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STEERING INTO THE FUTURE: EXPLORING THE POTENTIAL OF FOUR-WHEEL CONTROL SYSTEMS

Deepti Mehta, Nitin Choubisa, Manish Kumar Vyas, Pratik Singhal, Prabhjot Singh
E-Mail Id: mehta.deepti89@gmail.com
Department of Mechanical Engineering, Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

Abstract- Nowadays, most existing vehicles use the two-wheel steering system to control the movement of the vehicle whether it is a front-wheel drive, rear-wheel drive, or all-wheel drive. But due to the awareness of safety, four-wheel steering vehicles are being used increasingly, since they are also known for their high performance and stability. In standard two-wheel steering vehicles, the rear wheels do not play any role in association with the steering and follow the path of the front wheels. In four-wheeled steering, the wheels can be rotated either left or right as per the requirements. The rear wheels can be rotated in the same direction as the front or in the opposite direction. The four-wheel system is designed to function in 3 modes namely, in-phase rotation, counter-phase rotation, and zero rotation. 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. The dual axle steering system shows the working of the different motions of wheels concerning various turning arrangements. The machine consists of 3 different steering arrangements i.e., neutral phase, negative phase & positive phase. In the neutral phase only the front wheels either run in the right or left direction and the rear wheel is the follower of the front wheels. In the negative phase, both front and rear axles move in the opposite direction relative to each other. In the positive phase, both the axle front and rear move in the same direction relative to each other. Here we need to lift the shifter and place it into the respective slot for the required motion.

Keywords: front-wheel drive, rear-wheel drive, in-phase rotation, counter-phase rotation, and zero rotation, dual axle steering system.

1. INTRODUCTION

Dual-axis vehicle steering is an innovative approach to enhancing the manoeuvrability, stability, and control of vehicles by providing independent control over the steering of multiple axes. Unlike traditional steering systems that primarily manipulate the front wheels around a single pivot point, dual-axis steering systems offer the ability to control wheels on different axes separately, enabling more precise handling and versatile manoeuvring capabilities. At its core, dual-axis steering expands the possibilities of how vehicles navigate various terrains, negotiate tight spaces, and optimize performance across different driving conditions. By decoupling the steering of individual wheels or sets of wheels, engineers can tailor the steering response to specific needs, whether it's maximizing agility in urban environments, improving stability at high speeds, or enhancing off-road capability.

This technology finds applications across a range of vehicles, from compact cars to heavy-duty trucks and specialized machinery. It not only improves the overall driving experience but also opens up new possibilities for autonomous driving systems, where precise control over each wheel's movement can enhance safety and efficiency. As advancements in automotive engineering continue to evolve, dual-axis steering represents a significant step forward in redefining how vehicles interact with their surroundings, offering greater control, adaptability, and performance than ever before.

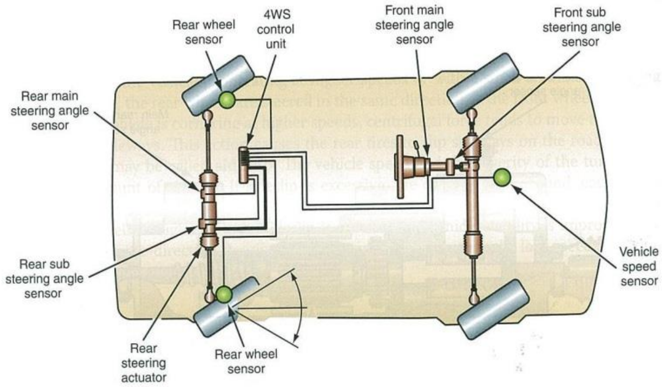

Fig. 1.1 Four-wheel Steering Mechanism

2. DESIGN OF STEERING SYSTEM

The advanced steering system of this vehicle utilizes a combination of a rack and pinion mechanism for the front wheels and tie rods for the rear wheels. The rear wheels are connected to the front wheels via a specialized connector that allows for both out-phase and in-phase turning. The connector is fixed to the rack at the front end and secured by a metallic ball at the other end, which sits in a plus-shaped slot that can rotate freely on its central axis. The tie rods are connected to the slot, allowing for the rear wheels to turn in conjunction with the front wheels. This innovative mechanism results in a reduced turning radius during out-phase turning and efficient lane changing during in-phase turning, without affecting the direction of the front wheels.

