# Design & Fabrication of Mechanised Car with the Help of Internal Gear to Obtain Zero Degree Rotation and Straight Line Stability

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## Abstract

In today's world due to Modern development and economical progression there is increase in number of cars on roads. Because of increase in number of cars, car parking is the major problem faced in most parts of the country. In a typical front wheel steering system the rear wheel do not turn in the direction of the curve. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, high speed lane changing would be very difficult due to vehicle's larger wheelbase and track width which brings high inertia and traction into consideration. Due to this the efficiency of two wheel steering reduces. Hence there is a requirement of a mechanism which result in less turning radius and increase stability and it can be achieved by implementing four wheel steering mechanism instead of regular two wheel steering. Implementing 4WS allows the vehicle to turn in a significantly smaller radius, sometimes judgmental for large trucks or vehicles with trailers. 4-wheel steering is a system employed by some vehicles to improve steering response, increase vehicle stability while steering at high speed and to decrease turning radius at low speed. It also helpful in avoiding skidding as well as parking problems occurs in metro cities, highways and in rural areas.
**Keywords- Four wheel steering (4WS) , Turning Radius , High speed stability**

## I. INTRODUCTION

The advanced new technology has led to various modifications in the automobile sector. There is no hard and fast formula to calculate the turning circle but it can be calculated using this; Turning circle radius= (track/2) + (wheelbase/sin (average steer angle)). Zero degree turning radius of a vehicle implies the vehicle rotating about an axis passing through the center of gravity of vehicle i.e. the vehicle turning at the same place, where it is standing. No extra space is required to turn the vehicle. So vehicle can be turned in the space equal to the length of the vehicle itself.

This technology exists in heavy earth movers like excavator which consists of two parts i.e. the upper part cabin and lower part crawler chain. The upper part of excavator can rotate about its center, so that the direction of cabin can be changed without changing direction of lower part. Conventional steering mechanism involves either the use of Ackerman or Davis steering systems. The disadvantage associated with these systems is the minimum turning radius that is possible for the steering action. This difficulty that is associated with the conventional methods of steering is eliminated by employing a four wheel steering system. In this system, the wheels connected to the front axles are turned opposite to each other, and so are the wheels connected to the rear axle. The wheels on the on left half vehicle rotate in one direction and the ones on the right half of the vehicle rotate in the opposite direction. This arrangement of the wheels enables the vehicle to turn 360 degrees, without moving from the spot, i.e. the vehicle has zero turning radius.

### A. *Problem Statement*

Most of the vehicles use the two wheel steering mechanism as their main handling system, but the efficiency of the two wheel steering vehicle is proven that it is still low compared to the four wheel steering car. 4 wheel steering system used in electric car which is manufactured by Mahindra and Tesla Company. They required high maintenance cost, due to the use of sensor for giving steering angle. So we will use mechanical arrangement that will reduce the cost and will give perfect steering angle.

### *B. Objective*

Our aim in this project is to design system that would replace or can be an alternate for Sensors operated 4 wheel steering and 2 wheel steering vehicle used in cars. So this project is based on how to prove that the 4WS is better than 2WS and 4WS operated by sensors in terms of turning radius and high speed straight line stability. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, high speed lane changing would be very difficult due to higher wheelbase and track width as it gives good comfort while travelling.

### *C. Methodology*

From the steering wheel the power is transmitted to the bevel gear and from bevel gear power is then transmitted to rack and pinion gear mechanism. Front wheels are steered by using rack and pinion gear steering mechanism. Then a transfer rod is placed in between the front and rear steering gear box to transfer the motion to rear steering gear box. Modification is made in the rear wheel assembly and addition of internal gears for steering the rear wheels. Therefore the zero degree rotation is obtained.

