

Design and fabrication of four wheel steering system for light motor vehicles

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Abstract: Four-wheel steering is used to improve maneuverability in light motor vehicles. In standard two-wheel steering vehicles the rear wheels do not play role in association with the steering and follow the path of the front wheels. In four wheels steering the wheels can be rotated either left or right as per the requirements. Rear wheels can be rotated in same phase as the front or in opposite phase. In four-wheel system is designed to function in 3 modes namely, in-phase rotation, counter-phase rotation and zero rotation. The selection and change between modes can be done by simple push of the lever. The front rack is connected to a custom-made selector box at the rear via a linkage, the selector designed to achieve the 3 modes. It helps achieve a reduction in turning radius about 20% to 30%. This system allows the vehicle to have reduced understeer and oversteer of vehicles. The vehicle has a turning motion with reduced radius in counter-phase and sliding motion in in-phase.

1. Introduction

In an automobile the steering of the vehicle plays a major role in control of the path of motion of the vehicle. The steering systems are designed to give the best control designed for the vehicle. The vehicles are designed with steering control to the front wheels or in certain cases steering control is given to the rear wheels. Yet in any vehicle the steering control is given to only front axle or in certain cases the rear axle. This is normally referred to as two-wheel steering system. Two-wheel steering system employs only two out the four wheels of a light motor vehicle [1]. We can observe that the turning radius of the vehicle increases as the vehicle becomes bigger, longer and wider. As the increased traffic in cities, smaller roads and congestions, bigger the vehicle more pressure and strain the driver undergoes. This makes turning the vehicle in small corners difficult. Even when the vehicle is driven on highways the vehicle is subjected to understeer and oversteer [2,3]. This effort can be reduced by even employing the



rear wheels of the vehicle to provide steering action. In a general steering mechanism, the rear wheels of the vehicle do not play a significant role in the steering control of the vehicle. The rear wheels are fixed along a straight path of motion. So, employing the rear wheels to provide steering action will help to reduce the turning radius of the vehicle thereby, reducing the steering effort on the driver [4]. The rear wheels of the vehicle can move in two phases with respect to the front wheels, in-phase and counter-phase. In counter phase the rear wheels rotate in opposite direction of that of the front wheels giving a reduced turning radius to the vehicle whereas, in-phase has the rear wheels rotating in the same direction as the front wheels providing a sliding action of the vehicle. The system is called a four-wheel steering system.

In the present study, steering system is designed to have a 3-mode function, counter-phase steering, in-phase steering and no steering modes. These modes are selectable depending on the driver [5]. It helps achieve a reduction in turning radius about 20% to 30%. This system allows the vehicle to have reduced understeer and oversteer of vehicles. The vehicle has a turning motion with reduced radius in counter-phase and sliding motion in in-phase.

2. Design

2.1 Concept

The four-wheel steering mechanism is obtained with the help of a rack and pinion for the front wheels and a connector turning the rear wheels. The front wheels are turned using a basic rack and pinion mechanism, while the rear wheels are controlled using tie rods. There is a connector between front and rear wheels which helps the rear wheels turn. At front end it is connected to the rack (Figure 1) while at the other end a metallic ball is attached to it at the bottom which sits in the plus-shaped slot as shown in Figure 2. This slot is fixed in such a way that it is free to rotate on its central axis and it is connected to the tie rods on its end which are further connected to the rear wheels. This mechanism will help to achieve two phases i.e., both out-phase and in-phase. In out-phase the rear wheels will turn opposite to the direction of front wheels and thus help reduce the turning radius, whereas in in-phase all the wheels will turn in same direction thereby, enabling an efficient way for lane changing. The turn angle of the rear wheels is just enough to assist the motion of front wheels and not provide own direction [6].