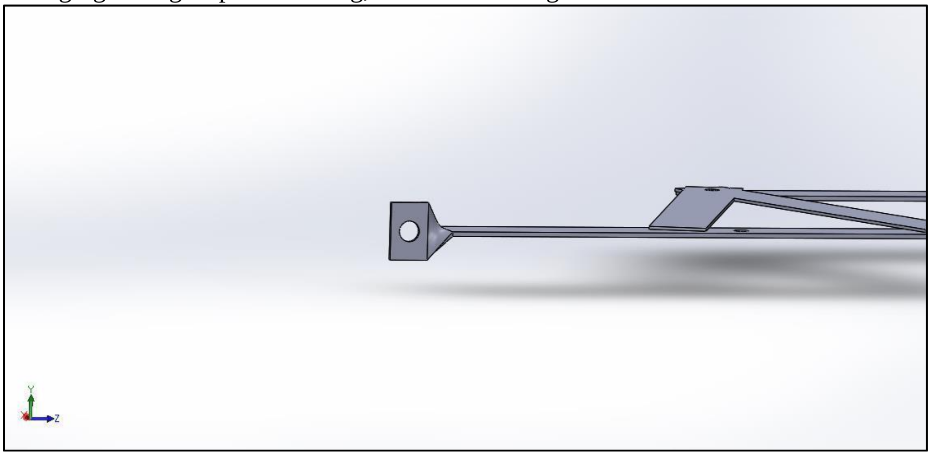

Fig. 2.1 Steering link: Front end

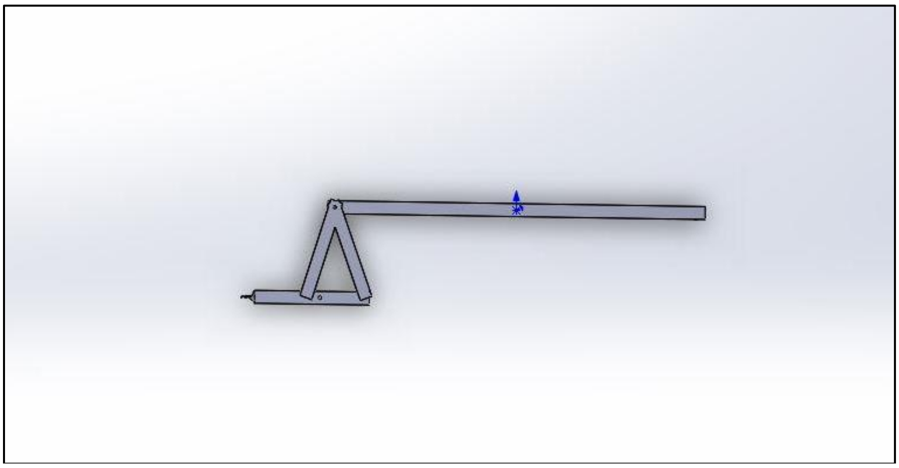

Fig. 2.2 Steering link

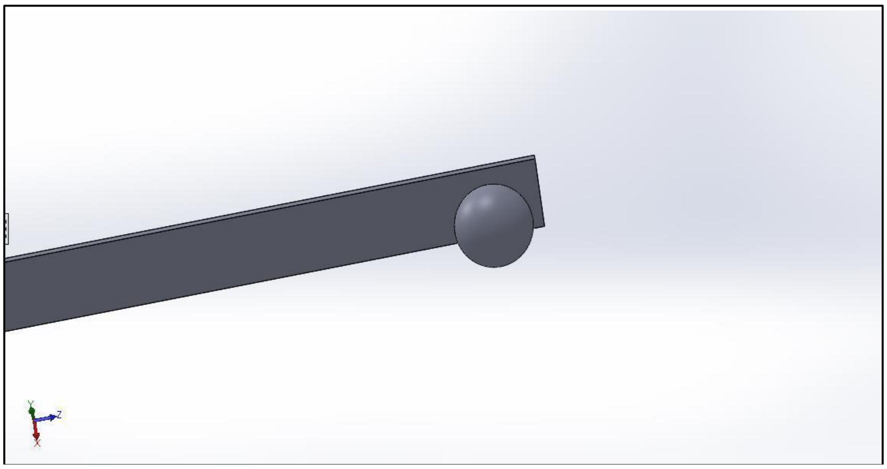

Fig. 2.3 Steering link: Rear end

The front wheels are controlled via rack and pinion, while the rear wheels receive assistance from a connector. This connector is comprised of two arms (refer to Figure 2.2) and a plus-shaped slot (refer to Figure 2.4). Both arms are 1.5 inches wide, but differ in length. The shorter arm, measuring 15.5 inches, is attached to the end of the rack and rotates along the vehicle frame's central axis. Meanwhile, the longer arm, measuring 46 inches in length and situated along the central axis, connects to the shorter arm via metal strips. This allows it to move linearly, with