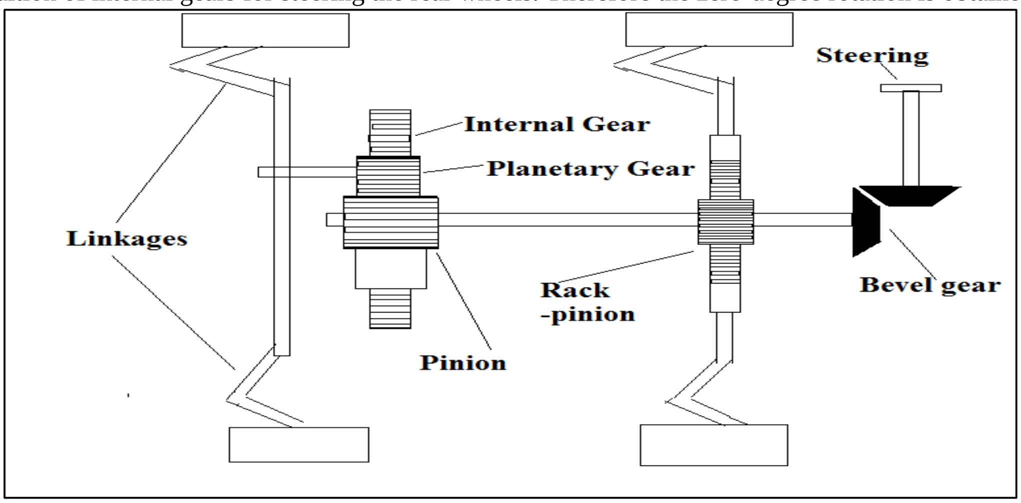


Fig. 1: The working diagram of mechanized car

## II. LITERATURE REVIEW

Amitesh Kumar, Dr. Dinesh.N.Kamble has worked on “Zero Turn Four Wheel Steering System” Conventional steering mechanism involves either the use of Ackerman or Davis steering systems. The disadvantage associated with these systems is the minimum turning radius that is possible for the steering action. This difficulty that is associated with the conventional methods of steering is eliminated by employing a four wheel steering system. In this system, the wheels connected to the front axles are turned opposite to each other, and so are the wheels connected to the rear axle. The wheels on the on left half vehicle rotate in one direction and the ones on the right half of the vehicle rotate in the opposite direction. This arrangement of the wheels enables the vehicle to turn 360 degrees, without moving from the spot, i.e. the vehicle has zero turning radius. This helps in maneuvering the vehicle in tight spaces such as parking lots and within small compounds.

Bhupendra Pratap Singh, Brijesh Kumar Yadav, Lal Bahadur Singh, Badri Vishal, Raj Kumar Yadav have worked on “Advanced Four Wheel Steering System” The aim of this project is to decrease the turning radius of the vehicle using four wheels symmetric steering system (4WS). The four wheel steering system has got cornering capability, steering response, straight line stability, lane changing and low speed maneuverability. Even though it is advantageous over the conventional two wheel steering system, four wheel steering is a complex and expensive.

Ajinkya tikley, Mayur kangane have worked on “Four Wheel Steering” This paper reports on advanced steering system by using rack and pinion mechanism. This steering system converts the rotational motion into the linear motion to turn the wheels. A 4-wheel steering is completely different from a 4-wheel drive, in which all 4 wheels are given power rather than to 2 wheels. In this system, power transferred from front axle to rear axle by using universal coupling through power transfer rod. It reduces the turning radius as well as the space required for turning. It also enables to change road lane while driving even at high speed. Quadra system allows for rear wheel to be steered in opposite direction as in front wheel during low speed and in same direction during high speed. This allows the vehicle to turn in a significantly smaller radius, sometimes judgmental for large trucks or vehicles with trailers. 4-wheel steering is a system employed by some vehicles to improve steering response, increase vehicle stability while steering at high speed and to decrease turning radius at low speed. It also helpful in avoiding skidding as well as parking problems occurs in metro cities, highways and in rural areas. A 4-wheel steering system is superior to a 2- wheel steering system. This type of system can be applicable to all types of special utility vehicles. In most active four-wheel steering systems, the rear wheels are steered by activators and coupling arrangement. Because of large work load on front wheels and uneven tyre wears of vehicle this system does not getting popularity.

Arshit Vashisht , Anand Baghel, Rishi Katara, Pradeep Sharma, Aakash Suran have worked on " Implementation of Four Wheels Steering Using 3-Way Worm Gearbox" In An All-Terrain Vehicle" This paper represents the use of 3-way worm gearbox in order to implement four-wheel steering in an ALL TERRAIN VEHICLE. The basic theme behind implementation of this gearbox is to reduce turning radius & provide directional stability while maneuverings the main characteristic of vehicle moving on road is related to its response to the drivers command and to environmental factors affecting the direction of motion of vehicle. The two basic problems in handling the vehicle are control of vehicle along the desired path and stabilization of the direction of motion of vehicle against external disturbances. The vehicle with best handling characteristics is the vehicle which can always be controlled by the driver. While parking the vehicle and doing sharp turnings the vehicle with two wheel steering cannot be more significant. The two wheel steering system takes large radius of turning and requires more space to take turn. Hence four wheel steering is preferable than two wheel steering systems. A multi-function four wheel steering system could improve directional stability at high speeds, sharp turning performance at low speeds, and parking performance of a vehicle the turning radius was reduced by 30% in comparison to normal two wheel steering system. The idea of selecting 3-way worm gearbox is to bear robust and rugged steering under critical conditions. The relation between steer travel and lock angle was established and for same Ackermann % was calculated. In this mechanism the basic work was done to reduce the gear ratio of front wheel & to increase gear ratio of rear Ratio according to weight distribution.

Dilip S Choudhari has worked on "four wheel steering system for future "both front as well as rear wheels can be steered according to speed of the vehicle and space available for turning. Quadra steer is system that gives full size vehicles greater ease while driving at low speed, and improves stability, handling and control at higher speed. Quadra steering system works in following three phases Negative phase, Neutral phase, Positive phase. It enables the car to be steered into tighter parking spaces. It makes the car more stable at speed (less body roll). It makes the car more efficient and stable on cornering, easier and safer lanes change when on motorways. The steering system allows the driver to guide the moving vehicle on the road and turn it right or left as desired. The main aim is that turning of the vehicle should not require greater efforts on the part of the driver. The Quadra steer steering system offers a 21% reduction in turning radius. So if a vehicle is capable of making a U-turn in a 25-foot space, Quadra steer allows the driver to do it in about 20 feet.

