FOUR WHEEL STEERING SYSTEM WITH MOVABLE HEAD LIGHTS

BY USING RACK AND PINION MECHANISM

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ABSTRACT

Now a days, many researchers put their efforts on four Wheel steering mechanism, implementation of this mechanism is needed in situations like low speed cornering, vehicle parking and driving at heavy traffic, tight spaces, where driving would be very difficult due to vehicle's larger wheelbase and track width. For avoiding this problem, we need a mechanism with less turning radius by implementing four wheel steering mechanism instead of two wheel steering mechanism. In a regular standard two wheel steering system, rear wheels are directed forward and do not play role in controlling the steering. In case of four wheel steering system, rear wheels play an active role for steering for guiding at any speed. If the vehicle have larger wheel base and track width in some cars, the driving would be very difficult in different situations like cornering at low speeds, parking the vehicle and city driving conditions with heavy traffic in very tight places. So, we require a mechanism, which is having less turning radius. This work also includes the hardware of movable headlight system for motor vehicles. For all the vehicles, head light control system is needed, which help the head light to rotate right and left independently, and keep the beam as parallel to the curved road to provide better visibility to the driver at night time. In the present work, we use rack and pinion mechanism to drive the optical axes, on which head lights are mounted. This result that, when tie rod arms are moving with steering arm, then it gives a predefined motion to the wheels along with head lights. In this work, for driving the optical axis, we use rack and pinion arrangement, when steering arm, tie rod arm is moved that give motion to the wheels as well as head lights.

KEYWORDS: Four Wheel Steering System, Rack and Pinion Mechanism & Movable Head light System

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INTRODUCTION

The steering system allows the driver to guide the moving vehicle on the road and turn it right or left as desired. Further, such turning of the vehicle should not require greater efforts on the part of the driver. There are mainly two types of steering system.

Car safety is the avoidance of automobile accidents or the minimization of harmful effects of accidents, in particular as pertaining to human life and health. Special safety features have been built into cars for years, some for the safety of car's occupants only, and some of the safety of others.

Jack Erjavee in 2009 said that when the vehicle is in high speed with subtle steering adjustments, both the front and rear wheels are turn in the same direction. As a result, the car moves in a crab-like manner rather than in a curved path. This action is advantageous to the car while changing lanes on a high-speed road. To eliminate

centrifugal effect and consequence reduction of body roll and cornering force on the type, improves the stability, so control becomes easier and safer. In a four wheel steering system, drive angle control at front and rear wheels is most essential.

In a typical front wheel steering system, the rear wheels do not turn in the direction of the curve, and thus curb on the efficiency of the steering.

However, these systems had the rear wheels steered by only 2 or 3 degrees, as their main aim was to assist the front wheels rather than steer by themselves, although such a complex four wheel steering model has not been created for production purposes, a number of experimental concepts with some of these technologies have been built and tested successfully.

The following are the advantages with four wheel steering mechanism compared with conventional two wheel steering mechanism.

- Good cornering stability.
- Great steering responsiveness and good precision.
- Good straight line ability at high speeds.
- Notable improvement in rapid lane changing maneuvers.
- Smaller turning radius and tight space maneuverability at low speed.
- Relative wheel angles and their control.

Usually in vehicles during turning, the tires are subject to the forces of grip, momentum, and steering input when making a movement other than straight ahead driving, the tires are subjected to road grip and slip angle. Grip holds the car's wheels to the road, and momentum moves the car straight ahead. Steering input causes the front wheels to turn. The car momentarily resists the turning motion, causing a tire slip angle to form. Once the vehicle begins to respond to the steering input, cornering forces are generated. The vehicle sways as the rear wheels attempt to keep up with the cornering forces already generated by the front tires. Since there is a time delay between steering input and vehicle reaction, this is termed as rear-end lag. As the steering is turned, the vehicle body sways as the rear wheels again try to keep up with the cornering forces generated by the front wheels.

The idea behind four-wheel steering is that a vehicle requires less driver input for any steering maneuver, if all four wheels are steering the vehicle. As with two wheel-steer vehicles, tire grip holds the four wheels on the road. However, when the driver turns the wheel slightly, all four wheels react to the steering input, causing slip angles to form at all four wheels. The entire vehicle moves in one direction rather than the rear half attempting to catch up to the front. There is also less sway when the wheels are turned back to a straight ahead position. The vehicle responds more quickly to steering input because, rear wheel lag is eliminated.