a metal ball attached to its lower end that moves along a defined path within the slot as the arm reciprocates (see Figure 2.5).

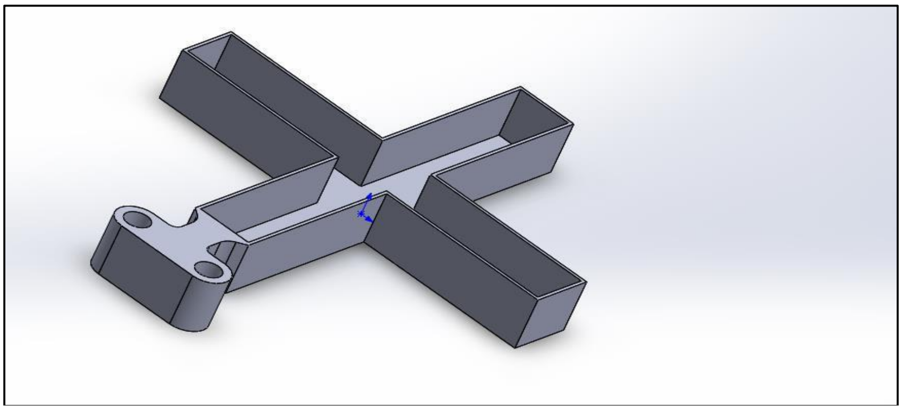

Fig. 2.4 Mode changing junction box for rear steering

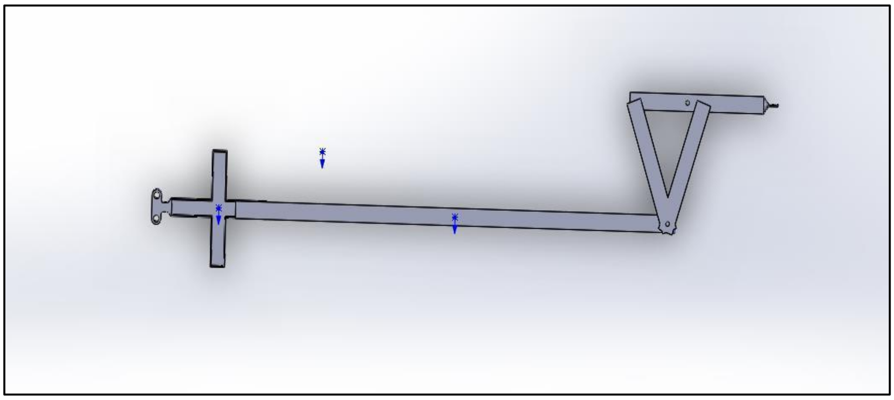

Fig. 2.5 Connected Junction box and Steering link

3. DESIGN CALCULATION

To proceed with calculations, we consider the weight to be equivalent to a small-size hatchback.
So, W = 650kg
The weight distribution between the front and rear axle in a front engine front wheel drive vehicle is 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 the turning radius of the prototype model for the standard 2-Wheel steering system,

$$R = L/\sin\ \delta$$
$$= 1625.6/\sin\ 33.020$$
$$= 2983.12\text{mm}$$
$$= 2.98\text{m (approx.)}$$