Manish K. Mistry have worked on "Driving Developing Quadra Steering System for Multi-Purpose of Vehicle and Give better Comfort for driving" There are three modes in 4-wheel steering each of which is individually implemented in most of the 4wheel steering cars. Each one has its own disadvantage like use of crab mode increases the turning radius which is turn decreases the ease of maneuvering the vehicle at sharp bends, similarly rear steer mode decreases the turning radius to a greater extent, thus increases the risk of toppling of the vehicle at high speed. Hence to overcome these problems, both the modes have been introduced together in a locomotive and its performance has been simulated.

## III. CONSTRUCTION AND WORKING

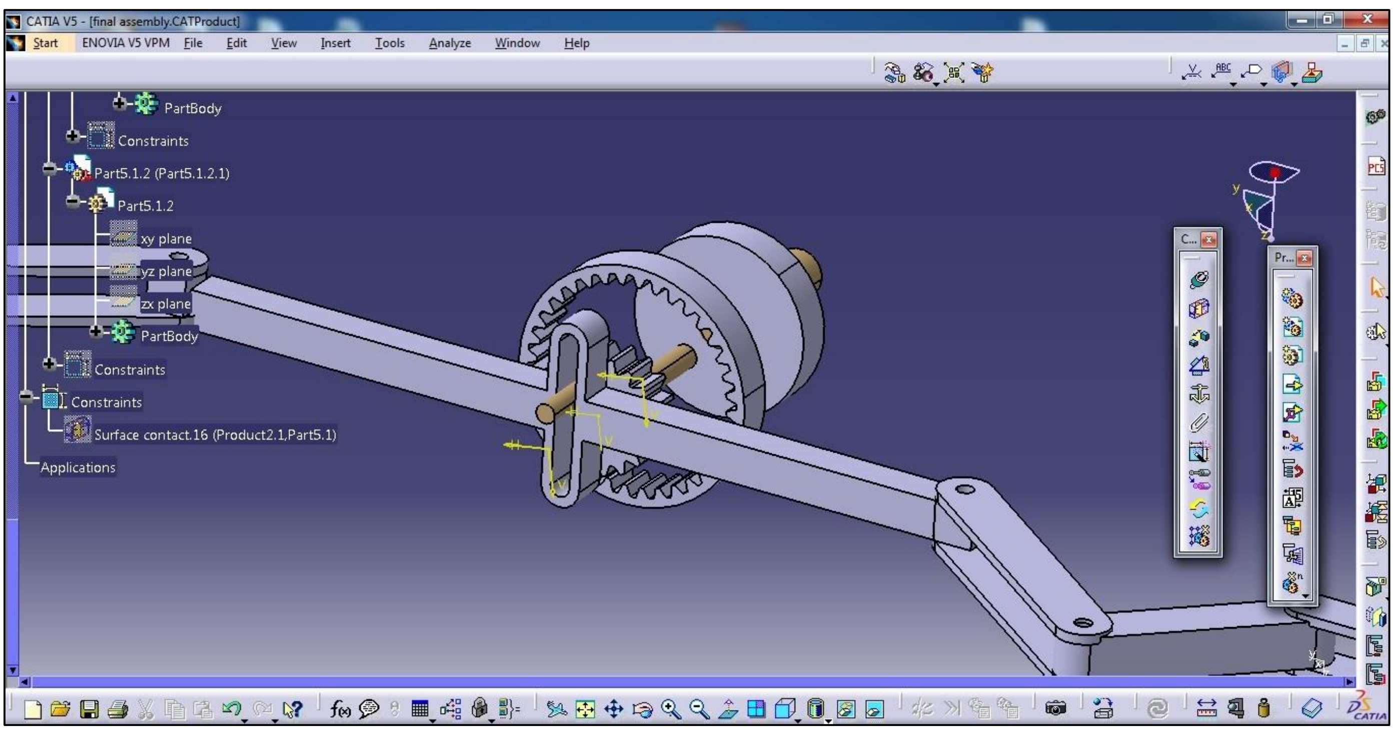


Fig. 2: Rear Wheel 3D Catia Model (Rear View)

