Paper Review on Manual Rack & Pinion Steering System for Solar Operated Vehicle

Shaikh Abdul Haseeb[1], Khan Mohd Salman[2], Khan Adil[3], Mohammed Shazeb Ali[4], Mohammed Abdul Azeem[5]
[1, 2, 3, 4, 5] Dept of Mechanical Engineering
[1, 2, 3, 4, 5] Everest College of Engineering and Technology, Aurangabad, India.

Abstract- *Manual rack and pinion steering systems are Commonly used due to their simplicity in construction and compactness. Rack and pinion type steering is selected over other type of steering. It has a lot of benefits like it is light weight, simplicity in design, cost is less. Apart from these benefits the rack and pinion isn't sloppy at the centre point and gives the drive a large range of motion. The rack and pinion provides a large degree of feedback and allows the driver to feel the ground.*

Keywords- Steering Wheel, Steering Column, Rack and Mechanism, Steering Ratio, Turning Radius.

I. INTRODUCTION

Steering system is one of most important part of an Automobile that is used to give directional stability to thevehicle. It controls the vehicle along the desired path and Stability of the direction of motion of vehicle against external Instabilities. The best characteristics of our solar operated vehicle are controlling system that steering provides.

The steering pinion at the lower end of the steering main shaft meshes with the steering rack. As the steering wheel is turned, the steering pinion rotates to move the steering rack to the right or left. The movement of the steering rack is transmitted to the knuckle arms via the steering rack ends and tie rod ends. Construction is compact, simple, and lightweight. Since the gear box is small, and the rack itself acts as the steering linkage. Gear meshing is direct, so steering response is very sharp. There is little sliding and rotational resistance and torque transmission is better, so steering is very light. The steering gear assembly is completely sealed so it is maintenance free.

II. TECHNICAL CONTENT

2.1 Steering System:

- The purpose of the steering system is to provide directional control of the vehicle. The steering column intermediate shaft attaches the steering column to the gear pinion. The rotation of the pinion moves the gear rack from side-to-side. This lateral action of the rack pushes and pulls the tie rods to change the direction of the front wheels.

2.1.1 Steering Mechanism:

We analyzed Davis and Ackermann steering mechanisms. Davis steering mechanism obtains the required steering angle using sliding pairs. Due to the presence of such sliding pairs, mechanical wear and tear increases. This increases the possibility of failure. Also due to the increase in the number of links, it increases the weight making it bulky and inefficient.

Ackermann steering mechanism is basically a 4 bar linkage mechanism. It consists of turning pairs and no sliding pairs. This helps to decrease the wear and tear of steering mechanism. Thus, we prefer Ackermann steering mechanism over Davis steering mechanism.

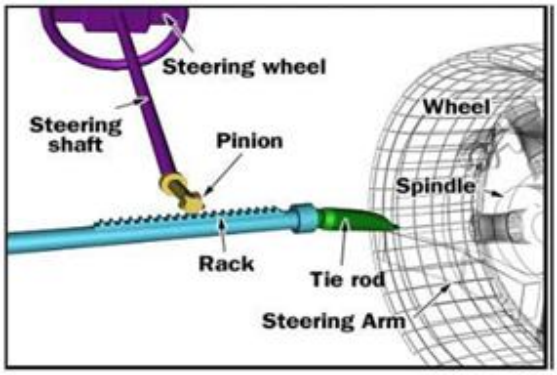

Fig.2.1 Steering Arrangement

Ackermann steering mechanism is basically of 3 types –

1. Ackermann steering mechanism-Angle turned by inner wheel is greater than that of outer wheel.
2. Anti-Ackermann steering mechanism-Angle turned by inner wheel is less than that of outer wheel.
3. Pro-Ackermann steering mechanism-Angle turned by outer wheel is equal to that of inner wheel.As per our requirement we are using ANTI ACKERMANN.

2.1.2 Rack & Pinion Steering:

1. Rack and pinion type steering is selected over other type of steering.
2. It has a lot of benefits like it is light weight, simplicity in design, cost is less.
3. The rack and pinion provides a large degree of feedback and allows the driver to feel the ground.
4. Also the rack and pinion places the pivot.
5. Rack shaft length is **17 inch (431.8 mm)** and over all steering ratio was **15:1**.

