Construction and performance of Four-Wheel Steering System of long chassis vehicle.

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Mechanical Engineering.

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A Project Report on

CONSTRUCTION AND PERFORMANCE OF FOUR-WHEEL STEERING SYSTEM OF LONG CHASSIS VEHICLE

Submitted in the partial fulfilment of the requirements for the award of degree of

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

By

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The authors

January, 2023

CERTIFICATION

This is to certify that the whole work submitted as a thesis work entitled **"Construction and performance of Four-Wheel Steering System of long chassis vehicle"** to the Faculty of Science and Engineering, Sonargaon University (SU) for the degree of Bachelor of Science in Mechanical Engineering was carried out under the superintendence of **Md. Istiaque Zahur** sir. This study has been carried out in the Mechanical Engineering, Sonargaon University Dhaka, Bangladesh. This is also to certifying that the research work presented here is an original work for the partial fulfillment of the degree of Bachelor of Science in Mechanical Engineering. To the best of our knowledge this thesis has not been submitted elsewhere.

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DECLARATION

This dissertation has been submitted as thesis entitled **"Construction and performance of Four-Wheel Steering System of long chassis vehicle"** to the Sonargaon university (SU) in partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering. This study has been carried out in the Department of Mechanical Engineering, Sonargaon University (SU) of Dhaka-1205. No part of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT

Vehicles with a long wheelbase such as trucks and buses often have trouble negotiating tight and congested turns. In such cases four-wheel steering system can be employed to assist in reducing the turning radius of the vehicle. This includes steering over all of the 4 wheels instead of 2 wheels as in the present world. This has led to greater comfort for the driver to drive the vehicle whether it comes to taking a turn or it comes to changing lane over the highway. Four-wheel steering system also known as Quadra Steering System controls all the 4 wheels while turning there are multiple components which are required for this steering system design. This system uses gear mechanism to steer the vehicle's rear wheels along with the front wheels thereby enabling the vehicle to turn fasted and more efficiently. Four-wheel steering technology is beneficial because it increases the vehicle's steering response time and helps keep the vehicle stable at higher speeds. With all four wheels steering, instead of only the front two, this technology offers unprecedented control and maneuverability. It advances its stability and control at higher speed, neutral steering, maneuverability, turning radius. In this project is made to make a cost effective and efficient mechanism of four-wheel steering using Electric DC motor, gear pinion and required parts. It allows the driver to change from two-wheel to four-wheel according to its requirement.

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1. INTRODUCTION

Widely used two-wheel steering system lags in stability during high speeds, lane changing becomes a difficult task, it also faces problem while parallel parking. Specially it is very hard for a long wheelbase vehicle as buses and trucks to take a U-turn on a busy road with the little space available for the vehicle to actually make the turn. It is also hard for the driver to take the vehicle a little backward and then make the turn as the roads are busy and small. Since the front wheels are over burden, as engine is placed at frontier position, due to these front tyres wear out quickly. As wheels are overburdened, it tends to under steer. While a heavy front provides adequate starting torque on wet roads, in all other conditions torque from a front wheel steer vehicle is inferior to a rear wheel steer vehicle. This is due to non-uniform weight distribution. The rear end of a front wheel steer vehicle is considerably lighter than its front end, which means the rear tyres do not grip the road very well. Since steering and engine power is handled by the front wheels, the latter sometimes tends to compromise the former. The force generated front the engine, sometimes tends to pull the either to the right or to the left. This is referred to as torque steering [5].

In such a case, if the vehicle is equipped with four-wheel steering system, it will be easy for the driver to actually make the turn with ease even in the small space that is available for him. But the main thing is that we have two configurations in four-wheel steering systems called same phase and opposite phase [5].

In order to reduce the turning radius of the vehicle, we need the opposite phase configuration of four-wheel steering system. The main intension of this project is to reduce the turning radius of a vehicle as much as practically possible without crossing the practical limits of design and assembly of the components of the steering system [3].

According to Akhtar (2013), "The turning radius or turning circle of a vehicle is the diameter of the smallest circular turn (i.e., U-turn) that the vehicle is capable of making.

Turning circle radius = (track/2) + (wheelbase/ sin (average steer angle)".

Based on these requirements, a four-wheel symmetric steering system is analyzed using kinematic approach and a conclusion is drawn regarding the geometry of the optimum steering system and the effect of this on the turning radius of the vehicle [3].

This system is seen not to cross any practical limitations of the vehicle in terms of assembly and spacing. Also, the wheels are turned to the optimum extent possible and not exceeding this limit.

2.1. OBJECTIVES

In four-wheel steering system, two objectives are to be achieved.

1. To develop a working model of four- wheel steering system.
2. To learn the advantages and benefits of the four-wheel steering system with respect to two-wheel steering system.

2.2. LITERATURE REVIEW

The four-wheel steering system is developed so that both front and rear wheel actively participate during turning, lane changing.

Kumar and Kamble (2014) states that "At slow speeds, the rear wheels turn in the direction opposite to the front wheels. This mode becomes particularly useful in case of pick-up trucks and buses, more so when navigating hilly regions [5]. It can reduce the turning circle radius by 25% and can be equally effective in congested city conditions, were U-turns and tight streets are made easier to navigate."

Lohith, Shankapal and Gowda (2013) found that "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” [1]. He also found and revealed comparison with a conventional two-wheel steering system, the advantages offered by a four-wheel steering system include:

1. Superior cornering stability.
2. Improved steering responsiveness and precision.
3. High-speed straight-line stability.
4. Notable improvement in rapid lane changing maneuvers.
5. Smaller turning radius and tight space maneuverability at low speed.
6. Relative wheel angles and their control.

According to Ruban, kumar, Shanmugavelan, Srinath and Ramesh (2017), the condition for perfect steering is “While taking a turn, the condition of perfect rolling motion will be satisfied if all the four-wheel axes when projected at one point called the instantaneous centre, and when the following equation is satisfied: $\cot\phi - \cot\theta = c/b$” [5].

Bhishikar, Gudhka, Dalal, Mehta, Bhil, Mehta (2014) stated that “The 4WS system performs two distinct operations: in- phase steering, whereby the rear wheels are turned in the same direction as the front wheels, and counter phase steering, whereby the rear wheels are turned in the opposite direction [9]. The 4WS system is effective in the following situations:

- Lane Changes
- Gentle Curves
- Junctions
- Narrow Roads
- U-Turns
- Parallel Parking

The four-wheel steering system can be developed in three different systems are:

1. Mechanical four-wheel steering

2. Hydraulically four-wheel steering

3. Electro-mechanical four-wheel steering

Different mechanical based four-wheel system already existing in vehicle is:

The bevel gear is used in the four-wheel steering system. As two bevel gears are considered, one bevel gear is attached to the steering column of the front steering box and the other bevel gear is attached to the intermediate shaft [2]. Use of bevel gear causes system more expensive, while it should be precisely mounted to avoid wear of tyre. Along with bevel gear universal joints with steering knuckle are used.

Fig: Bevel Gear

The bigger bevel gear mounted on a hollow shaft which is extended up to rear rack and pinion assembly connected by means of universal coupling Hence, rotary motion is transferred from front to rear pinion shaft [7]. On this shaft a Mechanism is fitted at mid which will help to make and break the rotary motion between front and rear to achieve two modes of steering i.e. Two-wheel steering and Four-wheel steering.

Fig: Universal Joint

Universal joints may cause wear if joint is not properly lubricated and it should be maintained. Another mechanism used the wheels are steers by using chain drive mechanism. In the chain drive mechanism, two sprockets are involved which can be connected by chain. In two sprockets, one is bigger than other. Bigger sprocket is attached to rear pinion shaft and smaller is mounted on the front pinion shaft [6]. Due to a greater number of components, it will complex in construction. So, to overcome this problem we use mechanism of spur gear for efficient cost, it also reduces fluctuating motions and easy to construct. [6]