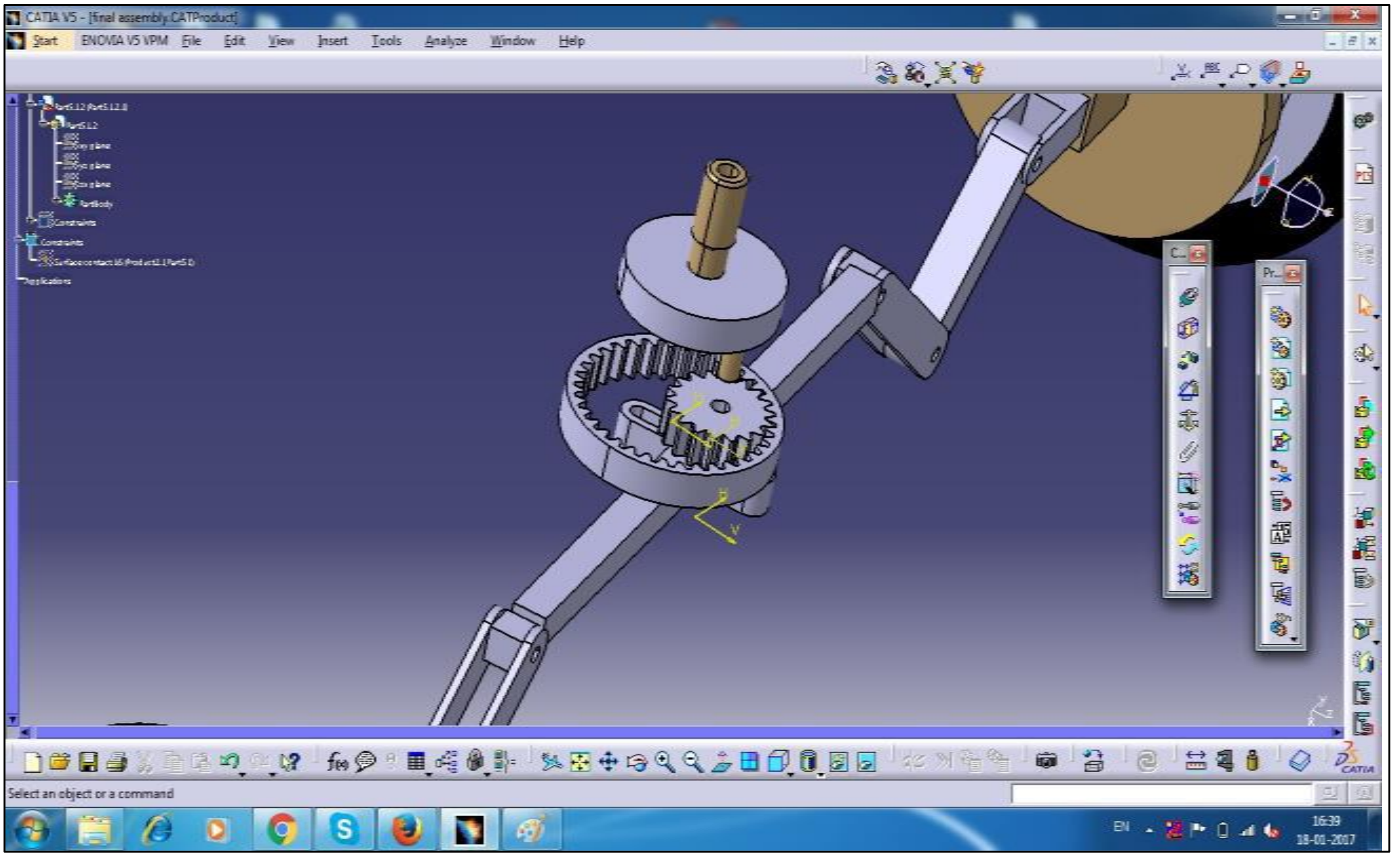


Fig. 3: Rear Wheel 3D Catia Model (Front View)

### *A. Basic Components*

1) Rack and pinion
2) Bevel Gear
3) Hub Gear
4) Linkages
5) Shafts
6) Bearing

### *B. Working*

In four wheel steering the rear wheels turn with the front wheels thus increasing the efficiency of the vehicle. The direction of steering the rear wheels relative to the front wheels depends on the operating conditions. At low speed wheel movement is pronounced, so that rear wheels are steered in the opposite direction to that of front wheels. At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction. 4 wheel steering or all wheel steering is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed or to decrease turning radius at low speed. In an active four-wheel steering system, all four wheels turn at the same time when the driver steers. In most active four-wheel steering systems, the rear wheels are steered by a computer and actuators. The rear wheels generally cannot turn as far as the front wheels. There can be controls to switch off the rear steer and options to steer only the rear wheel independent of the front wheels. By changing the direction of the rear wheels there is reduction in turning radius of the vehicle which is efficient in parking, low speed cornering and high speed lane change.

The power is transmitted to the bevel gear from steering and from bevel gear power is then transmitted to rack and pinion gear mechanism. Front wheels are steered by using rack and gear steering mechanism. Then a transfer rod is placed in between the front and rear steering gear box to transfer the motion to rear steering gear box. Modification is made in the rear wheel assembly and addition of internal gears for steering the rear wheels. Therefore the zero degree rotation is obtained.