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. This also simplifies the positioning of the car in situations such as parking in a confined space. Since the rear wheels are made to follow the path on the road taken by the front wheels, the rear of a four wheel steering car does not turn in the normal way. Therefore, the risk of hitting an obstacle is greatly reduced.

At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction. As a result, the vehicle moves in a crab like manner rather than in a curved path. This action is advantageous to the vehicle while changing lanes on a high speed road. The elimination of the centrifugal effect and in consequence the reduction of body roll and cornering force on the tire, improves the stability of the car, so that control becomes easier and safer.

In this work, we have concentrated on objectives to reduce turning radius of the vehicle, to prevent accidents at night time, park the vehicle in parking areas, we are selecting some references which is useful for this work. Some of them proposed their views regarding these problems. We take some of the authors can take as reference which is useful for this work.

Saket Bhishikar, et.al fabricated four wheel steering system because, the rear set of wheels are always directed forward and do not play an active role in controlling the steering. They have developed an innovative 4 wheel steering design to implement a mechanism that can serve the purpose of changing in-phase and counter-phase steering of rear wheels depending upon the conditions of turning and lane changing with respect to front wheels, thus enhancing the maneuverability of a sedan in accordance with its speed. This system assists in high speed lane changing and better cornering. It combats the problems faced in sharp turning. It reduces the turning circle radius of the car and gives better maneuverability and control while driving at high speeds, thus attaining neutral steering.

K. Lohith, et.al in the study fabricated that, four-wheel steering is a serious effort on the part of automotive design engineers to provide near-neutral steering. In their project, Maruti Suzuki 800 is considered as a benchmark vehicle. The main aim of this project is to turn the rear wheels out of phase to the front wheels. In order to achieve this, a mechanism which consists of two bevel gears and intermediate shaft, which transmit 100% torque as well turns rear wheels in out of phase was developed.

Dilip S Choudhari1 et.al in their work conclude that, both front as well as rear wheels can be steered according to speed of the vehicle and space available for turning. 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. Thus, the four wheel steering system has got cornering capability, steering response, straight-line stability, lane changing and low speed maneuverability.

Manisha V Makwana, et.al in the work fabricated the hardware of movable Headlight System for motor vehicles. In this system, used rack and pinion arrangement, which give drive to the optical axes on which headlight are mounted, so when a tie rod arms are moved with steering arm that give predefined motion to the wheel as well as headlights. This system helps to move headlights left or right as per requirement along with the turn, and can help to reduce accidents at night on sharp turning and hilly areas.

GadhavYogesh V, et.al introduced —Steering Controlled Headlight Mechanism, which acts as directional headlights. It was observed that when the steering wheel is rotated through a certain angle towards right side of the driver, the head lights are tilted through certain angle in degrees to the right with the help of different linkages arranged with respect to the steering wheel which were discussed earlier. The same features are observed when the steering wheel is turned to the left side.

Ajay R. Pawar, Mandhare et.al in the work, concentrated on the system can be adopted in any type of four wheel

vehicles/trucks or trailers etc., without being an economic burden on the end user, But, its adaptability according to the turn is its novel part. They observe there is considerable increase in visible area during night. An advantage of the developed headlight system is in its high adaptability, as it can be easily configured to fit within space confines of a variety of vehicle designs. Furthermore, the system is of inexpensive, simple and easy to assemble.

MATERIAL SELECTION

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Systematic selection of the best material for a given application begins with properties and costs of candidate materials.

MILD STEEL

Here, we can select the mild steel and the reasons for selecting the mild steel are mentioned below. Mild steel, also called as plain-carbon steel, is the most common form of steel, because its price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low-carbon steel contains approximately 0.05–0.3% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. It is often used when large quantities of steel are needed, for example as structural steel. Density of mild steel is 7850 kg/cm^3 and the Modulus of Elasticity is 210 GPa (30,000,000 psi).

REASONS FOR SELECTING THE MILD STEEL

- Steel has high melting point compared to cast iron
- Steel is made offwith a controlled amount of carbon
- Steel is mild, harder to cast and a relative high viscosity
- Steel does not break on bending
- Steel is more tensile strength
- Steel is more superior in tension

BEARING SELECTION

Ball Bearing

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. Select a footstep bearing minimum inner diameter of 20mm, minimum load carrying capacity of 100kg radially. The specification of ball bearing is 25x50x15mm.