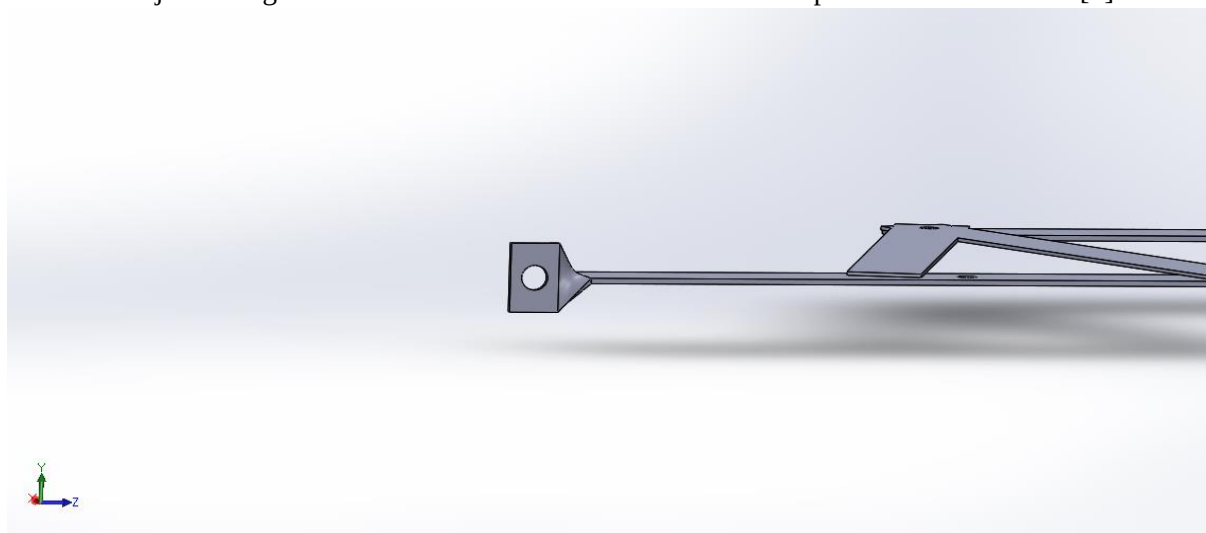


Figure 1. Steering link: Front end.

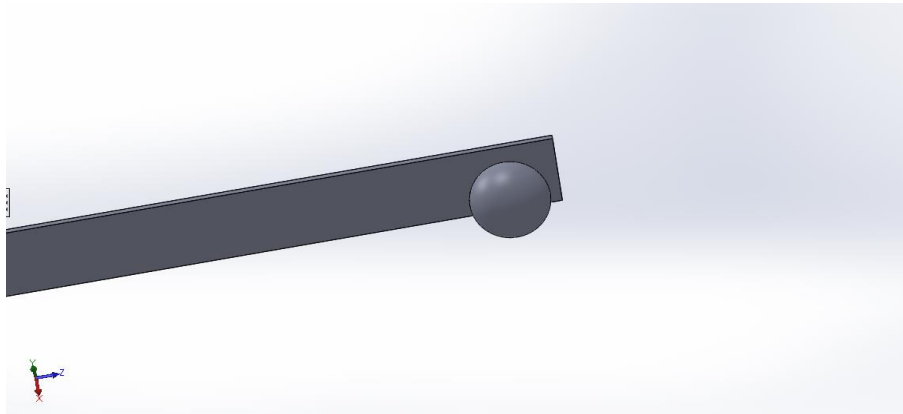


Figure 2. Steering link: Rear end.

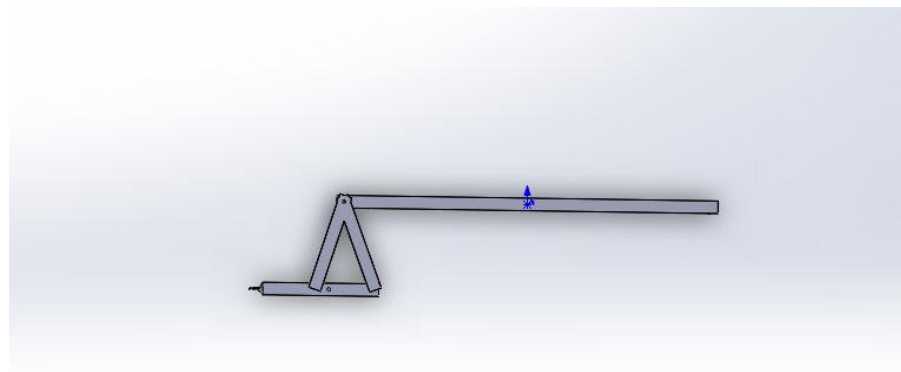


Figure 3. Steering link.