3.1. PHOTOGRAPHS OF SELF-MADE PROJECT

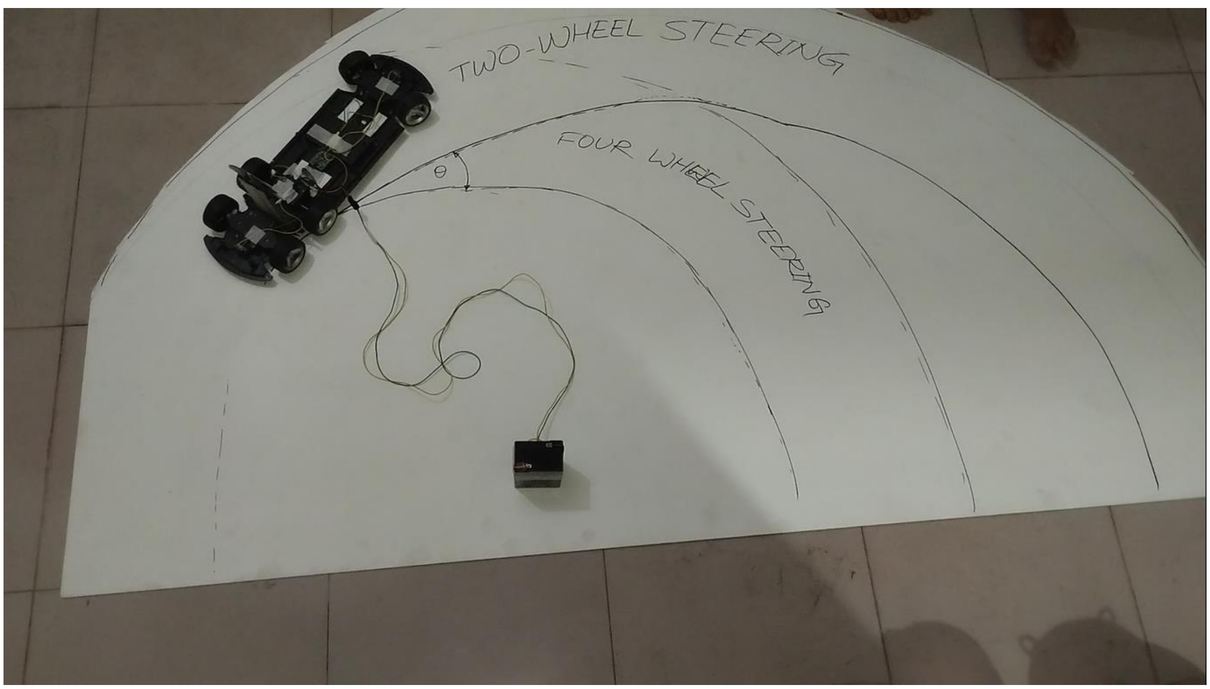


Fig: Project Photographs-01

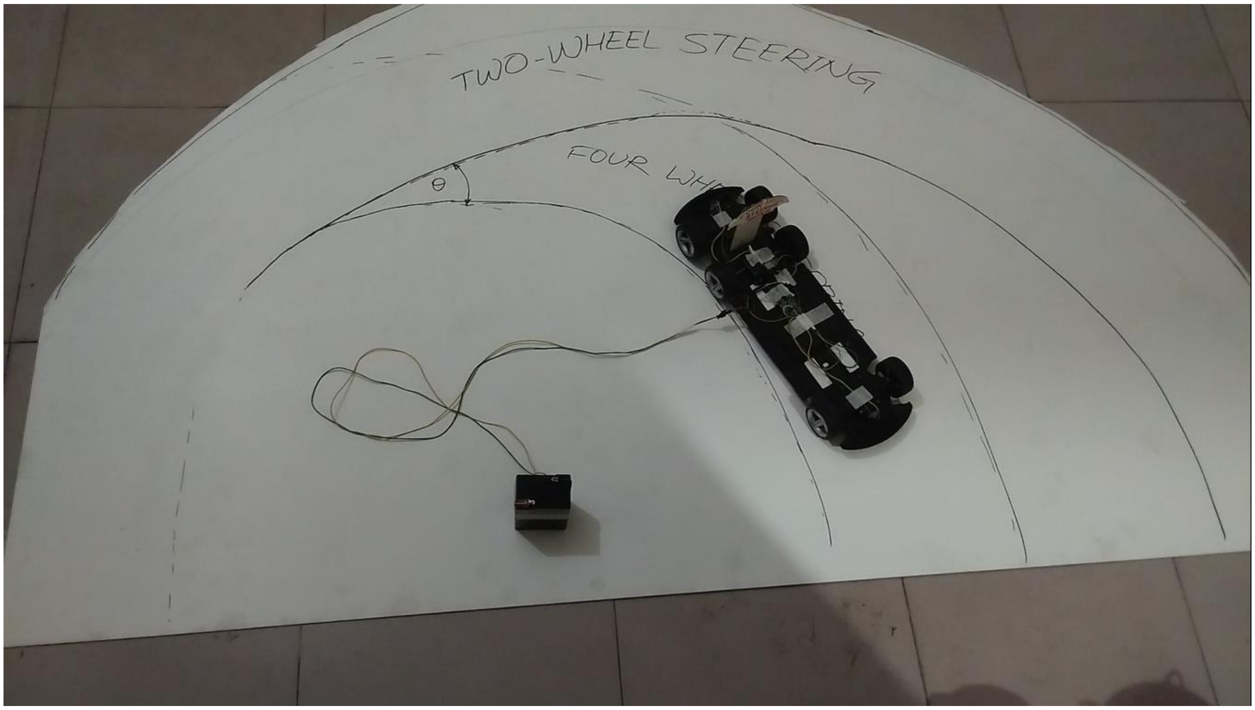


Fig: Project Photographs-02

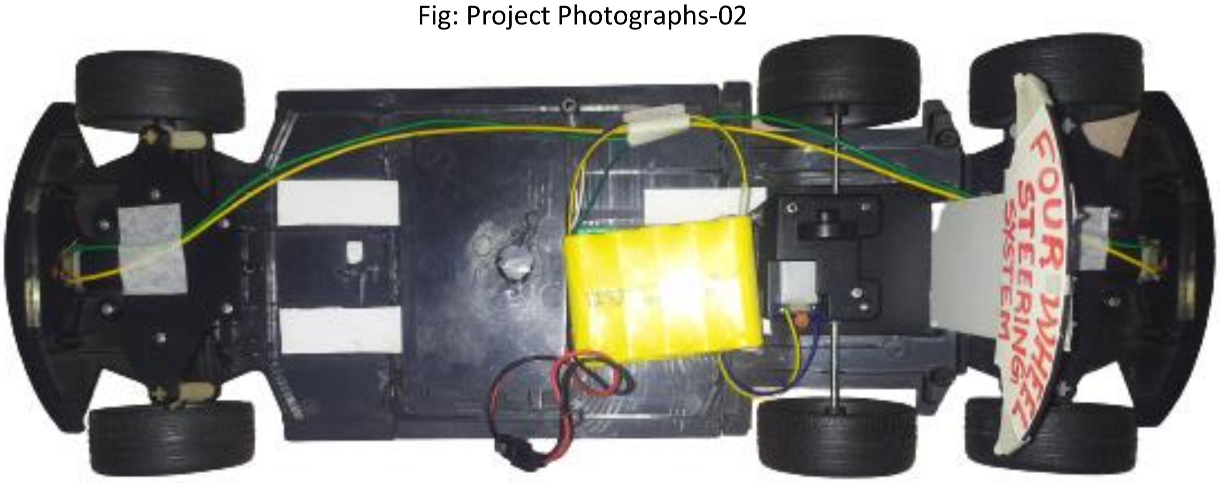


Fig: Project Photographs-03 (Mood-01)

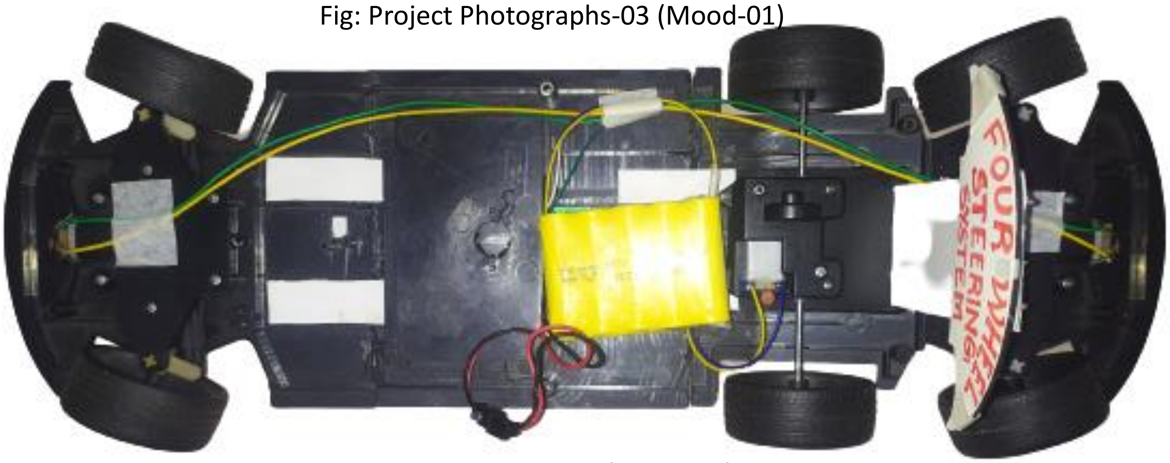


Fig: Project Photographs-04 (Mood-02)