Journal Bearing

This bearing has rubber seals on both sides of the bearing to keep lubricant in and contaminants out, and comes pre-lubricated from the manufacturer, so that no additional lubrication is required. This deep groove sealed ball bearing is for use in applications that involve combined radial and axial loads, and a need for high running accuracy at high rotational speeds. Such applications include clutches, drives, gearboxes, compressors, pumps, turbines, and printing and textile machines, among others.

Wheel Selection

Here, we select the alloy wheels for the fabrication. Alloy wheels are wheels that are made from an alloy of aluminium or magnesium. Alloys are mixtures of a metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of aluminium or magnesium are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. Although steel, the most common material used in wheel production, is an alloy of iron and carbon, the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys.

Live Axles with CV Joints

The operation of the final drive and differential assemblies in the live front axles is the same as in a rear axles. Gear ratios to increase engine torque will be the same as those of the rear axles on the vehicles. When the vehicle is travelling straight ahead, both inner and outer axles shafts are on the same line. If the front axle is engaged to the power train, the inner axle shaft will drive the cv joints.

The cv joint will, in turn, drive the outer axles shaft which are splined to the wheel hubs. As steering arms and the rods turn the knuckles the axles shafts will flex at the CV joints. During turns, the CV joint will continue to deliver a smooth, steady flow of torque. The steering linkages move both steering knuckles at the same time to the proper angle for the turn.

Figure 1: Live axle with CV Joint

Stub

It is used to transmit the power from the live axles, and also it can be used for steering. It can be mainly used for wheel rolling on the road, and depending on the steering on phases, the wheel can be toe-in, toe out

Figure 2: Stub

METHODOLOGY

Problem Definition

Nowadays, all vehicles are running with two wheel steering system, but it is proven that conventional two wheel steering system has less efficient when compared to four wheel steering system. So, this work is implemented to tell four wheels steering system is better than two wheel steering system in terms of turning radius. Generally, a vehicle with high turning radius has more problem in parking and low speed cornering, but the passenger prefer the vehicle to be higher wheelbase and track width as it gives good comfort while travelling. In this scenario, four wheel steering will be effective as the turning radius will be decreased for the same vehicle of higher wheelbase. In this work, a benchmark vehicle without changing its dimensions is considered to implement four wheel steering mechanism of the vehicle.

For achieving reduction, a mechanism is built, which turns the rear wheels opposite to the front wheels[8], the visibility area of driver at night, so that driver can't judge road turnings due to road accidents on sharp turning at night, specially in hilly areas[13].

Problem Rectifications

- In this work, we try to show that the four wheel steering system is better than two wheel steering system in terms of Turing radius.
- In this work, a benchmark vehicle without changing its dimensions is considered to implement four wheel steering mechanism of the vehicle.
- We achieved a reduction in turning radius as compared to other steering systems.
- At the sharp turning along with the steering move the headlights.
- While in turning we try ko keep headlight beam parallel to road as possible as can.
- To improve the visibility area of driver at night so that driver can judge road turning well.
- It is also important to prevent road accidents at night time due to sharp turning specially in hilly areas.

Fabrication

To every project, fabrication plays a major role. Fabrication is nothing but bringing our ideas into live model. In this work, four wheel steering is fabricated. Our project requires many items to be attached to the frame. The fabrication is done through many machines. The fabrication of four wheel steering system with movable head lights done by the processes that are involved in are:

- Gas cutting
- Grinding
- Drilling

In this work, tri-star clamp is used to connecting the wheels together. While climbing the stairs it is tedious to climb with a single wheel. Here, the wheels are connected to each of the arms of the clamp and while climbing the stairs Tri-Star setup rotates when it hits the edge of the stairs. The Tri-Star is fabricated using gas cutting process. The wheels are placed between the two clamps by using air cooled arc welding.