2.1.3 Steering Geometry:

When the vehicle is moving very slowly, there is a Kinematic condition between the inner and outer wheels that allows them to turn slip-free.For Complete Ackerman, the following condition is to be satisfied:

$$\cot \emptyset - \cot\theta = \frac{W}{L}$$

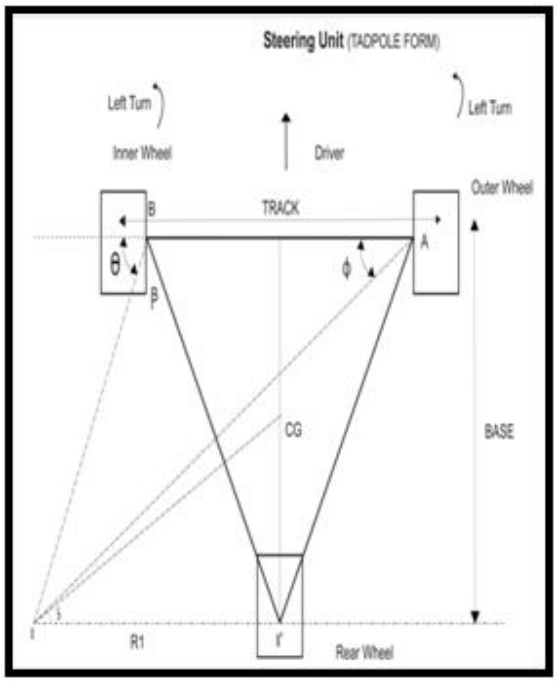

Fig.2.1.3: Steering Geometry

Where: θ = Max tuning angle of inner wheel
$\emptyset$ = Corresponding tuning angle of outer wheel
L = Wheel Base
W = Track Width

The inner and outer wheels are defined based on the turning center O.

The distance between the steer axes of the steerable wheels is called the track and is shown by **W**.

The distance between the front and rear axles is called the wheelbase and is shown by **L**. Track **W** and wheelbase **L** are considered as kinematic width and length of the vehicle. The mass center of a steered vehicle will turn on a circle with radius R.

$$R = \sqrt{a2^2 + L^2 \cot^2\delta}$$

Where,

δ is the cot-average of the inner and outer steer angles

$$cot\ \delta = (cot\ \emptyset + cot\theta)/2$$

The angle δ is the equivalent steer angle of a bicycle having the same wheelbase L and radius of rotation R.

$$R1 = L \times \cot \emptyset + W/2$$

III. CALCULATIONS

1. W=50*25.4= 1270 mm.
2. L=69*25.4= 1752.6 mm.
3. θ= 43º (assuming maximum inner steer angle)
4. cot $\emptyset$ – cot (43º)= 1320.8/1828.8 $\emptyset$= 28º
5. R1 =1752.6*cot(43º) + (1270 /2) = 2.51 m
6. Center of gravity shifts towards inertia therefore it is as follows
   $a_2 = (1/3)* L = (1/3)*(1752.6) = 584.2$ mm
7. $R = \sqrt{a_2^2 + L^2 \cot^2\delta}$, cot δ = (cot $\emptyset$ + cot θ)/2, $\delta = 27.87^0$
8. R = 2.57 m (Turning Radius)
9. Steering ratio calculation:

Steering wheel end to end rotation = 1080°
(Overall rotation of steering wheel)
Total rotation of wheel = 72°

$$\text{Steering Ratio} = \frac{\text{Steering wheel end to end rotation}}{\text{Total Rotation of Wheel}}$$

= 1080/72 = 15:1

We considered following factors while designing steering system:

1. Caster Angle:If we take positive and negative Caster angle the steering effort increases and tyre wears at

inside and outside respectively.Hence we are using Zero degree (0^0) Caster angle for better steer.

2. Camber angle:Positive camber anglereduces the net lateral force generated at the tires because of the counter-acting camber thrust and hence we provide 2° positive camber angle.This angle is measured from the gravity vertical line to the wheel plane. When the wheel is tilted outwards the Camber is positive. Camber helps straight ahead stability and to maintain optimum tire life.
3. Toe-in:The toe in provided to the wheel is **3 mm.** This increases the straight-line stability.

IV. CONCLUSION

The manual rack and pinion steering system is not used in heavy weight vehicles due to high axle loads, although it is simple in design and easy to manufacture, therefore it is Commonly used in light weight vehicles.The values calculated in the paper may differ practically due to steering linkages error or due to improper steering geometry, so these values are useful to understand the interdependency of the quantities on each other and to design a ideal manual rack and pinion system for the vehicle.

Fig.2.1.4 Top View of Actual Steering Arrangement

REFERENCES

[1] R.S. Khurmi, J.K. Gupta “Theory of Machines”, S. Chand & Company Pvt. Ltd., Vol 1, 14th Edition, 2014.
[2] S.K. Gupta “A Textbook of Automobile Engineering”, S. Chand & Company Pvt. Ltd., Vol 1, 1st Edition, 2014.
[3] Cristina Elena Popa, *Steering System and Suspension Design For 2005 Formula SAE-A Racer Car,* University of Southern Queensland, Faculty of Engineering and Surveying.
[4] Bhandari, Design of Machine Elements, third edition, McGraw Hill Education, India, 2010.