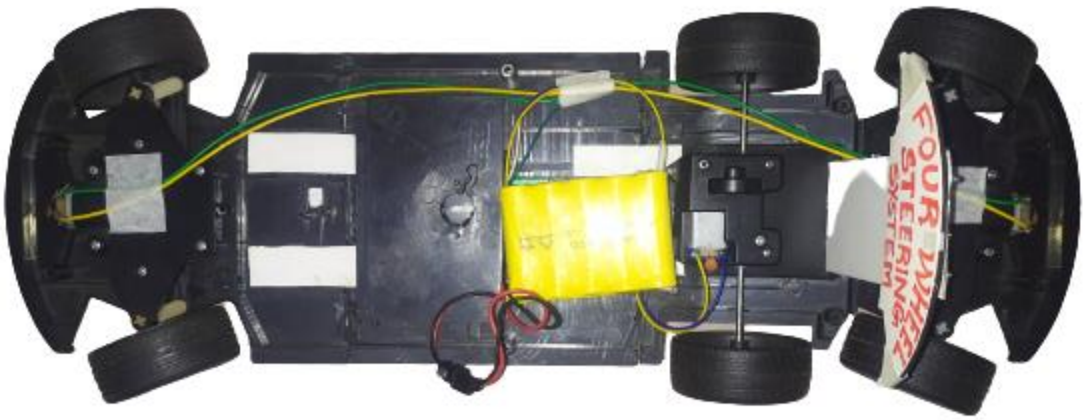


Fig: Project Photographs-05 (Mood-03)

4.1. FOUR-WHEEL STEERING SYSTEM

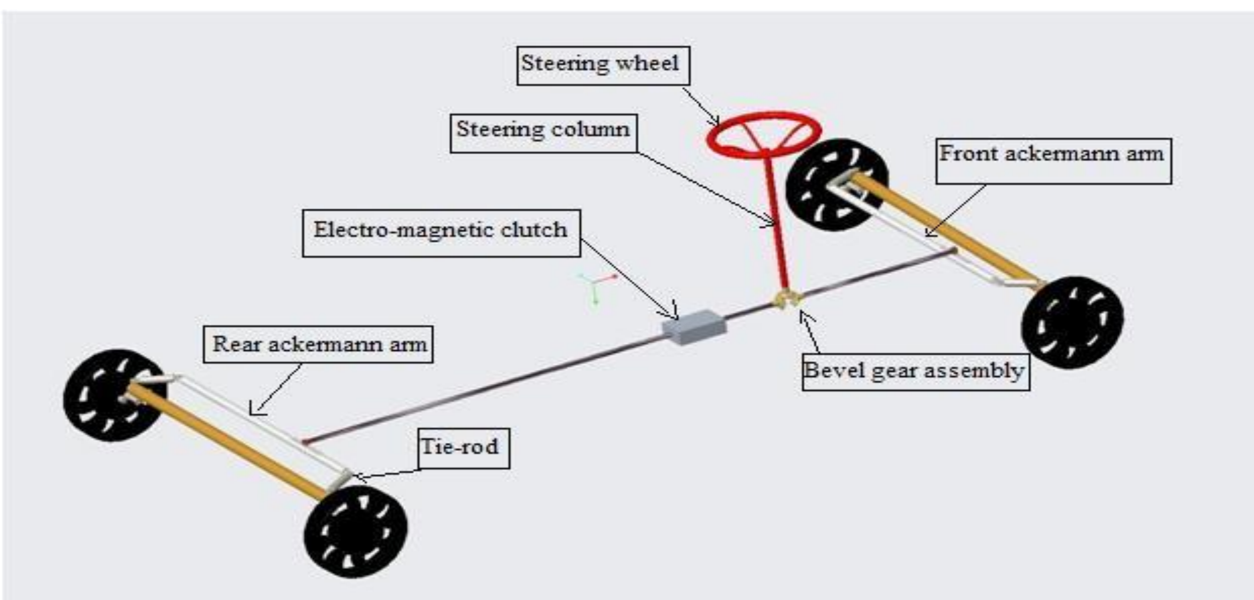
Four-wheel steering system is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed. In most active four-wheel steering systems, the rear wheels are steered by a computer and actuators.

In most active four-wheel steering systems, the rear wheels are steered by a computer and actuators. The rear wheels generally cannot turn as far as the front wheels. Some systems, including Delphi's Quadra steer and the system in Honda's Prelude line, allow for the rear wheels to be steered in the opposite direction as the front wheels during low speeds. This allows the vehicle to turn in a significantly smaller radius, sometimes critical for large trucks or vehicles with trailers. An electronic four-wheel steer system is an option available on the JCB FastTrack.

4.2. COMPONENTS OF FOUR-WHEEL STEERING SYSTEM

Four-wheel steering system consists of many important parts and components such as;

01. Steering wheel
02. Steering column
03. Bevel gear assembly
04. Electro-magnetic clutch
05. Tie rod
06. Rear Ackermann arm
07. Front Ackermann arm
08. King Pin Stub Axel Assembly
09. Tie Rod end
10. Steering pump etc.



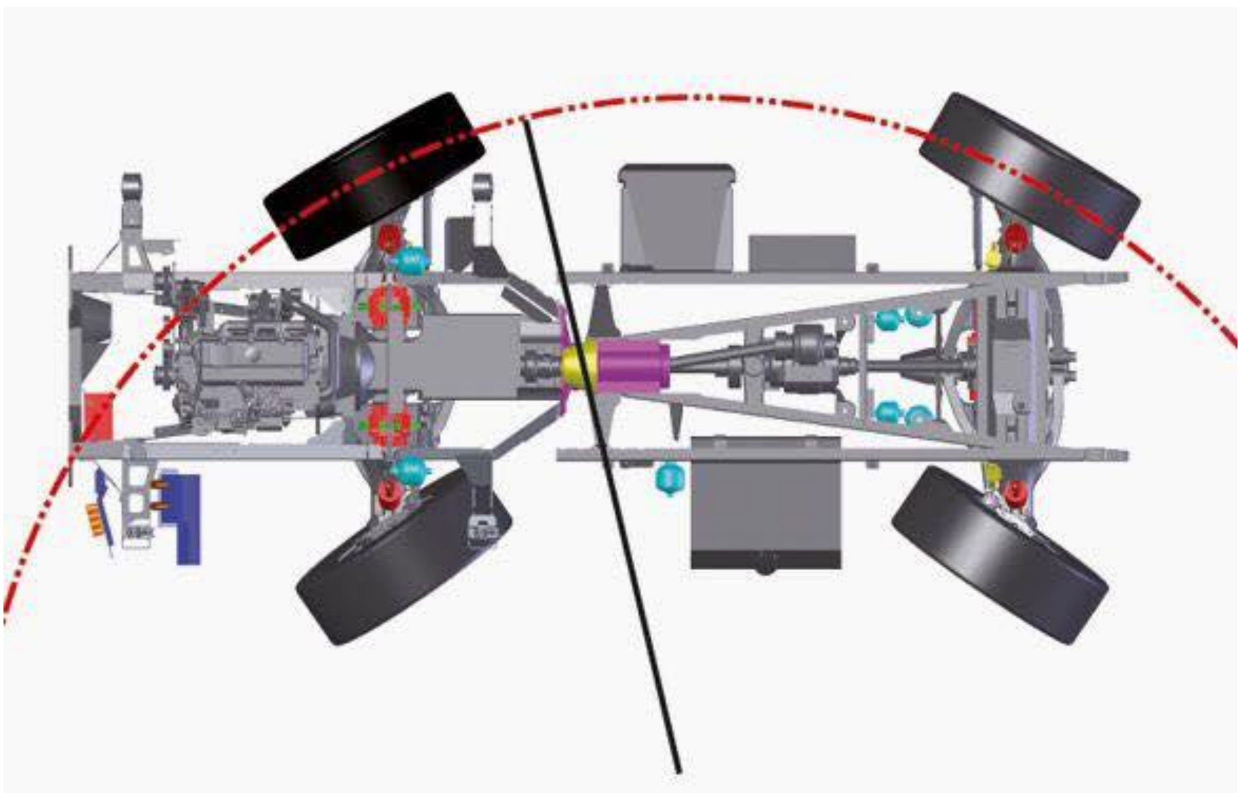
4.3. WORKING MECHANISM

Four-wheel steering is a mechanism that, when the steering wheel is turned, actuates the rear wheels' angles and either turns them in tandem with the front wheels or in the opposite direction to better increase a vehicle's low- or high-speed agility. We'll get into the different types of rear-wheel steering systems in a moment, but the general premise of these systems is using a set of hydraulic or electric actuators to change the toe of the rear wheels [1].

We have made both rear wheel and front wheel movable by the help of Ackerman steering system and due to that we have also connected both these by the help of link that are further connected to motor. To give the turning to the vehicle. We have used motor in terms of steering because of the compact size of the modal. For turning or as we can also say that for turning, we have used a DC motor in which gear are arranged to maximum torque can be exerted over the link to move the Ackerman Mechanism [10]. We have use L-type link to play the Ackerman mechanism and we connect a simple link to the L-type link to make the mechanism free to more. use of DC motor cannot use is hazardous & explosive conditions. It& initial cost is also high. It also makes the design heavy and robust in construction.

When the steering is steered, the power is transferred from the motor to the front rack and pinion steering gearbox, and a bevel gear arrangement is made to transfer the power to the rear rack and pinion steering gearbox. Bevel gear is used to transmit the rotary motion perpendicularly, so the one bevel gear is introduced in the front steering rod. Another bevel gear is connected to the transfer rod. Two supports are used to support the transfer rod. Transfer rod is connected to the rear rack and pinion steering gear box. Rear rack and pinion steering gear box is fixed to the car body by bolts and nuts and the ends of the steering box are connected to the rear wheel hub where the tyres are mounted. As the steering is steered the rear wheels also turn by the arrangements made and the rear wheel turn in the opposite direction by the arrangements in the bevel gear [4].

