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Design and Fabrication of ackerman steering For Hybrid Car

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Abstract- Steering is the collection of components, linkages, etc. which allows any Vehicle (i.e. Car, Bike etc.) to follow the desired path. The primary purpose of the steering system is to allow the driver to guide the vehicle. 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, to allow it to deviate from a straight line. The aim of this project is to highlight the design, modeling and explore the theories and techniques behind procedures of manufacturing a rack and pinion steering system for Hybrid vehicle car. This newly manufactured mechanism will be used in 2018 ISIE EVENT. Various systems were studied but very effective rack and pinion steering system was manufactured with the consideration of the driver.The normal standard steering systems available in the market are in ratio 16:1 which means for complete turn of vehicle the steering wheel must be rotated 4 times, a power steering overcomes the problem of rotation and does the full turn in 2 revolutions of steering wheel. Hence a need arise to manufacture a steering system that could take a full turn in half rotation of steering wheel, this was accomplished by using a rack and pinion steering system with low steering ratio to 12:1. The mechanism is designed with a view to keep the steering ratio low as possible so the various tentative events like auto cross can be easily be faced. The mechanism has been, analyzed, manufactured, tested and installed successfully.
Key words: steering mechanism, Hybrid car, universal joints, design, rack and pinion

1. INTRODUCTION

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, 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. Trackedvehicles 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, using clutches and brakes, to bring about a change of course or direction.

The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. One of the fundamental concepts is that of *caster angle* – each wheel is steered with a pivot point ahead of the wheel; this makes the steering tend to be self-centring towards the direction of travel.

The steering linkages connecting the steering box and the wheels usually conform to a variation of Ackermann steering geometry, to account for the fact that in a turn, the inner wheel is actually travelling a path of smaller radius than the outer wheel, so that the degree of toe suitable for driving in a straight path is not suitable for turns. The angle the wheels make with the vertical plane also influences steering dynamics as do the tires.

The car steering system is a widely studied system by automobile manufacturers and research institutes across the globe. Current research shows that the modern vehicle may sport a steering wheel which will not be physically connected with the car wheel through linkages, but the driver will still receive haptic feedback from a complex array of sensors and control system feedback. The steering feel based on a rack and pinion type steering mechanism is still important because most midrange consumer vehicles will continue to bear a rack and pinion type steering mechanism.

2. DESIGN OF STEERING SYSTEM:

2.1 Steering System

A schematic of the steering system is shown in Figure 2.1. The steering system comprises of a steering wheel turning a steering column. The steering column is connected to an intermediate shaft through a universal joint. The universal joint transmits torque to a lower shaft through another universal joint. A pinion at the end of the lower shaft mates with the rack and converts the column rotary motion into translator motion of the rack.

For modelling purposes, the rack can be visualized as two similar sections on either side of the pinion. A ball joint is used to connect the end of the rack to a tie rod, which connect to a knuckle through another revolute joint. The kingpin axis is aligned with the global Z axis. The knuckle carries the road wheel which turns due to the translator motion of the rack.

This complete system had been divided into three subcomponents for analysis, namely the universal joint, the rack & pinion assembly and the tie rod & knuckle assembly.

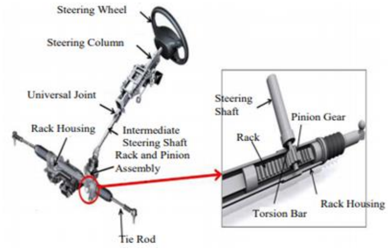


Fig.2.1 steering system

2.2 Rack And Pinion Type Steering System

The rack and pinion steering gear has become increasingly popular for today's small cars. It is simpler, more direct acting, and may be straight mechanical or power assisted in operation. Figure 2.2 shows the schematic of a rack and pinion steering system. As the steering wheel and the shaft are turned, the rack moves from one side to another. This pushes or pulls on the tie rods, forcing the knuckle to pivot about the kingpin axis. This turns the wheel to one side or the other so that the car is steered. The steering gear and the tie rod are visible in the figure.

The universal joint is at the upper end of the steering shaft and the flexible coupling at the lower end. In small cars, rack and pinion steering is quick and easy. It provides the maximum amount of road feel as the tires meet irregularities in the road.

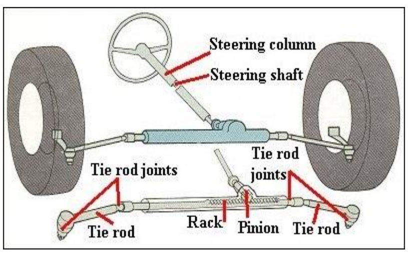


Fig 2.2 schematic of rack & pinion

2.3 Universal Joint:

A universal joint, U joint, Cardan joint, Hardy-Spicer joint, or Hooke's joint is a joint in a rigid rod that allows the rod to 'bend' in any direction, as shown in Figure 2.3 It is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft.

