(\beta + \delta i) + d\sin(\beta - \delta o))^2 + (d\cos(\beta - \delta o) - d\cos(\beta + \delta i))^2$



S.No.	Maximum Inner angle θi	Maximum Outer angle θo	Angle at 18°	Angle at 20°	Angle at 24°	Angle at 26°	Angle at 28°	Angle at 30°	Angle at 32°	Angle at 34°
1	5	4.632	4.847	4.827	4.786	4.763	4.74	4.716	4.691	4.665
2	10	8.632	9.4	9.325	9.168	9.086	8.912	8.821	8.821	8.725
3	15	12.152	13.666	13.504	13.169	12.815	12.815	12.63	12.439	12.241
4	20	15.284	17.642	17.364	16.793	16.498	16.196	15.887	15.569	15.243
5	25	18.117	21.314	20.893	20.033	19.593	19.144	18.668	18.221	17.774
6	30	20.717	24.664	24.073	22.875	22.267	21.652	21.027	20.391	19.745
7	35	23.138	27.664	260878	25.3	24.505	23.703	22.893	22.073	21.242
8	ERROR		1.914	1.72	1.319	1.124	0.723	0.2891	0.454	0.8191

5. CALCULATION OF TIEROD LENGTH:



Ackermann angle (β) = 30° Steering arm Length (d) = 165.1mm

Pivot to pivot distance = 1060 mm

Ackermann angle = 30^0

x = 165.1*2Sin (30^0)

= 165*2(0.5)

= 165mm

Then, 2x=165mm

Therefore:

Tie rod length = (pivot to pivot distance) – (2x)

= 1060mm – 165.1mm

=894.9mm

Tie rod length = 894.9mm

GRAPHS :

Graph between inner, outer and ackermann angle

Graph between error and various ackermann angles:

This error graph describes the procedure of proper mountings of steering arms for the clamps to get perfect steering condition for the vehicle

CALCULATION FOR CRITICAL VELOCITY:

Formula for critical velocity is given by

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$V = (fRg)^{1/2}$

Where

f = coefficient of friction

R = Turning radius of vehicle while Turning

g = Acceleration due to gravity

Let us consider; R = 2.3 meters

$v = (0.6 \times 2.3 \times 9.81)^{1/2}$

$= 3.6 m/s$

ADVANTAGES:-

1. Force can be exerted more easily.
2. Steering can be accomplished quickly.
3. Positioning can be done accurately.
4. Burden on the driver can be reduced.

Advantages in terms of vehicle motion:-

1. Line traceability is improved.
2. Lap time is improved.

APPLICATIONS:-

1. This type of steering mechanism is used in airplanes.
2. In history bullock carts were moving by same pull and push type mechanism which is now modified as twin lever mechanism.

It is also used in F1 Formula car racing

II. DESIGNING OF STEERING ARM

Designing of steering arm has been done in Fusion 360 software.

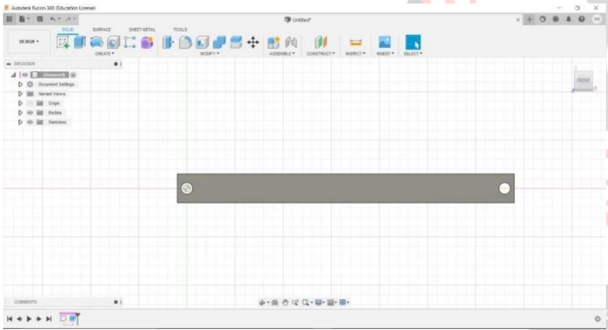

Fig 6.1: Front View of the steering arm

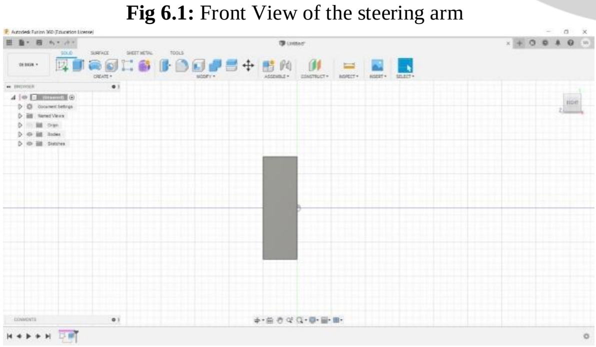

Fig 6.2: Side View of the Steering Arm

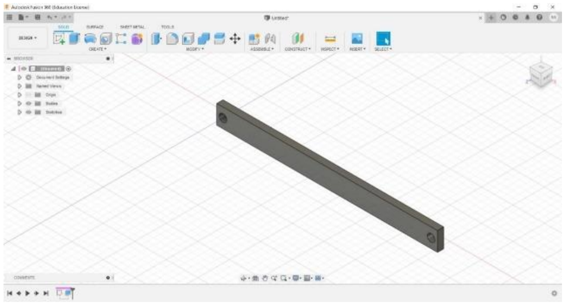

Fig6.3: Isometric View of the steering arm

6.2. ANALYSIS OF STEERING ARM

Ansys, Inc. is an American company based in Canonsburg, Pennsylvania. It develops and markets multi-physics engineering simulation software for product design, testing and operation and offers its products and services to customers worldwide. Ansys was founded in 1970 by John Swanson. Swanson sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, Ansys acquired numerous other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and other physics analysis.**Ansys, Inc.** is an American company based in Canonsburg, Pennsylvania. It develops and markets multi-physics engineering simulation software for product design, testing and operation and offers its products and services to customers worldwide. Ansys was founded in 1970 by John Swanson. Swanson sold his interest in the company to venture capitalists in 1993. Ansys went public on NASDAQ in 1996. In the 2000s, Ansys acquired numerous other engineering design companies, obtaining additional technology for fluid dynamics, electronics design, and other physics analysis.