The vehicle comes in a situation where it needs all the four wheels to be coupled to the front steering wheel, a lever is provided next to the driver seat so as to engage the rear steering mechanism to the front steering mechanism by pulling up the lever Thus this engaging lever engages the front steering wheel to rear steering mechanism by the mechanical linkages provided in- between these two-wheel steering mechanism. Once the all four wheels of the vehicle get coupled to the steering wheel the steering wheel does its function and makes all the four wheels of the vehicles to steer simultaneously and the operation of four-wheel steering is performed. Once this process is over the wheels are brought back again to the straight position and the lever is pulled down to disengage the rear steering mechanism with the steering wheel and the vehicle again become a normal two-wheel steering system. Due to mechanical linkages, it can cause more vibration and noise to driver. It can't be adjusted. It also developed wear and backlash. [7]



As stated above that four-wheel will be move simultaneously by the help of kinematics of linkage. Four-wheel steering has been applied using Ackerman steering in both axles. As in front as well as in rear. As stated by Shakir, Mahadik and Singh (2017), "According to Ackerman steering system, geometric arrangement of linkages in the steering of a vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radius. The intention of Ackermann geometry is to avoid the need for tires of slip sideways when following the path around a curve" [4]. So, we have made both rear wheel and front wheel movable by the help of Ackerman steering system and due to that we have also connected both these by the help of link that are further connected to motor. To give the turning to the vehicle. We have used motor in terms of steering because of the compact size of the modal. For turning or as we can also say that for turning, we have used a DC motor in which gear are arranged to maximum torque can be exerted over the link to move the Ackerman Mechanism. We have use L type link to play the Ackerman mechanism and we connect a simple link to the L type link to make the mechanism free to more. And because of the link arrangement we have to make the mechanism possible to give high efficiency in terms of less power. So, we have designed the Mechanism first and then we implement our idea over that. We have attached two DC motor to rear axle drive to provide equal movement to both the wheel so that forward and backward motion of the vehicle can be done [8]. We have connected all the motor and arranged switched to provide the motion and turning by the help of circuit board. We used Iron Bar to connect link mechanism to each other and wheel that we use are of plastic and motor that we used in it are DC motor. With DC motors we connect a Gear Box to provide more torque so slide movement of steering can be done.

Normally, it will steer front two-wheels as done in most of the vehicles. The steer rod will be connected to the arrangement of rack and pinion which will convert circular motion of steering wheel into linear motion and thus directs the front wheel, but as the shaft is not inserted inside the serrated rod, thus the motion is not transferred to the rack and pinion arrangement at position 1' which is further connected to rear wheels. Thus, motion is only transferred to front wheels and hence only front wheels get steer.

In a position 2, shaft is already engaged fully when the vehicle is steering on front two wheels. It is not connected to rack and pinion arrangement for rear wheels, fig1, and position 1'. At the times, when driver wants his vehicle to steer on rear wheels too, rod, has to be pulled, which makes the two shafts partially engaged and engages its end to rack and pinion assembly for rear wheels, position 1'. As a result, speed is been transmitted and contact gets established, which in turn helps to steer rear wheels. Thus, this flexibility helps driver to drive smoothly.

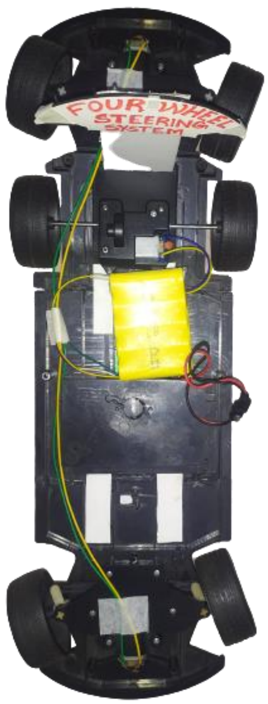


Fig: 1

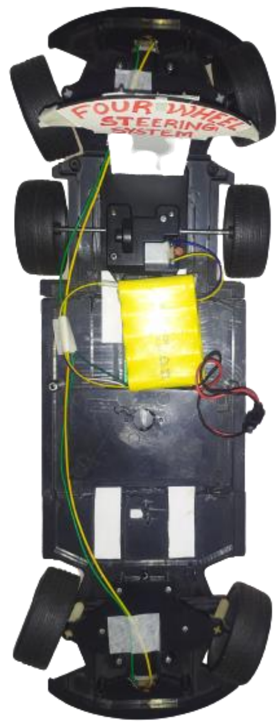
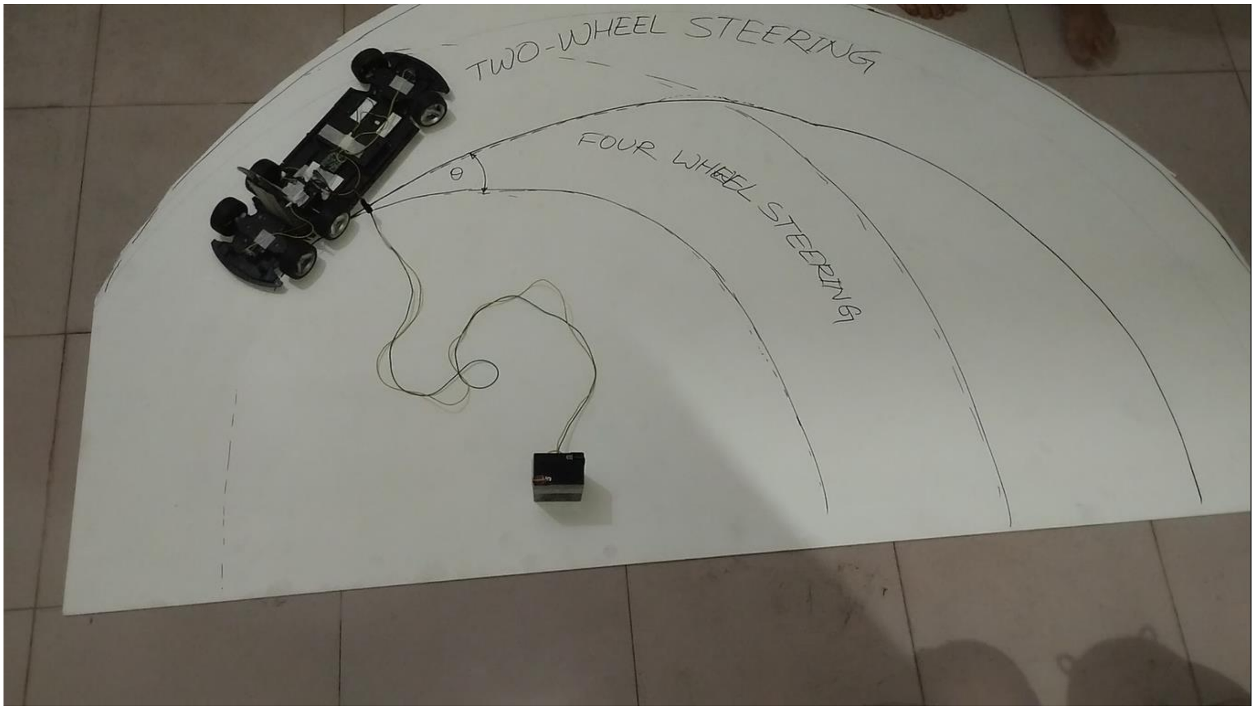


Fig: 2

In rear-wheel steering, the vehicle’s system changes both rear wheel’s toe in tandem, which means the rear wheels move right or left in unison so they’re pointed in the same direction. This is the complete opposite of how toe works on a vehicle’s front wheels



While each system is unique, the resulting movement from the rear tires in four-wheel steering is exactly the same across different systems. When the driver turns the steering wheel at low speeds, the front wheels turn in the direction of travel while the rear wheels turn in the opposite direction, effectively reducing the car’s turning circle. This makes low-speed maneuvers quicker and easier.

Steering at higher speeds turns both the front and rear wheels in the same direction for increased high-speed stability. What that means in the performance world is you can have a long, somewhat heavy vehicle such as a Porsche Panamera keep up with a sports car with a shorter wheelbase such as a Porsche 911.

These systems also give larger, heavier vehicles better performance than they would have if only the front wheels turned. This is seen in examples such as the Lamborghini Urus, Bentley Flying Spur, and the Mercedes-Benz S-class.

4.4. APPLICATIONS

According to Bevinkatti, Mali, Bayas, Ghadage and Anuse (2015), the application of four-wheel steering system is:

1. Parallel parking: Due to smaller turning radius the parking and un-parking of vehicle is easily performed towards the right or left side.
2. High speed lane changing: In this is less steering sensitive this does require a lot of concentration from driver since he has to judge the space and vehicles behind them.
3. Slippery road surfaces: Due to the rear wheel steering operation on low friction surfaces occurs hence vehicle direction easier to control.
4. Narrow Roads: Due to rear wheel steering on narrow roads with tight bends, counter phase steering reduces the turning radius.
5. U-Turns: By minimizing the vehicle's turning radius and counter phase steering of rear wheels enables U-Turns to be performed on narrow roads.