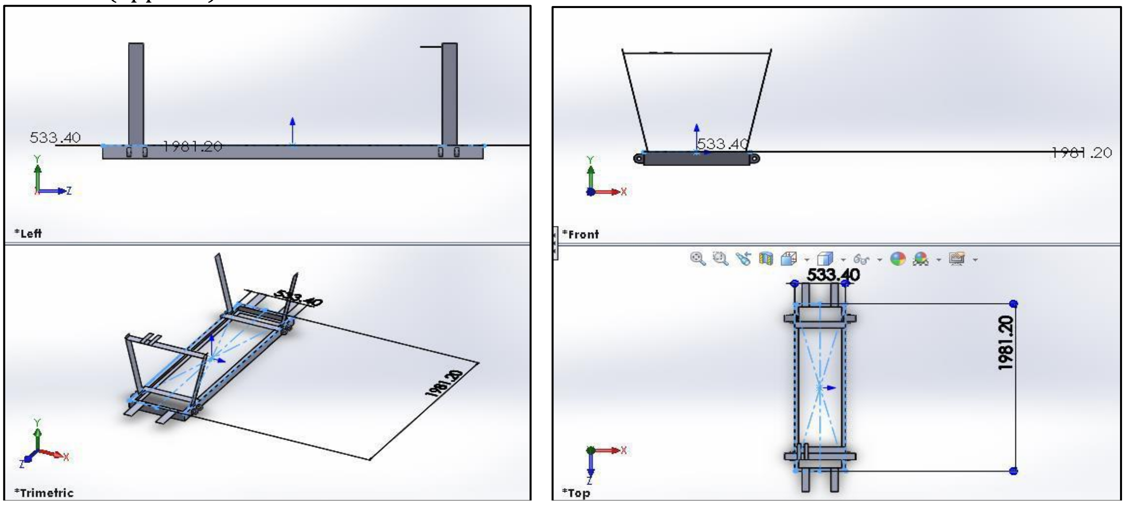

Fig. 3.1 Frame Dimensions

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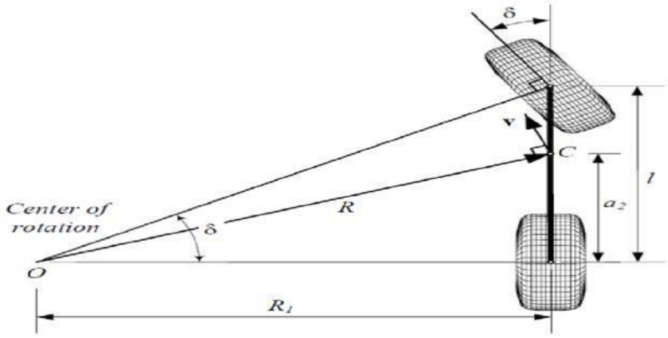

Fig. 3.2 Two-wheel steering turning

We know from Fig.3.2 that,
$R2 = a_2^2 + R_1^2$
To obtain a_2,
$W_f = (W a_2)/L$
$a_2 = (W_f L)/W$
$= 894.08mm$
From the above relation.
$R_1 = 2845.98mm$
From the prototype fabricated the angles for each wheel is obtained.
$\delta_{if} = 33.0240$
$\delta_{ir} = 32.0050$
$\delta_{of} = 24.2280$
$\delta_{or} = 25.2970$
Finding instantaneous centres,
$\tan \delta_{if} = C_1/(R_1 - T/2)$
$C_1 = \tan \delta_{if} \times (R_1 - T/2)$
$C_1 = 1436.92mm$
Since,
$C_1 + C_2 = L$
$C_2 = 188.68mm$
Calculating turning radius from Fig. 8 for the prototype in 4-wheel Counter phase steering,
$\delta_{if} + \delta_{ir} = \delta_i = 65.0290$
$\delta of + \delta_{or} = \delta_o = 49.5250$