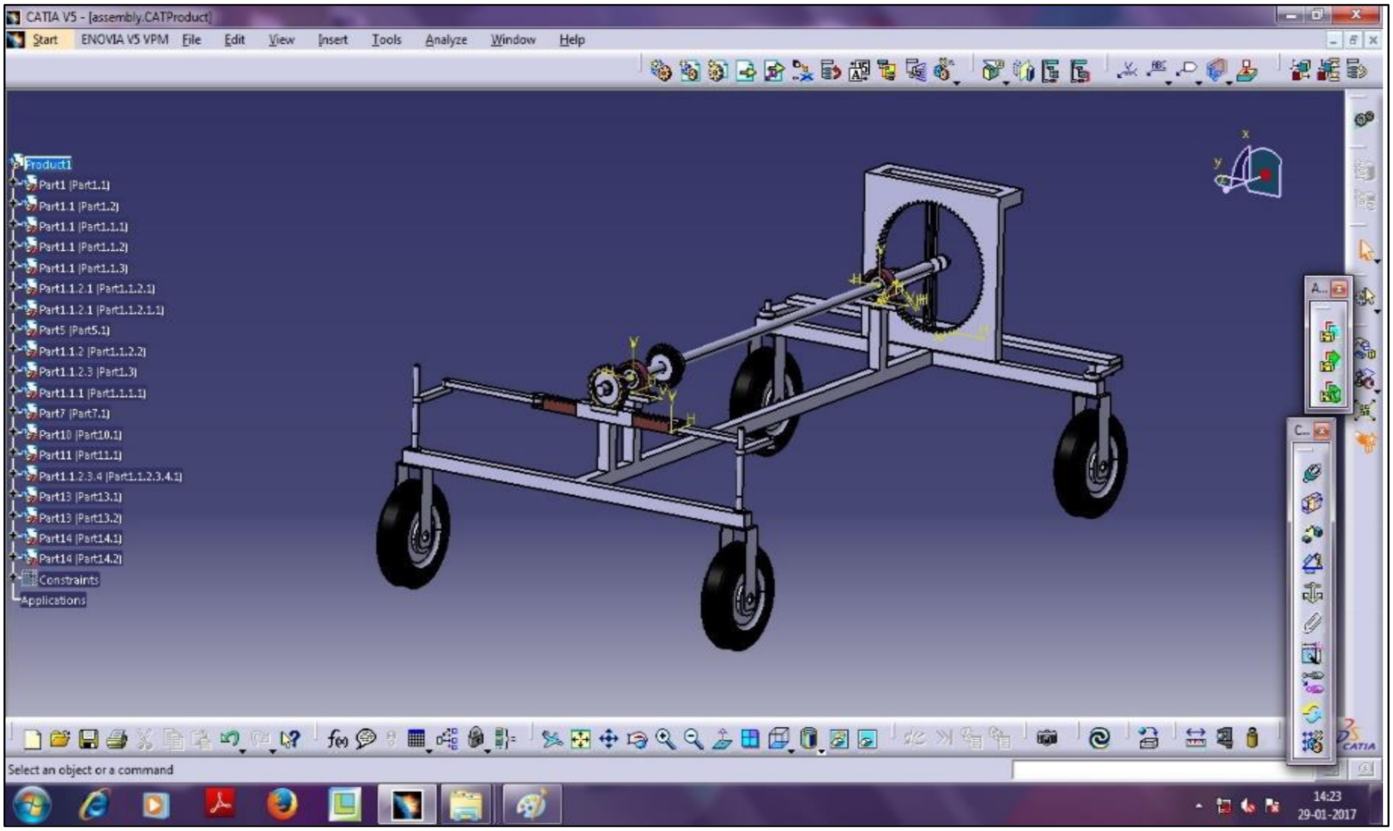
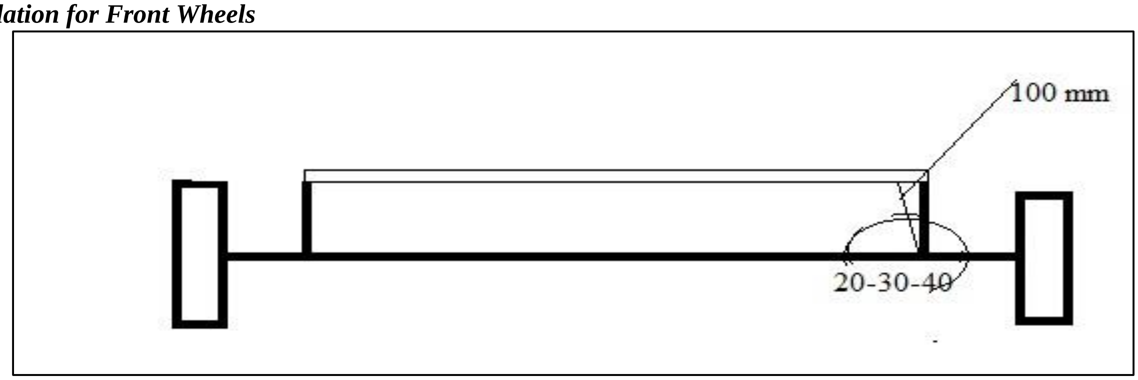