Final Assembly

- Initially, we bolted the live axle and the stubs at the starting stage of assembly, we have drilled 12mm holes at rear end of the frame, to which we can able to attach the live axles. Further to the axles, the stubs are attached with the tyre sets. The tub creates both steering and power transmission to the wheels.
- Later on, we arrange clamps to which the sun gears are welded at the centre of the frame.
- Two tie rods from each side of the stub are routed to the sun gear position, and from there we are able to connect the tie rods to the sun gears by using long threaded bolts of 10mm.
- The above process is done for the lower sun gear also.
- Tie rod with tie rod ends on both sides are fixed to sun gears at the rear end.
- From the front wheel C-clamp, a tie rod from each side is routed towards the steering column and is fixed by long fully threaded bolts.
- The shaft which drives the steering motion from front to rear wheels is fixed rigidly by using a journal bearing and gets meshed.
- Finally assemble the tyre sets.
- After the final assembly frame is taken for testing and later on readings like turning radius before and after meshing, the sun and planet gear meshing is taken.
- Later on, the headlights are fixed at the clamps of the wheels in a L-shape manner, which is the simplest form of moving headlamps, according to the steering of the vehicle. They rotate through an angle of 120 degrees maximum with the help of steering. The connections are given according to the requirements and by the design of the automobile.

CALCULATIONS

Bevel Gear Calculations

Wear Strength of Bevel Gears

The contact between two meshing teeth of straight bevel gears is a line contact, which is similar to that in spur gears. In order to determine the wear strength, generally bevel gear is considered as equivalent to a formative spur gear in a plane perpendicular to the tooth at the large end the large end. Applying Buckingham's equation to these formative gears,

$$S_w = \frac{b Q D_p K}{\cos \gamma}$$

Where,

b = face width of gears = 15mm

γ = Pitch angle = 45°

Q = Ratio factor

D_p = Pitch circle diameter of the pinion at the large end of the tooth (mm) = 50mm

K = material constant (N/mm²)

$Z_g \& Z_p = 20$

Ratio factor is calculated as

$$Q = \frac{2Z_g'}{Z_g' + Z_p'}$$

Where,

$$Z_p' = \frac{Z_p}{\cos \gamma} Z_g' = \frac{Z_g}{\cos (90 - \gamma)}$$

Substituting these values, in Q we get

$$Q = \frac{2Z_g}{Z_g + Z_p \tan \gamma}$$

$$Q = \frac{2 \times 20}{20 + 20 \tan 45}$$

$$Q = 1$$

Material Constant can be given as,

$$K = 0.16 [\text{BHN}]^2 / 100^2$$

Where,

BHN = Brinell Hardness Number = 201

Therefore, $K = 0.16 [201]^2 / 100^2$

Therefore, Material Constant (K) = 0.6464

Therefore,

Substituting the above calculated values in the equation, $S_w = \frac{bQDpK}{\cos\gamma}$

$$S_w = \frac{15 \times 1 \times 50 \times 0.6464}{\cos 45}$$

$$S_w = 685.610 \text{ N}$$

Therefore, Wear Strength of Bevel Gear = 685.610 N

Bearing Calculations

These Bearings are placed between the two rear pinions, so as to support the easy movement of the pinion to switch the racks. According to the application in our project, we choose the 6003 type of Ball Bearing.

The expression for dynamic load is given by:

$$P = XF_r + YF_a$$

Where,

P = Equivalent dynamic load (N)

Fr = Radial load (N)

Fa = Axial or Thrust load (N)

$$D = 35 \text{ mm}$$

$$B = 10 \text{ mm}$$

$$C = 6050 \text{ N}$$

$$C_o = 2800 \text{ N}$$

Fr = 1000 N (Assumption on basis weight of casing, body weight, etc.)

Fa = 2000 N (Assumption on basis weight of casing, body weight, etc.)

Comparing the ratio of Radial and Axial load to get the value of X and Y

$$\frac{F_a}{F_r} = \frac{1000}{2000} = 0.5$$

For $(F_a/F_r) = 0.5$, i.e. should be equal to 0.44.

So, now $(F_a/F_r) > 0.44$, i.e., $0.5 > 0.44$

Therefore, X = 0.56, Y = 1

Thus,

$$P = 0.56(2000) + 1.4(1000)$$

$$P = 1120 + 1400$$

$$P = 2520 \text{ N}$$

Therefore,

Equivalent Dynamic Load Acting on Bearing is = 2520 N

Dynamic Load Capacity of a Bearing is given by: $C = P(L_{10})^{1/2}$

Where,

L_{10} = Rated bearing life (in million revolutions) = $6050 = 2800 (L_{10})^{1/2}$

L_{10} = 10.08 Million Revolutions

Therefore, Rated Bearing life is 10.08 Million Revolutions[12]

Turning Radius Calculations

Calculation for steering angles for the turning radius of 4.4m.