4.5. COMPARISON

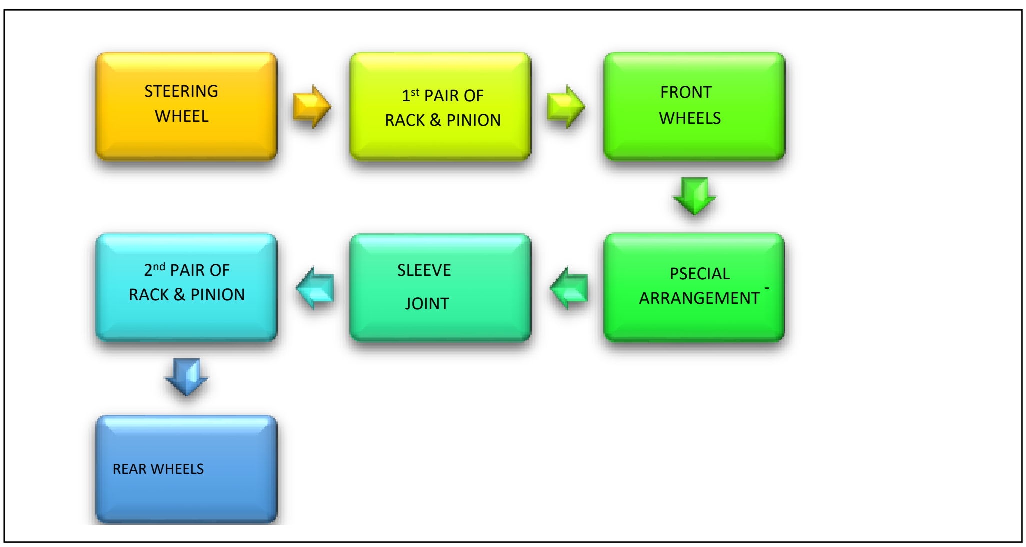
Four-wheel steering system has led to following benefits over the two-wheel steering system:

1. Four-wheel steering system can be employed to work as a two steering gear mechanism also so all the benefits of two-wheel steering are absorbed in the four-wheel steering system.
2. With the use of 4-wheel steering system vehicle becomes more efficient and stable while on corners.
3. Stability of 4-wheel steering system is more for straight line motion.
4. 4-wheel steering system provides smaller turning radius as compared to 2-wheel steering system.
5. This has led to greater reduction in driver efforts for turning a bigger vehicle.

5.1. CONSTRUCTION

The block diagram below that is drawn for the 4-wheel steering mechanism, shows the components of a steering system. The first component of the steering system is is steering wheel. It is connected to the front wheels through the steering shaft. Tie rod is a connection between the wheels and steering system. 1 st pair of rack and pinion is situated on the tie rod. The pinion is connected to the steering shaft. As steering wheel rotates, Pinion will roll along with the rack. The rack and Pinion arrangement attached with an intermediate shaft.

That shaft is cut into the two parts but it is always in engaged position whether it is fully engaged or partially engaged. It is a special arrangement used to vary the length. The shaft is further connected to the sleeve joint. Sleeve joint has serrations on the inner side up to the certain distance. Sleeve joint is used to increase the length of the shaft. It is further connected to the 2nd pair of rack and pinion. As shaft transmits the torque, Pinion will rotate and rear wheels of the steering system will move in a left or right direction.



5.2. BLOCK DIAGRAM

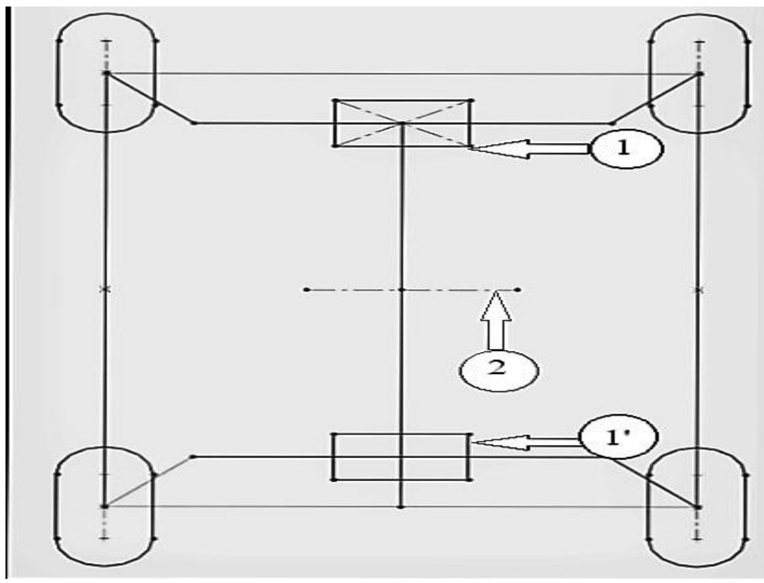


Fig: Line Diagram of Four-Wheel Steering Mechanism line diagram

In above fig shows the position of the mechanical assemblies. Position 1(for front wheels) and 1’ (for rear wheels) consist of rack and pinion assemblies each. Where the spur gear is used. Gear used is always in mesh with the rack. Where position 2 indicates special arrangement, which allows engaging in four-wheel steering mechanism [5].

Position 1 and 1’as in fig 2 comprises with rack and pinion, a rack and pinion is a type of linear actuator that comprises a pair of gears, (here spur gear) which converts rotational motion into linear motion

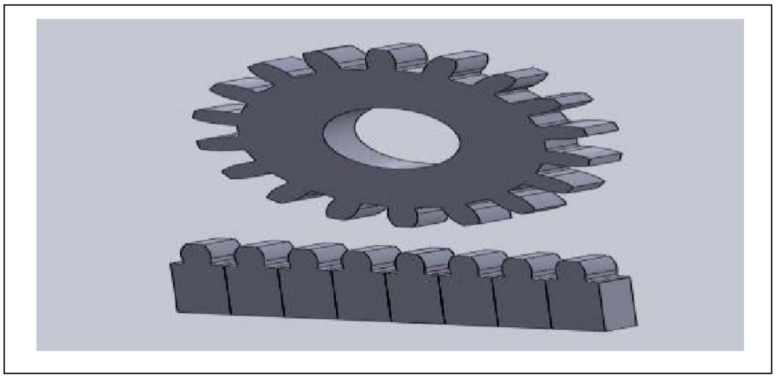
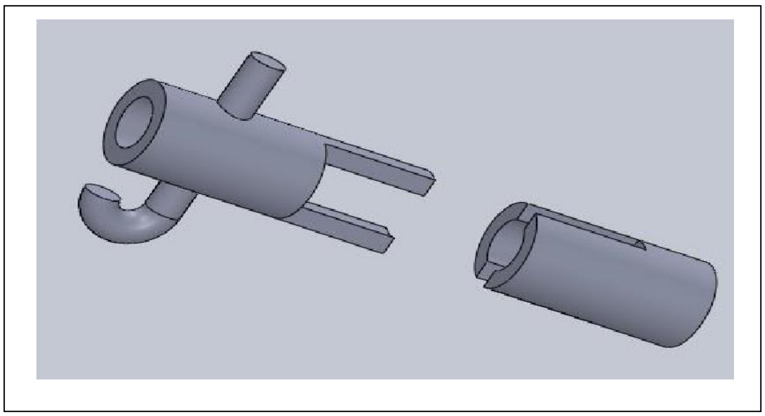


FIG 2: RACK AND PINION



In above design spur gear is used as it has a high-power transmission efficiency, which makes them ideal for preserving efficiency of the system. Manufacturing of spur gears is simple as compared to other gears and thus cost efficient, and serves the purpose [6].

These two assemblies are connected by an intermediate shaft. As shown in fig 1, position 2, a shaft is cut into two separate parts. Cut parts of the shaft have serrations on it, as in fig 4, up to the certain distance. There is a hole present in a shaft. A rod is placed in a hole. With the help of the rod, engagement and disengagement of the rear side rack and pinion occurs.