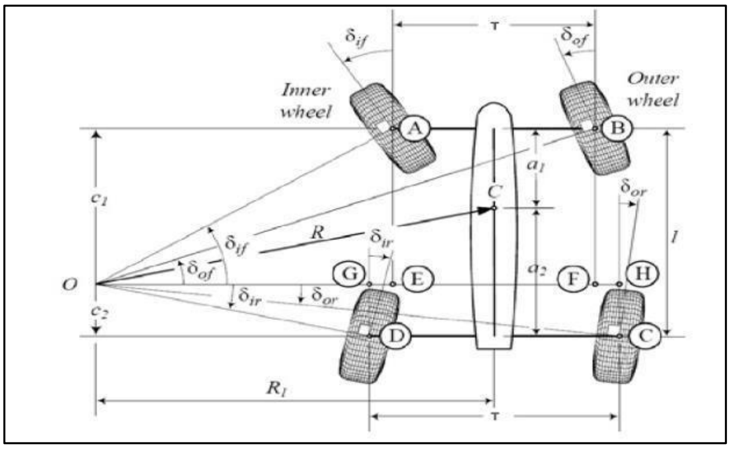

Fig. 3.3 Four-wheel steering

$\cot \delta = (\cot \delta_i + \cot \delta_o)/2$
$= (\cot 65.029^0 + \cot 49.525^0)/2$
$= 0.659$
$\delta = 56.610$
To obtain the turning radius of the vehicle we use
$R^2 = a_2^2 + L^2 \cot^2$
$R = 1395.34mm$
$= 1.39m$ (Approx.)
Using,
$R_2 = a_2^2 + R_1^2$ and $\tan \delta_{if} = C_1/(R_1 - T/2)$

We get,
R_1 = 1071.52mm
C_1 = 521.17mm
C_2 = 1104.43mm

Table-3.1 Shows the comparison of design parameters 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
R_1(mm)	2845.98	1071.52
C_1(mm)	1436.92	188.68
C_2(mm)	521.17	1104.43

Reduction in turning radius is 1.59m
So, the percentage reduction in turning radius = 53.36%

Nomenclature

R is the turning radius of the vehicle
R_1 be the distance between the axis of the vehicle and the instantaneous centre
a_1 be the distance between the front axle and the centre of gravity
a_2 be the distance between the rear axle and the centre of gravity
C_1 be the distance between the front axle and the instantaneous centre
C_2 be the distance between the rear axle and the instantaneous centre
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 3.4 shows the fabricated prototype model of the four-wheel steering system.

Fig. 3.4 Fabricated Model

CONCLUSION

The project carried out by us made an impressive task in the field of automobile industries. It is very useful for drivers while driving the vehicle. The project is based on Dual Axis Vehicle Steering Mechanism where due to the awareness of safety, four-wheel steering vehicles are being used increasingly since they are also known for their high performance and stability. In standard two-wheel steering vehicles, the rear wheels do not play any role in association with the steering and follow the path of the front wheels. In four-wheeled steering, the wheels can be rotated either left or right as per the requirements. The rear wheels can be rotated in the same direction as the front or in the opposite direction. The four-wheel system is designed to function in 3 modes namely, in-phase rotation, counter-phase rotation and zero rotation. 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. The dual axle steering system shows the working of the different motions of wheels concerning various turning arrangements. The machine consists of 3 different steering arrangements i.e., neutral phase, negative phase & positive phase. This project has also reduced the cost involved in the concern. The project has been designed to perform the entire requirement task which has also been provided.

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