From the benchmark vehicle, we know that turning radius is 4.4 m.

We know that, $R^2 = a_2^2 + R_1^2$ (1)

Where,

R = Turning radius of the vehicle.

a_2 = Distance of CG from rear axle

R_1 = Distance between instantaneous centre and the axis of the vehicle.

To find a_2 , $W_f = (W * a_2) / L$ (2)

Where,

W_f = Load on front axle.

W = Total weight of car.

L = Wheelbase = 1300 mm.

So from equation 2 and 1

$a_2 = 2500$ mm, $R_1 = 2993$ mm.

To find steering angles;

From test we found that the inner angle of front tire is,

$\delta_{if} = 15.60^\circ$, $\tan \delta_{if} = C_1 / (R_1 - w_f/2)$ (3)

$C_1 + C_2 = L$ (4)

Where,

C_1 = Distance of instantaneous centre from front axle axis.

C_2 = Distance of instantaneous centre from rear axle axis.

W_f = Front track width = 1160 mm

From equation 3 and 4, $C_1 = 1156.26$ mm, $C_2 = 143.73$ mm.

To find δ_{of} = outer angle of front tire, $\tan\delta_{of} = C_1 / (R_1 + w_f / 2)$ (5)

$\delta_{of} = 17.9^\circ$

To find δ_{ir} = inner angle of rear tire.

$\tan\delta_{ir} = C_2 / (R_1 - w_r / 2)$ (6)

$\delta_{ir} = 3.80^\circ$

To find δ_{or} = outer angle of rear tire, $\tan\delta_{or} = C_2 / (R_1 + w_r / 2)$ (7)

$\delta_{or} = 2.15^\circ$

Now, considering the same steering angles for front and rear tires, we reduce in the turning radius of the vehicle but keeping the wheelbase and track width same as the benchmark vehicle.

Calculation for turning radius for same steering angles.

To find turning radius, R

$R^2 = a_2^2 + L^2 \cot^2 \delta$ (8)

Where,

δ = Total steering angle of the vehicle.

To find δ , $\cot\delta = (\cot\delta_i + \cot\delta_o) / 2$ (9)

Where,

δ_i = total inner angle of the vehicle.

δ_o = total outer angle of the vehicle.

$\cot\delta = 2.025$.

From equation 8, $R = 3110.02$ mm.

Further calculation for C_1 and C_2 from equation 3 and 4 considering, turning radius as **3110.02** mm.

$C_1 = 1156.26$ mm.

$C_2 = 143.73$ mm.

RESULTS

Four wheel steering system with movable head lights has good cornering capability, steering response, straight-line stability, lane changing when the vehicle is at high speed and low speed maneuverability with the bevel gear set up. The effective Headlight Moving mechanism with Steering was designed, based on fixing the head lights with front wheel steering system fixed with bolt and nut to move the steering arm that gives predefined motion to wheel and

headlights. It is observed that when the steering wheel is rotated through a certain angle towards right or left side of the driver, the head lights are tilted through certain angle in degrees to the right or left, with the help of different linkages arranged with respect to the steering wheel. The results we have achieved with mechanically actuated steering control are; the benchmark vehicle's turning radius is 4.4 m, and the turning radius of four wheel steering system with movable headlights is $R = 3.1$ m.

CONCLUSIONS

As per the focus of the project, we have created an innovative 4 wheel active steering system with movable head lights, the mechanism which is feasible to manufacture, highly efficient in achieving neutral, in-phase and counter-phase rear steering with respect to the front wheels. This type of system gives better cornering and high speed lane changing. It eliminates the problem faced in sharp turning. Even at high speeds, it gives better maneuverability and control by reducing turning circle radius as like in neutral steering. Moreover, these systems are feasible, economical and components are easily available in the market. The system assembly is easy to install and light in weight and can be implemented in all sections of cars efficiently. Moment of headlights as per requirement along with the turn as added advantage, which helps to reduce accidents at night on sharp turning and hilly areas, by doing so making nation with accidents free roads. It is found that, as the steering wheel rotates to any side towards right side or left side, the headlights are also moved with some angle with the help of rack and pinion mechanism.

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