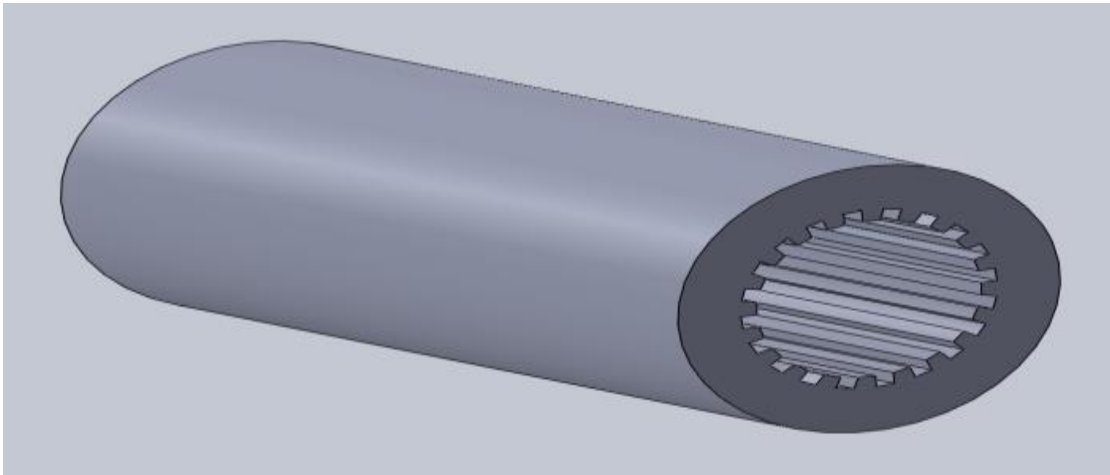
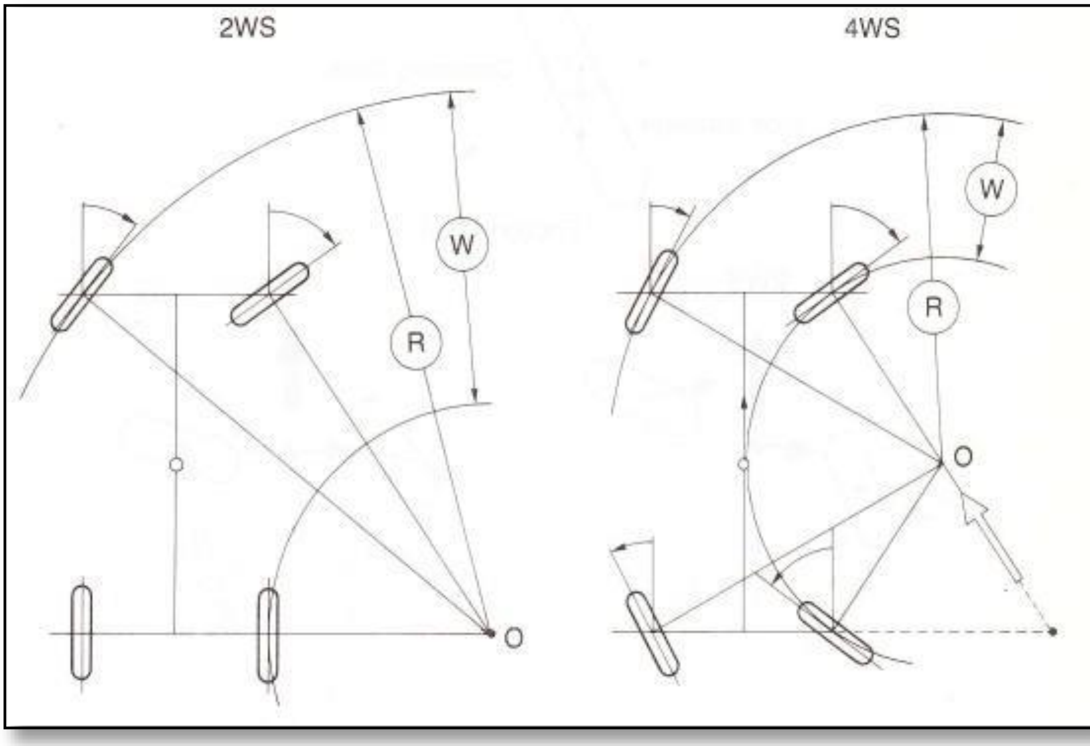


Fig: Serrated Rod

6. DIFFERENCE OF RESULTS BETWEEN 2WS AND 4WS

Parameters	**2 Wheel Steering System**	**4 Wheel Steering System**
Turning radius	4.77 m	3.3 m
Ackermann angle	13.18˚	25.09˚
Steering ratio	9.7:1	9.32:1
Outer front angle	25˚	42.35˚
Inner front angle	35.79˚	54˚
Outer rear angle	0˚	18˚
Inner rear angle	0˚	14.11˚



7.1. TYPES OF FOUR-WHEEL STEERING SYSTEM

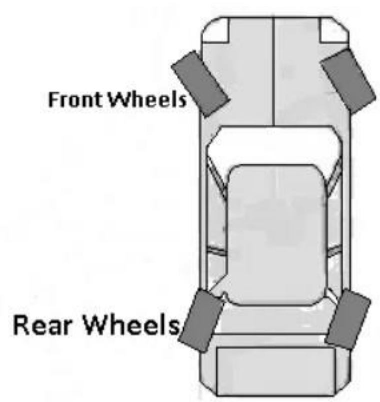
Four-wheel steering system operates in three modes which are

(i) Negative Phase

(ii) Neutral Phase

(iii) Positive Phase.

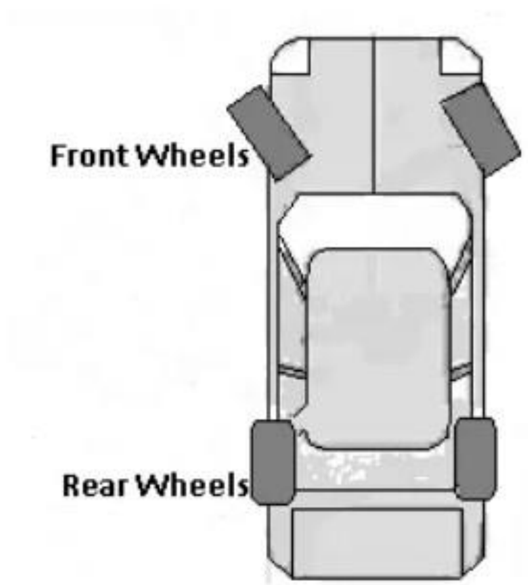
Negative Phase



Negative Phase

In negative Phase both the front and the rear wheels of the vehicle move in opposite direction with respect to each other. This type of mode is useful for slow driving case and a steep curve or during parking of the vehicle as this requires very less space for turning of the vehicle as compared to other modes. This mode is very much beneficial where traffic is a big problem.

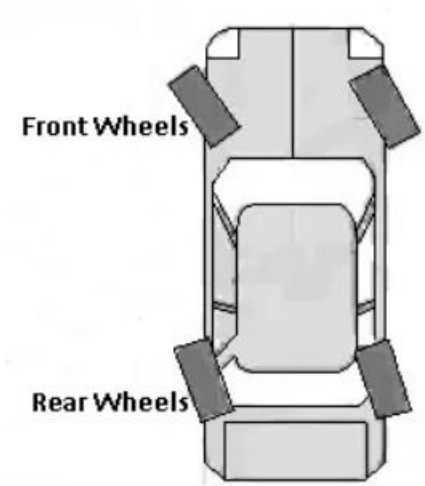
Neutral Phase



Neutral Phase

In neutral Phase only the front wheels are steered and the rear wheels remain straight. This mode is simply the conventional steering mechanism.

Positive Phase



Positive Phase

In positive phase the front and rear wheels rotate in the same direction. This mode is very much beneficial for the lane changing during driving at comparatively higher speeds.

All these 3 Phases can be brought in action as per our requirement. For this a lock nut can be provided in the main arrangement which will engage and disengage the positive mode or negative mode as and when required. When the lock nut is removed from the main arrangement the steering operation is carried out in normal conditions. In this normal condition only, front wheels will steer. When the lock nut is inserted into the engaging mechanism the other two modes can be used. When the locking nut is pushed to one position, the attached gears get engaged and the steering of rear wheel is provided in same direction as that of the front wheels. When the locking nut is pushed to other side secondary gears get engaged and the rear wheel steers in opposite direction to the front wheel. This results in negative mode steering.

7.2. FEATURES OF THE FOUR-WHEEL STEERING SYSTEM

The Four-Wheel 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. It allows the driver to do it in about 20 feet. A front wheel active steering function was added to Rear Active Steer adopted on the Fuga. By controlling the steering angle of all four wheels, this active steering system helps improve stability and response at high speed and helps reduce driver's steering workload at low speed. To achieve precise vehicle

- Vehicles move smoothly and are easy to drive both in the city and on winding roads.
- Added stability means vehicles can be driven safely on expressways and when changing lanes.
- Quick and responsive control system will allow gentle steering operation

7.3. AVOIDING AN OBSTACLE DURING EXPRESSWAY DRIVING

At high speeds, the four-wheel system avoids skidding in cars taking higher n sharper turns using ABS system. And at slow speeds, the four-wheel steering system helps in reducing v turning radius by 21% which has its applications in parking etc.

For parking and low-speed maneuvers, the rear Wheel steer in the opposite direction of the front wheels, allowing much sharper turns. At higher speeds, the rear wheels' steer in the same direction as the front wheels. The result is more stability and less body lean during fast lane changes and turns because the front wheels don't have to drag non-steering rear wheels onto the path.