2.2 Connection

2.2.1 Metal arms

Since the front wheels are controlled using rack and pinion, the rear wheels are assisted with the help of a connector. This consists of two arms (Figure 3) and a plus-shaped slot (Figure 4). The two arms are 1.5" wide but have different lengths. The short arm, of length 15.5", is connected to the rack on end. It sits on the frame of the vehicle fixed on its center which allows it a rotating motion as the rack moves. Longer arm, situated along the central axis, is connected to the short arm with the help of metal strips. This allows it to attain a linear motion. It measures 46" in length. It has a metal ball attached to its other end on lower side, this ball sits in the slots and moves along the defined path as the arm reciprocates as shown in Figure 5.

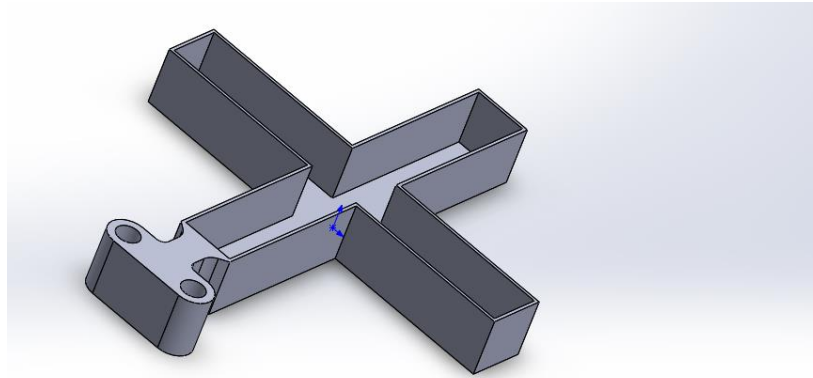


Figure 4. Mode changing junction box for rear steering.

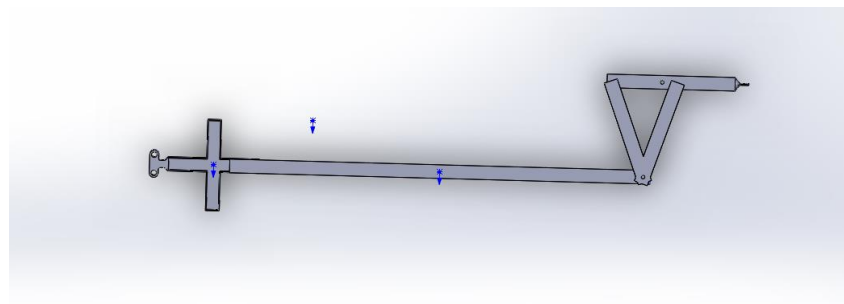


Figure 5. Connected Junction box and Steering link

2.2.2 Slot

It is a plus-shaped slot which gives a defined path to the ball which sits inside it. This slot works in two modes. One mode is usual front wheel steering, in this mode the ball moves vertically in the slot without disturbing it. The other mode is the four-wheel steering, where the ball is shifted to either of the sides according to the required steering phase. This plus-shaped slot measures 10"x10" open on the top. The open part is 1.5" wide. This is fixed at the center of the frame, which enables it to rotate along its central axis. Two tie rods are connected on its end which move linearly, as the slot rotates, and further help to turn the rear wheels. This slot is situated along the central axis of the frame just in front of the rear wheels.

2.3 Frame

A basic rectangular metal frame has been used for this work. The frame is a C-channel frame. The section is 3" deep and 1.5" wide. The whole frame is 74" long and 21" wide. Two cross members are added within the frame, one supports the rack in the front while the other is used to fix the slot at the rear. Additional cross members are extended from the front and rear end of the frame, they are used to mount the stabilizer bars for front and rear wheels. Mounts are added on either side of the frame to fix the wheels. To mount the suspension, angular mounts are added vertically. This inclination is set according to the required camber angle. The following Fig. 6 gives the detailed view of the frame.

3. Design Calculations

To proceed with calculations, we consider the weight to be equivalent to a small size hatch back.

So, $W = 650\text{kg}$

Considering the system being employed in a front engine front wheel drive vehicle. So, the weight distribution between front and rear axle is in the ratio of 55:45.