Fig. 4: Front View of Mechanical 4WS

## IV. CALCULATIONS

### A. *Calculation for Front Wheels*




Length travelled by rack for $30^0$ rotation
Tan 30 = $\frac{Opp}{Adj} = \frac{X}{100}$
X = 58 mm
For $30^0$ of wheel rotation link has to move 58mm
Pitch of rack = 5mm
No of teeth in engagement with rack and pinion = 2
So At a time rack will move 10 mm
So 6 teeth will engage with rack to move 58 mm
As 45 no of teeth on pinion each teeth will rotate = (360/45) = $8^0$
6 teeth will rotate pinion by $48^0$
So shaft will also rotates by $48^0$
The bevel gear will also rotates by $48^0$
So, the steering wheel has also to rotate by $48^0$.
By regression analysis values for different angles

| *Angle of rotation (degrees)* | *Length travelled by rack (mm)* | *Pitch of Rack (mm)* | *Teeth required to travel length* | *6 teeth will rotate pinion by (degrees)* | *Rotation of Shaft (degrees)* | *Rotation of bevel gear (degrees)* | *Rotations of steering (degrees)* |
|---|---|---|---|---|---|---|---|
| *20* | *36.39* | *5* | *4* | *32* | *32* | *32* | *32* |
| *30* | *58* | *5* | *6* | *48* | *48* | *48* | *48* |
| *40* | *83.90* | *5* | *8* | *64* | *64* | *64* | *64* |

### *B. Calculation for Rear Wheels*

As shaft rotates by $48^0$ for the inclination of front wheel same shaft will transmit power rear wheels.
As we rotate front wheels by $30^0$ we have to move rear wheels by $30^0$.
For $30^0$ of wheel rotation link has to move 58mm
The link is attached to scotch yoke mechanism.

### *C. Calculations for Bevel Gear*

Max power:
P = 49.05
$Z_1 = 28$ $Z_2 = 28$
np = 10 rpm ng= 10 rpm
Ka = 1.1 Km = 1
Nf = 2.0 $\varphi = 20^o$
$(BHM)_p = 400$
Sut = 440 N/mm$^2$
$\sigma_{bp} = \frac{440}{3} = 146.66$ N/mm$^2$
$\sigma_{bg} = \frac{440}{3} = 146.66$ N/mm$^2$
Gear Ratio ,
$G = \frac{np}{ng} = \frac{Zg}{ng} = \frac{10}{10}$
$\tan \Upsilon_p = \frac{Zp}{Zg} = \frac{28}{28} = 1$
$= 45^0$
$\tan \Upsilon g = \frac{zg}{zp} = 1$
Formative no. of teeth
$Zp' = \frac{Zp}{\cos Yp} = \frac{28}{\cos 45} = 39.59$
$Zg' = \frac{28}{\cos 45} = 39.59$
$\Upsilon g = 0.484 - \frac{2.87}{39.59} = 0.411$
$\Upsilon p' = 0.411$
$\sigma_{bp}\ \Upsilon p = 146.66*0.411$
$= 60.35$
$\sigma_{bg}\ \Upsilon g = 146.66*0.411$
$= 60.35$
$\sigma_{bp}\ Yp = \sigma_{bg}\ Yg$
Pinion and gear have equal bending loads hence, we can’t conclude which gear or pinion will fail in bending,
For this proceeding calculation further
dp = mZp= 28m
dg = mZg = 28m
Cone distance

$$A_0 = \sqrt{\left(\frac{dp}{2}\right)^2 + \left(\frac{dy}{2}\right)^2}$$

$$= \sqrt{\left(\frac{28m}{2}\right)^2 + \left(\frac{28m}{2}\right)^2}$$

$A_0 = 19.79$
b = 10m OR $\frac{A0}{3} = \frac{19.79}{3}$
$= 6.59$
$= 6.6$
There for b = 6.6
Bending force,
$Fb = \sigma bp\ b\ m\ Yp = \left[1 - \frac{b}{A0}\right]$

$= 146.66 * 6.6 * m^2 * 0.411\left[1 - \frac{6.6* m}{19.59*m}\right]$

Fb = 265.15 $m^2$ N

Wear strength

$Q' = \frac{2\ Zg'}{Zg'+Zp'}$

$= \frac{2*39.59}{39.59+39.59}$

Q'= 1

Brinell hardness

$K= 0.16\left[\frac{BHN}{100}\right]^2$

$= 0.16\left[\frac{400}{100}\right]^2$

K = 2.56

Wear load

$Fw= \frac{0.75*dp*b*Q'*K}{\cos Yp}$

$= \frac{0.75*28m*6.6m*1*2.56}{\cos 45}$

Fw= 501.78 $m^2$ N

Fb<Fw

Gear pair is weaker in bending hence it should be designed for safety against bending failure

Efficiency load:

$V = \frac{\pi\ \text{dp np}}{60*1000} = 0.014$ m

$Ft = \frac{P}{V} = \frac{49.05}{0.014\ m} = \frac{3345.66}{m}$ N

The velocity factor is given by,

Effective load

$Feff = \frac{Ka\ \ Km\ \ Ft}{Kv}$

$= \frac{1.1*\ 1*3345.66}{m\left(\frac{6}{6+0.014m}\right)}$

$Feff = 613.37* \left(\frac{6+0.014m}{m}\right)$

Estimations of module:-

To avoid the bending failure,

$Fb = Nf * F_{eff}$

$265.15m^2 = 2*613.37 * \left(\frac{6+0.014m}{m}\right)$

$265.15\ m^3 = 7360.45+17.17m$

m=1.4

Next standard module m=2

### *D. Dimensions of Gear Pair*

m = 2mm

Zp = 28

Zg = 28

b = 6.6 * m = 6.6 *2 = 13.2

dp = m Zp = 56

dg = 56

$A_0 = 19.79*m = 19.79*2 = 39.58$

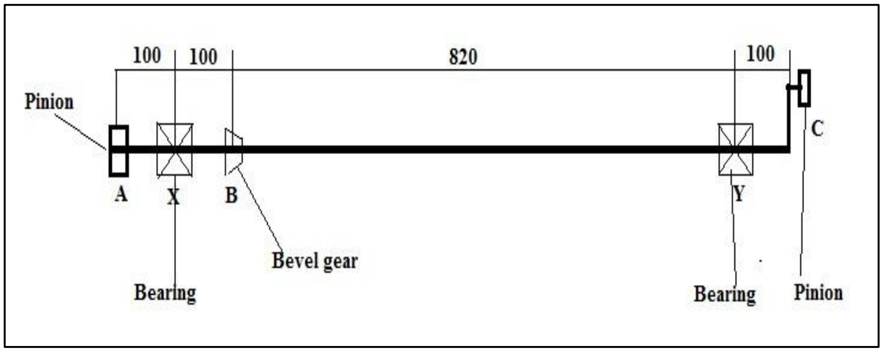
$h_a = 1 * m = 2$

$h_f = 1.2 * m = 2.4$ mm

ϒp = 45

ϒg = 45

### E. Design of Shaft




(Reference: Design of machine element. V Bhandari. Chapter 9. Shaft, key, couplings. 9.7)
Shaft is made of MS. Standard values of MS are as follows.
Young's Modulus of elasticity = E = 2.0 * $10^5$ Mpa.
Mass density = ρ = 7850 kg/m3
Yield stress = σy = 250 Mpa & Sut = 841Mpa
Kb = Kt = 1.0
Permissible shear stress
By shear stress theory
0.30 syt = 0.30 * 250 = 75 N/mm$^2$
0.18 sut = 0.18 * 841 = 151.38 N/mm$^2$
Taking minimum
Tmax = 0.75 * 75 = 56.25 N/mm$^2$
Power required to rotate the steering by human efforts, P = 75 W
Average rpm by human hands, N = 60 rpm
Torsional moment
Mt = $\frac{75 * 60}{2 * \pi * 60}$
Mt = 11.9366 Nm
Mt = 11936.6 Nmm
Mass of pinion,
M = 0.3 kg
W = 2.943 N
Mass of bevel gear,
M = 0.6 kg
W = 5.886 N
Total length of shaft is 1120 mm

#### 1) Reactions at Support

Moment at X
-2.943 * 100 + 5.886 * 100 – $R_y$ * 920 + 2.943 * 1020 = 0
$R_y$ = 3.58 N
Resultant force in vertical
$R_x$ + $R_y$ - 2.943 - 5.886 - 2.943 = 0
$R_x$ + 3.58 - 2.943 - 5.886 - 2.943 = 0
$R_x$ = 8.192 N

#### 2) Shear Force Calculation

$SF_{AL}$ = 0 N
$SF_{AR}$ = - 2.943 N
$SF_{XL}$ = - 2.943 N
$SF_{XR}$ = - 2.943 N + 8.192 N = 5.294 N
$SF_{BL}$ = 5.294 N
$SF_{BR}$ = 5.294 - 5.886 = - 0.637 N
$SF_{YL}$ = - 0.637 N
$SF_{YR}$ = - 0.637 + 3.58 = 2.943 N
$SF_{CL}$ = 2.943 N
$SF_{CR}$ = 2.943 – 2.943 = 0 N

*3) Bending Moment Calculations*

Bending moment at A, initial point,
$BM_A = 0$
Bending moment at X
$BM_X$ = 8.192 * 100 = 819.2 N mm
Bending moment at B
$BM_B$ = 8.192 * 100 - 5.886 * 200 = -358 N mm
Bending moment at Y
$BM_Y$ = 8.192 * 100 - 5.886 * 200 + 3.58 * 1020 = 3292.6 Nmm
Bending moment at C
$BM_C$ = 0 N mm
Bending moment is maximum at point Y
Therefore, Resultant Bending moment = $M_b$ = 3292.6 Nmm
Calculate the shaft diameter

$\tau \max = \frac{16}{\pi * d^3} \sqrt{(Kb * Mb)^2 + (Kt * Mt)^2}$

$d^3 = \frac{16}{\pi * \tau\ max} \sqrt{(Kb * Mb)^2 + (Kt * Mt)^2}$

$d^3 = \frac{16}{(\pi)(56.25)} \sqrt{(1 * 3292.6)^2 + (1 * 11936.6)^2}$

d = 7.019 mm
d = 15 mm for safe design and availability assume F.S. = 2 approx.