The mechanism due to which the rear wheels turn one way at low speeds and another direction at high speeds can be controlled electronically or hydraulically too. The Japanese automakers have come up with an astonishing variety of technological solutions. Example: Mazda's 626 four-door sedan turns its rear wheels electronically. Sensors monitor the car's speed and its front-wheel angle and pass the information to an onboard computer, which determines in what direction the back wheels should turn. At speeds less than 22 mph, the rear wheels' counter steer; at more than 22 mph, their turn version is simpler but more limited. On its four-wheel steer, some models, now available in Japan, the rear wheels are incapable of counter steering, but they can turn with the front wheels in the same direction as the front wheels. Mitsubishi's

Galant at high speeds, the action is controlled hydraulically. The higher the oil pressure, the more sharply the rear wheels turn.

The 2002 Sierra Denali's turning radius is almost 10 feet smaller than the 2001 Sierra C3.

7.4. RECENT APPLICATION

Four-wheel steering found its most widespread use in monster trucks, where maneuverability in small arenas is critical, and it is also popular in large farm vehicles and trucks.

General Motors offers Delphi's Quadra steer in their consumer Silverado/Sierra and Suburban/Yukon. However, only 16,500 vehicles have been sold with this system since its introduction in 2002 through 2004. Due to this low demand, GM will not offer the technology on the 2007 update to these vehicles [10].

Previously, Honda had four-wheel steering as an option in their 1987-2000 Prelude, and Mazda also offered four-wheel steering on the 626 and MX6 in 1988.

A new "Active Drive" system is introduced on the 2008 version of the Renault Laguna line. It was designed as one of several measures to increase security and stability.

The Active Drive should lower the effects of under steer and decrease the chances of spinning by diverting part of the G-forces generated in a turn from the front to the rear tires. At low speeds the turning circle can be tightened so parking and maneuvering is easier [10].

1. New high-performance GT versions of New Laguna Hatch and Sport Tourer available to order in the UK from 9 May 2008
2. Featuring innovative Active Drive chassis with four-wheel steering for the ultimate in handling and response
3. Exclusively available with 205hp two-litre turbo petrol engine or 180hp two-litre turbo diesel – both making their debut in New Laguna
4. Prices start from £21,050 for the Hatch and£22,000 for Sport Tourer

5. New versions feature numerous sport stylingtouches, including: lateral air-intakes and larger front grille, new 18-inch alloy wheels, smoked rear light clusters and black background to the headlamps
6. Inside, the new models boast GT-embossed leather/ alcantara sports seats, drilled aluminum pedals, aluminum gear knob and GT steering wheel

8.1. ADVANTAGES OF FOUR-WHEEL STEERING SYSTEM

Better Steering Response: With four-wheel steering, your vehicle will undoubtedly respond faster when turning and switching lanes. More precise and controllable steering is safer for you, fellow drivers, and pedestrians. While it might not make a world of difference in everyday driving scenarios, it can when an unexpected obstacle is in your way.

Cornering Stability: When the roads are wet or icy, some corners can be quite challenging. Four-wheel steering will help your car complete corner turns with stability and control. With all four wheels turning, you're less likely to fishtail or get stuck.

Tighter Turning: Four-wheel steering means all wheel's steer. It doesn't mean that they all have to turn the same way, though! When you're able to turn the rear wheels in the opposite direction of your front wheels, this allows you to complete smaller circular turns at lower speeds.

Better on Tougher Terrains: Canadian winters can be pretty brutal. We're all aware of the benefits of four-wheel driving in the snow, but four-wheel steering can be equally helpful. If you're stuck in a patch of snow or hit ice while driving, four-wheel steering can help you re-gain control more quickly potentially saving you from an accident, with accompanying repairs. No one like to see their vehicle on the back of a tow truck!!

Straight Line Stability: When you're driving your vehicle on a straight road, four-wheel steering can still help. The system will give you the best stability imaginable and will let you handle potholes and high winds with minimal swaying.

Changing Lanes: When you're cruising on the highway and you need to change lanes quickly, all-wheel steering works like a dream. You can easily cross over without turning the wheel much at all and won't need to accelerate as much to maintain your speed.

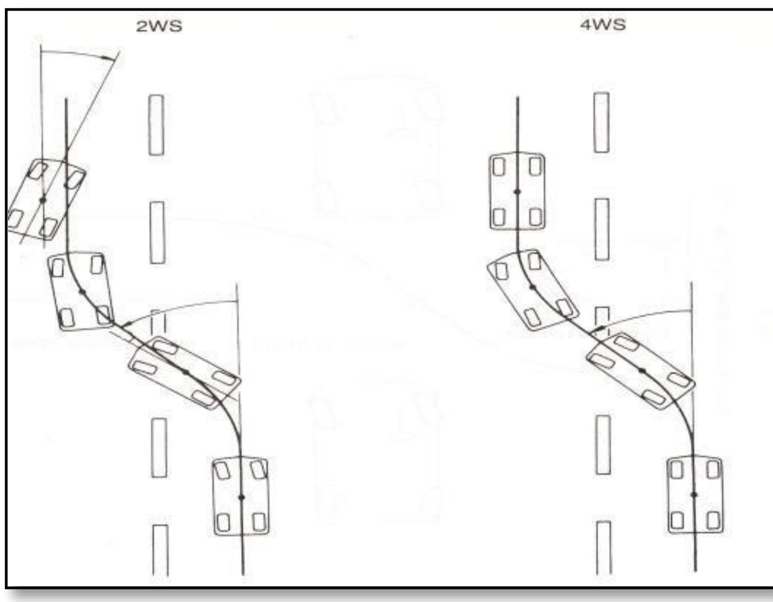


FIG: Lane change (

8.2. DISADVANTAGES OF FOUR-WHEEL STEERING SYSTEM

The Price Tag: As safe and useful as four-wheel steering systems can be, they also tend to be reserved for higher-end makes and models. They require a lot more components and calibration than traditional steering systems, and this carries an accompanying cost.

For reference, if we look at the cars currently offering four-wheel steering. Audi, BMW, Lexus, Porsche, Lamborghini, Ferrari, Mercedes, and Acura all have car models that offer four-wheel steering. They're all also Import vehicle manufacturers which tend to be more expensive to purchase and maintain overall.

Potential Repairs: At Master Mechanic we want you to be aware of what you're getting into. Since four-wheel steering systems have many mechanical and electrical components, if one malfunctions, your entire steering system could be compromised. Since they are more complex, four-wheel steering systems also tend to take more time to repair. While these costs may not be a deal breaker for a Ferrari driver, it's something you'll want to account for if it's a car that is your daily driver.

9. TURNING RADIUS CALCULATION FOR FOUR-WHEEL STEERING SYSTEM

We are using standard data of car Maruti Alto 800 as a reference.

Wheel track(t_w)	1300 mm
Wheel base (L)	2360 mm
Steering axis inclination (SAI)	12°
Scrub radius	7.8 mm
Ackermann angle (α)	13.18°
Tie road length (R)	972.5 mm
Inner steering angle	44°
Outer steering angle	31.5°
Turning radius	4.6 m
Steering ratio	9.7:1

Steering wheel lock to lock	610° or 1.69
Weight of car (W)	1140 kg
Weight Distribution	60: 40 (F: R)

1. Calculation of Inside Lock Angle of Front Wheels (θ_{if})

By Ackerman Mechanism, SIN (α $+\theta_{if}) = \frac{Y+X}{R}$

Where, α = Ackerman Angle = 13.18°

θ_{if} = Inside Lock Angle

Y = Arm Base = 1.368”

X = Linear Displacement of rack for one rotation of pinion

R = Tie-rod length = 6”

$\text{SIN}\ (13.18 + \theta_{if}) = \frac{1.368\ +3.1}{6}$

$\boldsymbol{\theta_{if}}$ **= 34.95°**

Therefore, Inside Lock Angle of Front Wheel is = 34.95°

2. Calculation of position of Centre of Gravity with respect to the rear axle

From the benchmark vehicle (Maruti 800) we know that turning Radius is 4.6 m.