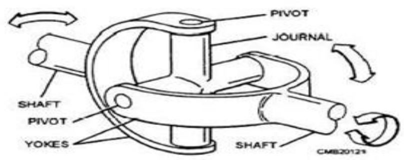


Figure 2.3 Universal Joint

Relation between different parameters for a Universal joint as shown in figure have been stated in and are as follows:

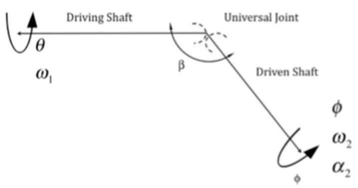
$$\omega_2 = \frac{\omega_1 \cos\beta}{1-\sin\beta^2 \sin\theta^2} \qquad 3.4c$$

$$\text{Tan}\ \phi = \frac{\tan\theta}{\cos\beta}$$

$$\omega_2 = \frac{\omega_1 \cos\beta}{1-\sin\beta^2 \sin\theta^2}$$

$$\alpha_2 = \frac{-\omega_1^2 \sin\beta^2 \cos\beta \sin\gamma\theta}{(1-\sin\beta^2 \sin\theta^2)}$$

$$\alpha_2 = \frac{-\omega_1^2 \sin\beta^2 \cos\beta \sin\gamma\theta}{(1-\sin\beta^2 \sin\theta^2)}$$



Where;

θ= angle of the driving shaft

∅= angle of the driven shaft

β= angle between the shaft axis

ω_1=angular velocity of the driving shaft

ω_2 = angular velocity of the driven shaft

α_2 = angular acceleration of the driven shaft

2.4 Tie Rod And The Knuckle

The tie rod is part of the steering mechanism in a vehicle. A tie rod is a slender structural rod that is used as a tie and is capable of carrying tensile loads only as shown in Figure 2.4. It is a rod with a "ball and socket" at one end that is connected to the steering arm or the knuckle. The other end is connected to the rack. When the steering wheel moves, causing the rack to move, the ball and socket allows the wheel to turn. Stud swing from side to side allows the tie rod to function as the vehicle moves up and down. When two tie rods are used, their length are kept adjustable, allowing the wheels to be aligned. Proper tie rod function is important, as excessive movement can

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contribute to toe change, which can affect tire wear and car stability. The knuckle is mounted about the kingpin axis. It is mounted between the shockers and the stub axel. The car wheel is installed on the knuckle and as it turns about the kingpin axis it turn the vehicle.

In Figure 2.4 axis is at the point O along the Z-axis which is perpendicular to the XY plane.

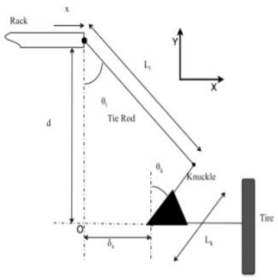


Fig 2.4 Tie Rod and Ball Joint

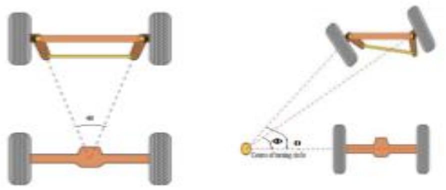
Where
x = lateral rack displacement
L_x = lateral distance between the pinion and the king pin axis
δ_x = lateral distance between rack and the king pin axis
d = longitudinal distance between the rack and kingpin axis
L_t = length of the tie rod
L_k= length of the knuckle arm
θ_t= acute angle made by the tie rod
θ_k = acute angle made by the knuckle arm

3. FABRICATION OF ACKERMAN STEERING

Ackerman steering is used to change the dynamic toe setting, by increasing front wheel toe out as the car is turned into the corner. The typical steering system, in a road or race car, has tie-rod linkages and steering arms that form an approximate parallelogram, which skews to one side as the wheels turn. If the steering arms are parallel, then both wheels are steered to the same angle. The Ackermann steering geometry takes its name from a London agent that patented the design in 1816. The geometry allows the outer front wheel to cover a larger radius than the inside wheel. As a result both wheels will follow individual radii without skidding or scrubbing as the vehicle corners.

According to Ackermann Steering geometry, the outer wheels moves faster than the inner wheels, therefore, the equation for correct steering is:

$\text{Cot}\,\Phi - \text{Cot}\,\theta = \frac{b}{l}$ Φ = outer wheel angle
θ = inner wheel angle
b = track width
L = wheelbase
α = Ackermann angle



The intention of Ackermann geometry is to prevent the tyres from slipping outwards when the wheels follow around a curve while taking a turn. The solution for this is that all wheels to have their axles settled as radii of circles with a common Centre point. Since the rear wheels are fixed, this Centre point must lie on a line extended from the rear axle. So we need to intersect the front axle to this line at the common Centre point. While steering, the inner wheel angle is greater than outer wheel angle. So for obtaining different results we need to vary the parameters in order to obtain desired steering geometry.