## *F. Selection of Bearing*

*1) Bearing Design*

Shaft diameter = 15 mm
Radial load, Fr = weight of shaft + total load of transmission
= 3 * 9.81 + 2*2.943 + 5.886
= 41.202 NS
L10h=20000 (V.B.Bhandari) P NO 575
Bearing life in million revolution,
L10= (60*n*l10h)/10^6
= (60*60*20000)/10^6
= 72 million of revolutions
Dynamic load calculations
Load, P = (xFr+yFa) S
= (1*41.202+0)1.1
= 41.3222 N
C=P (L10)1/b
= 41.322 (72) ^1/3
= 14.38 N
We select bearing no.6202 for diameter 15 mm.
Type of bearing is pedestal ball deep groove bearing, for easy mounting.

## *G. Frame Design*

Material used –mild steel, square pipe
Area=1*1inch=25.4*25.4=645.16 $mm^2$
Length of link=30" = 760 mm
Weight of project=10 kg= 10*9.81 =98.1N
Weight of human being 75 Kg = 75*9.81 = 735.75N
Total load = 833.85 N
Young's modulus=E=210GPa

*1) Solution*

1) Effective length
Effective length, when both end fixed,
$L_e = \frac{L}{2} = \frac{760}{2}$ = 380 mm
2) Internal Area
Internal width and depth, which have 3 mm thickness,
d=b=25.4-2*3 =19.4 mm

3) Moment of inertia

$I=\frac{BD^3-bd^3}{12}=\frac{25.4*25.4^3-19.4*19.4^3}{12}$=22882.048mm$^4$

4) Crippling load by Euler's formula

$\mathbf{P_c}=\frac{\pi^2 EI}{Le^2}=\frac{\pi^2*210*10^3*22.88*10^{\wedge}3}{380^2}=$

=328403.568 KN

Pc = 328403.568 KN > Total load = 833.85 N

Hence design safe.

### *H. Frame Design*

Material used –mild steel, square pipe

Area=1*1inch=25.4*25.4=645.16 mm$^2$

Length of link=48" = 1220 mm

Weight of project=10 kg= 10*9.81 =98.1N

Weight of human being 75 Kg = 75*9.81 = 735.75N

Total load = 833.85 N

Young's modulus=E=210GPa

*1) Solution*

1) Effective length

Effective length, when both end fixed,

$L_e=\frac{L}{2}=\frac{1220}{2}$= 610 mm

2) Internal Area

Internal width and depth, which have 3 mm thickness,

d=b=25.4-2*3 =19.4 mm

3) Moment of inertia

$I=\frac{BD^3-bd^3}{12}=\frac{25.4*25.4^3-19.4*19.4^3}{12}$=22882.048mm$^4$

4) Crippling load by Euler's formula

$\mathbf{P_c}=\frac{\pi^2 EI}{Le^2}=\frac{\pi^2*210*10^3*22.88*10^{\wedge}3}{610^2}$

=127442.8251 KN

Pc = 127442.8251 KN > Total load = 833.85 N

Hence design safe.

### *I. Frame Design*

Material used –mild steel, square pipe

Area=1*1inch=25.4*25.4=645.16 mm$^2$

Length of link=48" = 1220 mm

Weight of project=10 kg= 10*9.81 =98.1N

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*1) Solution*

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$\mathbf{P_c}=\frac{\pi^2 EI}{Le^2}=\frac{\pi^2*210*10^3*22.88*10^{\wedge}3}{610^2}=$

=127442.8251 KN

Pc = 127442.8251 KN > Total load = 833.85 N

Hence design safe.

## V. CONCLUSION AND FUTURE SCOPE

For the first stage project presentation the required research work has been completed and calculations for selection of gears have been completed. Hence it can be said that the aim of the project "Design and Fabrication of mechanized car with help of internal gear to obtain zero degree rotation and straight line stability" can be achieved successfully. The further designing and fabrication of the working model will be completed by February 2017. After which the different experiments will be conducted for efficiency improvement.

## ACKNOWLEDGMENT

It is indeed a great pleasure and moment of immense satisfaction for we to present a project report on "Design and Fabrication of mechanized car with help of internal gear to obtain zero degree rotation and straight line stability" amongst a wide panorama that provided us inspiring guidance and encouragement, we take the opportunity to thanks to thanks those who gave us their indebted assistance. We wish to extend our cordial gratitude with profound thanks to our internal guide Prof. A.A. Patil for his everlasting guidance. It was his inspiration and encouragement which helped us in completing our project. Our sincere thanks and deep gratitude to Head of Department, Prof. M. M. Joshi and other faculty member; but also to all those individuals involved both directly and indirectly for their help in all aspect of the project. At last but not least we express our sincere thanks to our Institute's Principal Dr. R. S. Prasad, for providing us infrastructure and technical environment.

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