Hence,

Weight on front axle (W_f) = 357.5kg

Weight on rear axle (W_r) = 292.5kg

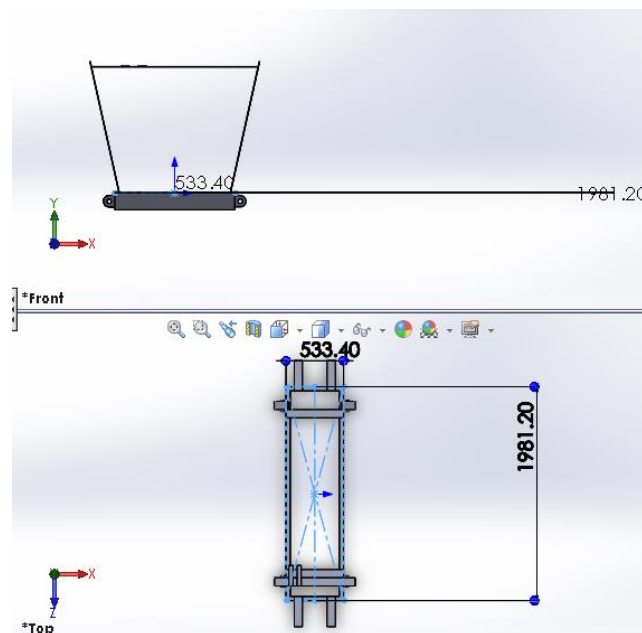
Dimensions obtained from the prototype models.

Wheelbase (L) = 1625.6mm

Track width (T) = 1260mm

Obtaining turning radius of the prototype model for standard 2-Wheel steering system,

$$\begin{aligned} R &= L / \sin \delta \\ &= 1625.6 / \sin 33.02^\circ \\ &= 2983.12\text{mm} \\ &= 2.98\text{m (approx.)} \end{aligned}$$



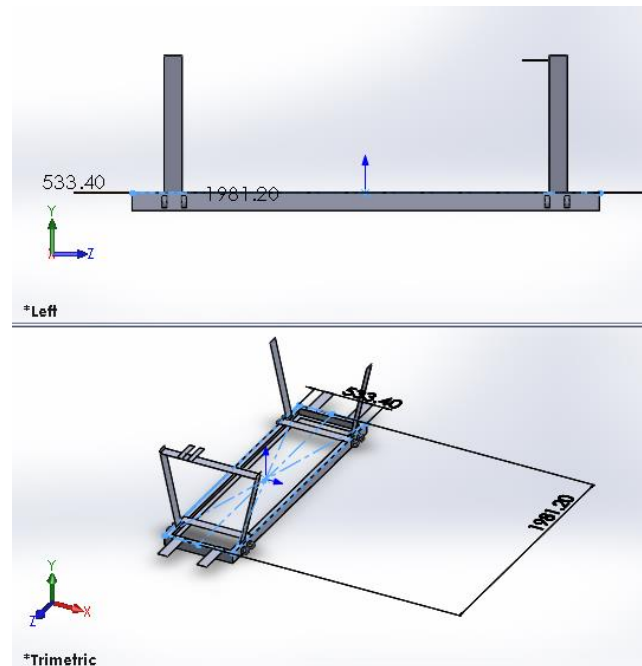


Figure 6. Frame Dimensions.

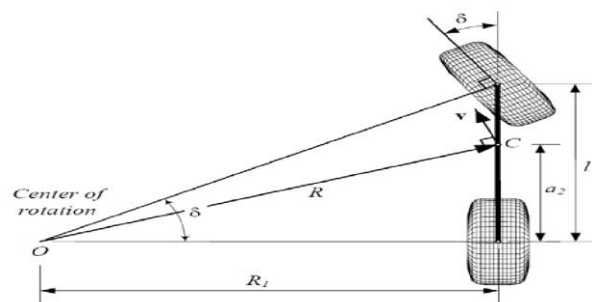


Figure 7. Two-wheel steering turning

We know from Fig.7 that,

$$R^2 = a_2^2 + R_1^2$$

To obtain a_2 ,

$$W_f = (W a_2)/L$$

$$a_2 = (W_f L)/W$$

$$= 894.08\text{mm}$$

From the above relation.

$$R_1 = 2845.98\text{mm}$$

From the prototype fabricated the angles for each wheel is obtained.