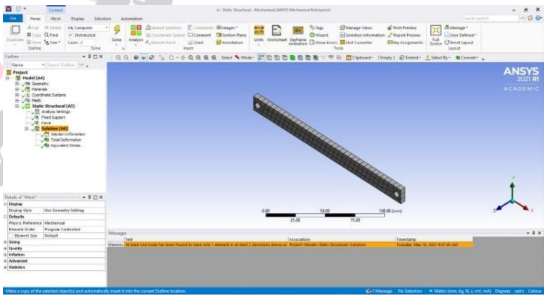

Fig 6.4: Meshing the Steering Arm

Fig 6.5: Applying force

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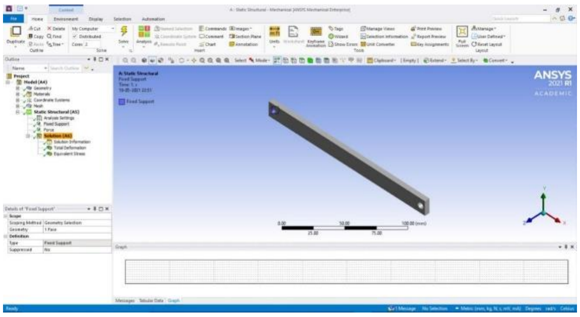

Fig 6.6: Applying Fixed Position

RESULTS:

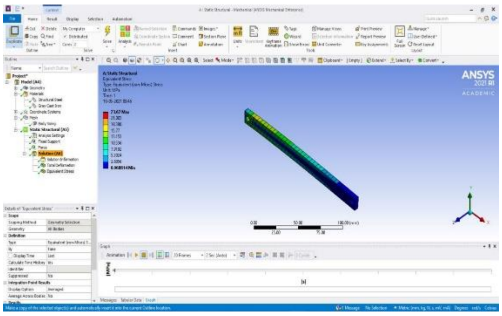

Fig 7.1: Stress Results of Structural Steel

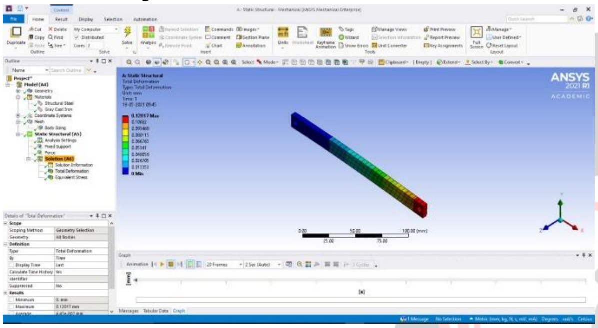

Fig 7.2: Deformation Result of Structural Steel

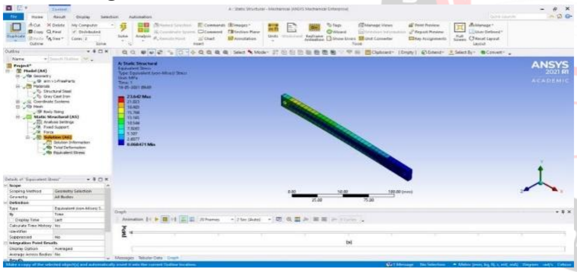

Fig 7.3: Stress Results of Grey Cast Iron

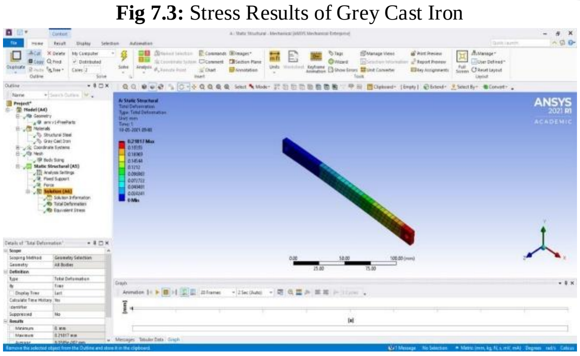

Fig 7.4: Deformation Result of Grey Cast Iron

III. CONCLUSION

A vehicle featuring low cost and user-friendly steering mechanism has been introduced. This focused on a steering mechanism which offers feasible solutions to a number of current maneuvering limitations. By this calculation we observed that at an angle of 30 degree with arm length giving minimum error. This prototype was found to be able to be maneuvered very easily in tight spaces, also making 360° steering possible. The prototype was tested to ensure the conformity with same. The steer forces required on each wheel was obtained and applied.

After performing the structural analysis of steering arm for structural steel and grey cast iron. The structural steel is giving better results when compare to grey cast iron, where the deformation of structural steel is 0.12017mm when compare to 0.21817mm. Resulting stress is quite similar where the structural steel induces 23.62 and grey cast iron inducing 23.642.

By observing the analysis results SS deforming less compare to grey castIron.

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