Fig3.1(a) proposed Steering Wheel (b) Fabricated steering wheel

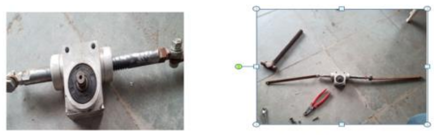


Fig3.2(a) Rack and pinion system (b) Rack and pinion system with tie rod

Fig 3.3 Steering rod

4. EXPERIMENTATION

***4.1 Working Principle*:**

To achieve true rolling for a four wheeled vehicle moving on a curved track, the lines drawn through each of the four wheel axes must intersect at the instantaneous centre. The actual position the instantaneous centre constantly changes due to the alternation of the front wheel angular positions to

correct the steered vehicle's path. Since both rear wheels are fixed on the same axis but the front wheel axles are independent of each other, the instantaneous centres lies somewhere along an imaginary extended line drawn through the axis of the rear axle.
The Ackermann principle is based on the two front steered wheels being pivoted at the ends of an axle-beam. The original Ackermann linkage has parallel set track-rod-arms, so that both steered wheels swivel at equal angles. Consequently, the intersecting projection lines do not meet at one point. If both front wheels are free to follow their own natural paths, they would converge and eventually cross each other. Since the vehicle moves along a single mean path, both wheel tracks conflict continuously with each other causing tyre slip and tread scrub. Subsequent modified linkage uses inclined track-rod arms so that the inner wheel swivels about its king-pin slightly more than the outer wheel. Hence the lines drawn through the stub-axles converge at a single point somewhere along the rear-axle projection

4.2 Calculations:

In the figure below it is shown that the total length of the vehicle from the centre of the front wheel to centre of the rear wheel is called Wheel Base (b). Similarly, the total length between centreof the front left wheel to centre of front right wheel is called Wheel Track (t). The distance between the two pivot joints of steering system is called Kingpin Centre to Centre distance (k). The calculation of Ackermann angle is shown below:

4.2.1 Ackerman angle:

Tan (Ackermann angle)= kingpin to kingpin distance/2*wheel base
Ackerman angle = tan inverse of (kingpin to kingpin distance/2*wheel base)
=tan inverse of(41.82/2*64.5)
Ackermann angle (alpha) = 17.971°

4.2.2Ackermann percentage calculation:

We have steering ratio as 12:1
Steering lock condition 1.5 turns i.e. 540°
So angle turned by the wheel tire is = 12/1=540/X
So,X=45° which is considered as the angle made by inner wheel while making a turn.
We know that for a perfect steering condition,
Cot (Y)-cot (X)=w/l
Where,Y=angle made by outer wheel
X=angle made by the inner wheel
From this we have both w=41.82, l=64.5
From this we obtain the angle made by the outer wheel as Y=31.24°

4.2.3 Turning radius of the vehicle:

Cot (θ) = ([cot(inner angle)+cot(outer angle)])/2
=38.44

R = L/sin θ
= 64.5/sin((38.44))
= 2635mm

4.2.4 Steering wheel diameter:

[3*(3.14)*R]/rack travel lock to lock = 12:1
R=5.41 inches

Diameter =10.82 inches

Where:
θo = turn angle of the wheel on the outside of the turn
θi = turn angle of the wheel on the inside of the turn
B= track width
L = wheel base
b = distance from rear axle to centre of mass
R=√ (R12+B2)
R12=R2+B2
R1=√ (R2+B2)
R=4.5
B=1.55
R1=4.43m
R1=B/tan θi +L/2
R1=1.55/tan θi +1.195/2
Θ_1 = 22.02
Through the calculations we can find out that for a turn of maximum radius 4.5 m the steer angle for the inner tire is 22.02 degrees and the outer tire is 17.13 degrees.

5. RESULTS AND DISCUSSIONS

1) The Fabrication of Ackerman Steering system for ISIE was successfully done.
2) The ratio of Ackerman Steering has been calculated as 16:1.
3) Ackerman steering geometry can achieve less Gear ratio when compared to Modern Steering Geometry.

6. CONCLUSIONS

1. After all the calculations were completed and the final steering assembly was designed in Solid works.
2. This steering system designed for the turns generally encountered in the ISIE events was optimal to counter negative impacts of bump and roll steer and also possessed self-returning capability. Universal joints have been added in the steering column to line it up nicely with the pinion shaft.
3. An innovative feature of this steering linkage design and its ability to drive all four (or two) wheels using a single steering actuator. Its successful implementation will allow for the development of a four-wheel, steered power.

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