$$\delta_{if} = 33.024^\circ$$

$$\delta_{ir} = 32.005^\circ$$

$$\delta_{of} = 24.228^\circ$$

$$\delta_{or} = 25.297^\circ$$

Finding instantaneous centers,

$$\tan \delta_{if} = C_1 / (R_1 - T/2)$$

$$C_1 = \tan \delta_{if} \times (R_1 - T/2)$$

$$C_1 = 1436.92\text{mm}$$

Since,

$$C_1 + C_2 = L$$

$$C_2 = 188.68\text{mm}$$

Calculating turning radius from Fig. 8 for prototype in 4-Wheel Counter phase steering,

$$\delta_{if} + \delta_{ir} = \delta_i = 65.029^\circ$$

$$\delta_{of} + \delta_{or} = \delta_o = 49.525^\circ$$

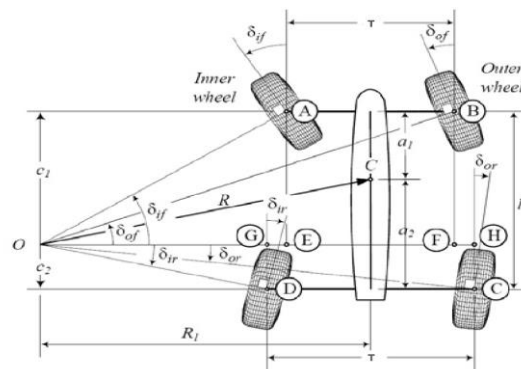


Figure 8. Four-wheel steering.

$$\cot \delta = (\cot \delta_i + \cot \delta_o)/2$$

$$= (\cot 65.029^\circ + \cot 49.525^\circ)/2$$

$$= 0.659$$

$$\delta = 56.61^\circ$$

To obtain the turning radius of the vehicle we use

$$R^2 = a_2^2 + L^2 \cot^2$$

$$R = 1395.34\text{mm}$$

$$= 1.39\text{m (Approx.)}$$

Using,

$$R^2 = a_2^2 + R_1^2 \text{ and } \tan \delta_{if} = C_1 / (R_1 - T/2)$$

We get,

$$R_1 = 1071.52\text{mm}$$

$$C_1 = 521.17\text{mm}$$

$$C_2 = 1104.43\text{mm}$$

Table 1. Shows the comparison of design parameter for two-wheel and four-wheel steering.

Parameter	2 Wheel Steering	4 Wheel Steering
δ_{if} (Degree)	33.025	33.025
δ_{of} (Degree)	24.228	24.228
δ_{ir} (Degree)	0	32.005
δ_{or} (Degree)	0	25.297
R (m)	2.98	1.39
R1(mm)	2845.98	1071.52
C1(mm)	1436.92	188.68
C2(mm)	521.17	1104.43

Reduction in turning radius is 1.59m

So, the percentage reduction in turning radius = 53.36%

Nomenclature

R be the turning radius of the vehicle

R_1 be the distance between axis of the vehicle and the instantaneous center

a_1 be the distance between front axle and center of gravity

a_2 be the distance between rear axle and center of gravity

C_1 be the distance between front axle and instantaneous center

C_2 be the distance between rear axle and instantaneous center

δ_{if} be the angle formed by the inner front wheel

δ_{ir} be the angle formed by the inner rear wheel

δ_{of} be the angle formed by the outer front wheel

δ_{or} be the angle formed by the outer rear wheel

The Fig 9 shows the fabricated prototype model of the four wheel steering system.

**Figure 9.** Fabricated Model

4. Conclusion

The following conclusions are drawn from the analytical analysis:

- There is a 53.36% reduction of turning radius.
- It can be used in three different phases or modes like 2-wheel steering, in-phase and counter-phase rear steering.
- By these modes the stability, lane changing, U-turns and near neutral steering can be achieved.

5. References

- [1] Kirpal Singh M Automobile *engineering* (Delhi- Standard publishers).
- [2] Chanpreet Singh, Rupesh Gupta, Himanshu Jindal and Rajeev Kumar Dang 2015 *Adv.Mater.Manuf.Technol.* **4** 10.
- [3] Aman Doraya, Mohit Singh Panesir, Bhavya Bhardwaj and Aditya Bochare 2015 *Int. Jour.Mech.Engg.Technol.* **6** 2.
- [4] <http://what-when-how.com/automobile/four-wheel-steering-4ws-automobile/>
- [5] Amitesh Kumar Er and Kamble, D N 2014 *Int.Jour.Sci.Engg.Res.* **5** 1635.
- [6] <http://www.scribd.com/doc/34677964/FourWheel-Steering-report>.