We know that,

$R^2 = a_2{}^2 + R_1{}^2$ ----------------------(8.1) Where, R = Turning radius of the vehicle = 4.6m

(Standard Specification of Maruti)

a_2 = Distance of CG from rear axle

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

To find a_2

$W_f = \frac{w * a_2}{L}$ ------------------------(8.2)

Where, W_f= Load on front axle = 684 kg (On basis weight distribution)

W = Total weight of car = 1140kg

L = Wheelbase = 2.36m

Therefore,

$\boldsymbol{a_2}$**= 1.416 m**

Substituting the value of a_2 in the above equation (8.2)

$\boldsymbol{R_1}$ **= 4.377 m**

3. To find position of Instantaneous Centre from both the axles

From our standard calculations of 2 Wheel Steering,

θ_{if} = 34.95°

$\tan\theta_{if} = \frac{C_1}{R_1 - \frac{t_w}{2}}$ --------------------------------(8.3)

Where t_w = Front track width

θ_{if} = Inside Lock angle of front wheel therefore,

$\text{Tan } 34.95° = \frac{C_1}{4.377 - 0.65}$

$\boldsymbol{C_1}$**= 2.605 m**

$C_1 + C_2$ = R -----------------------------------(8.4)

Where, C_1 = Distance of instantaneous centre from front axle axis

C_2 = Distance of instantaneous centre from rear axle axis Therefore, C_2 = 4.6 – 2.605

C_2 = 1.995 m

Therefore, from equation (8.3) and (8.4) C_1= 2.605m

4. Find the remaining lock angles

To find tanθ_{of} = Outer Angle of Front Wheel

$$\tan\theta_{of} = \frac{C_1}{R_{1+\frac{t_w}{2}}} \quad \text{---------------------------------(8.5)}$$

$$\tan\theta_{of} = \frac{2.605}{4.377+0.65}$$

$$\boldsymbol{\theta_{of} = 27.4258°}$$

To find tanθ_{ir} = Inner Angle of Rear Wheel

$$\tan\theta_{ir} = \frac{C_2}{R_{1-\frac{t_w}{2}}} \quad \text{----------------------------------(8.6)}$$

$$\tan\theta_{ir} = \frac{1.995}{4.377-0.65}$$

$$\boldsymbol{\theta_{ir} = 28.1593°}$$

To find tanθ_{or} = Outer Angle of Rear Wheel

$$\tan\theta_{or} = \frac{C_2}{R_{1+\frac{t_w}{2}}} \quad \text{----------------------------------(8.7)}$$

$$\tan\theta_{or} = \frac{1.995}{4.377+0.65}$$

$$\boldsymbol{\theta_{or} = 21.6733°}$$

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.

5. Calculations for turning radius for same steering angle

To find turning radius, R

R = $\sqrt{{a_2}^2 + L^2 cot^2 \delta}$ ----------------(8.8)

Where, δ = Total steering angle of the vehicle

To find δ cot$\delta = \frac{(cot\,\theta + cot\,\phi)}{2}$ ----------------------(8.9)

Where, θ = total inner angle of the vehicle ϕ = total outer angle of the vehicle

Therefore,

cot$\delta = \frac{cot\,(34.35+28.16) + cot\,(27.426+21.674)}{2}$

Thus, cotδ = 0.69325°

Therefore, substituting the above values in equation (8.10)

R = 2.838 m

We put this above value of R in equation (8.1), to get the new value of R_1 2, i.e., $R^2 = a\,^2{}_2 + R_1$

R_1 = 2.461 m (For the new value of R)

$$1.249 = \sqrt{2 - 2COS\,(\frac{720}{n})}$$
$$1.559 = 2 - 2COS\,(\frac{720}{n})$$
$$0.441 = 2COS\,(\frac{720}{n})$$

C_1 and C_2 COS $(\frac{720}{n})$ = 0.2204

Considering the turning radius as 2.838 m, Further calculation for C_1 and C_2 from equation (8.3) and (8.4)

$\tan\theta_{if} = \frac{C_1}{R_1 - \frac{t_w}{}}$

$C_1 + C_2 = R$

C_1 = 1.238 m

C_2 = 1.6 m

Therefore, considering the new values of we find that the inside and outside lock angle of front and rear wheels is as follows:

Thus, re-substituting the new values of C_1 and C_2 in equation (8.3), (8.5), (8.6), (8.7) to get the final values of Inside and Outside Angles, this is as follows:

$\tan\theta_{if} = \frac{C_1}{R_{1} - \frac{t_w}{2}}$ $\tan\theta_{of} = \frac{C_1}{R_{1} + \frac{t_w}{2}}$

$\tan\theta_{ir} = \frac{C_2}{R_{1} - \frac{t_w}{2}}$ $\tan\theta_{or} = \frac{C_2}{R_{1} + \frac{t_w}{2}}$

θ_{if} = 34.95° (Inside Lock Angle of Front Wheel)

θ_{of} = 21.7° (Outside Lock Angle of Front Wheel)

θ_{ir} = 44.46°(Inside Lock Angle of Rear Wheel)

θ_{or} = 27.22° (Outside Lock Angle of Rear Wheel)

Therefore,

$\theta = \theta_{if} + \theta_{ir}$

θ = 34.95° + 44.46° = 79.41(Total Inner Angle of the Vehicle)

$\phi = \theta_{of} + \theta_{or}$

ϕ = 21.7°+ 27.22° = 48.92° (Total Outer Angle of the Vehicle)

$\cot\delta = \frac{(\cot\theta + \cot\phi)}{2}$

$\cot\delta = \frac{(\cot\ 79.41° + \cot\ 48.92°)}{2} = 0.529$

Therefore, substituting the above value in equation (8.8)

R = 1.89 m Thus, the Turning Circle Radius of whole car = 1.89 m

Thus, here we can see that the original Turning Circle Radius of 4.6 m is reduced to 1.89 m, i.e., the total reduction in Turning Circle Radius of the car is 58.95%.

6. Calculation of Steering Ratio

Steering Ratio of car is calculated by the following formula: R = $\frac{S}{\sqrt{2-2COS\left(\frac{2a}{n}\right)}}$

Where, R = radius of curvature (same as units of wheelbase) = 1.89 m = 74.41”

R = wheelbase = 92.91339” a = steering wheel angle = 360°(assumed for one rotation of steering wheel)

n = steering ratio (E.g.; for 16:1 its 16)

$$74.41 = \frac{92.91339}{\sqrt{2-2COS\left(\frac{720}{n}\right)}}$$

$$\left(\frac{720}{n}\right) \overset{n}{=} 77.27$$

n = 9.32

Thus, the steering ratio of our car is 9.32:1, i.e., for 9.32° of rotation of steering wheel the tire is turned by an angle of 1°. Thus, from the above obtained value of Steering Ratio, we can conclude that driver has to apply less effort to turn the car, giving much better maneuverability and control on the car.

10. FUTURE SCOPE

Having studied how 4WS has an effect on the vehicle’s stability and driver maneuverability, we now look at what the future will present us with. The successful implementation of 4 Wheel

Steering using mechanical linkages & Electro-magnetic Clutch will result in the development of a vehicle with maximum driver maneuverability, uncompressed static stability, front and rear tracking, vehicular stability at high-speed lane changing, smaller turning radius and improved parking assistance. Furthermore, the following system does not limit itself to the benchmark used in this project, but can be implemented over a wide range of automobiles, typically from hatchbacks to trucks. With concepts such as “ZERO TURN” drive as used in, Tata Pixel and “360º Turning” used in, Jeep Hurricane, when added to this system, it will further improve maneuverability and driver’s ease of access.

11. CONCLUSION

As per the focus of the project we have created an innovative 4-wheel active steering mechanism which is feasible to manufacture, easy to install and highly efficient in achieving in-phase and counter-phase rear steering with respect to the front wheels using Electro-magnetic Clutch.

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.

Moreover, components used in this system are easy to manufacture, material used is feasible, reliable and easily available in market. The system assembly is easy to install and light in weight and can be implemented in all sections of cars efficiently.

Our 4 Wheel Steering System gives 35% reduction in turning circle radius as per kinetic analysis and gives 58% reduction in turning circle radius as per design of system. In analysis results of all parts get safe in safety limit with application of necessary material.

12. REFERENCES

1. V. Arvind, "Optimizing the turning radius of a vehicle using symmetric four-wheel steering system", International Journal of Scientific & Engineering Research, Volume 4, Issue 12, December-2013, ISSN 2229-5518.
2. Saket Bhishikar, Vatsal Gudhka, Neel Dalal, Paarth Mehta, Sunil Bhil, A.C. Mehta, "Design and simulation of 4-wheel steering system", International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 12, June 2014, ISSN: 2277-3754
3. S. Nithyananth, A. Jagatheesh, K. Madan, B. Nirmal Kumar
"Convertible Four Wheels Steering with Three Mode Operation", International Journal of Research in Aeronautical and Mechanical Engineering, Volume 2, Issue 3, March 2014, ISSN: 2321-3051
4. Shijin T. G., Sooraj V. T., Shuaib A. V., Shirin P. R., M. Dinesh "Four Wheels Steering Control with Three Mode Operation", International Journal of Research In Aeronautical and Mechanical Engineering, Volume 2, Issue 3, March 2014, ISSN: 2321-3051
5. Automotive engineering power train chassis system and vehicle body (edited by David A. Crolla and published by ELSEVIER)
6. Automobile engineering (J. P. Hadiya, H. G. Katariya and published by BOOKS INDIA)
7. Chetan Dhuri, Aditya Masur, Aniket Warang & Aditya sudhir "Selection, Modification and Analysis of Steering Mechanism for an All-Terrain Vehicle", International Journal on Theoretical and Applied Research In Mechanical Engineering (IJTARME), Volume 2, Issue 4, 2013, ISSN: 2319-3182.
8. Boby George, Akhil T Benny, Albert John, Aswin Jose, Denny Francis "Design and Fabrication of Steering and Braking System for All Terrain Vehicle", International Journal of Scientific & Engineering Research, Volume 7, Issue 3, March-2016, ISSN 2229-5518.
9. www.irjet.net/journal/4ws; Impact Factor value: 6.171; ISO 9001:2008 Certified Journal
10. www.google.com/search?