



“ZERO-TURNING STEERING SYSTEM”

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ABSTRACT- The design and fabrication of ZERO-degree wheel rotation vehicle using DC motor and steering is done to reduce time to turn from one direction to other direction. This vehicle can move in all direction at a same position by used of steering, sprocket, DC motor, bearing and chain drive. Main function of this vehicle is easy to move from one direction to other direction. Modern development and economical progression of Indian society resulted in increase of people on railway platform; increase of vehicle on the road, due to space constraints, in hospital is major problem of the country. Present study aims for development of a system to reduce the turning radius of vehicle. In this system at first vehicle is stopped and wheels are then turned in the required direction with help of steering system and DC motor. It has turning radius nearly equal to negligible of length of the vehicle itself. This vehicle used to carry the goods in various areas such as, railway platform, hospital, industries and market.

Keywords: Zero-turning steering system, DC Motor, Ackermann mechanism, Pneumatic Cylinders

INTRODUCTION-

In present world of industrialization and fast-growing population automobile has become basic necessity for transportation of goods and passengers. The market demand, more than 3.9 million automotive vehicles were produced in India in 2015 and in 2019 production was 4.1 million units. According to society of Indian Automobile manufacturers, annual vehicle sales are projected to increase to 5 million by 2018. Fuel economy, aesthetic features, ergonomics spare available and other features are focused by the companies. Now days, companies are providing the car at minimum cost such as Tata Nano. In power steering, by means of pneumatic, hydraulic or electrical system the front wheel steering is easier. Power steering reduces the efforts required to steer the vehicle. But the turning circle radius of the vehicle doesn't reduce. In many or all vehicles are steered by turning the front wheels in desired direction, while rear wheels following there are several problems of parking at public places, parking at home, parking at multiplexes and traffic jam etc. So, to overcome this problem, main aim is to developing the system having minimum turning radius or required minimum turning space. Zero turn vehicles mean the vehicle rotating about axis passing through Centre of gravity of vehicle. Vehicle do not require extra space to turn, so the vehicle turns in the space equal to longest length of vehicle itself. Longest length acts as a diameter for zero turn of vehicle. Turning radius of conventional steering is large in normal vehicle. But in zero turn vehicle the outer turning radius of vehicle is reduced. Zero turn vehicle is the name itself giving the meaning that a vehicle takes the sharp turn with zero turning radius and follow exact circular path without leaving its vertical axis passing through the center. The zero-radius wheel steering arrangement is best suitable when there is very less space in between the two parked vehicles of the order of nearly equal to the size of the vehicle and we required to park the vehicle then using zero radius wheel steering we can do the task in the available space suitably.

SR N O	YEAR	AUTHOR	MAJOR FINDINGS
1	2012	Hsien Yu	Study on power train of two axles four-wheel drive electric vehicle. The works include mechanism and design for clutch less AMT, optimal transmission gear shifting design and finally power split strategy design in 4wd.
2	2013	Lohith	Development of 4-wheel steering system for a car. The main aim of this project is to turn the rear wheels out of phase to the front wheels.
3	2014	Schwab	Balance and control of a rear-wheel steering speed record recumbent bicycle. This shows that one can design a rear wheel steered bicycle which shows a stable forward speed range. It is shown that rider steer torque stays with in human bounds.
4	2015	Pushkin Gautham	Selectable all wheel steering for an ATV. In this, the engagement and disengagement of 4-wheel steering can be done as per driver requirement.

ZERO TURNING RADIUS VEHICLES- Zero turn vehicle takes the sharp turn about a vertical axis passing through its center of gravity. For zero turn vehicle there is no need of additional space the vehicle rotate in the circle having diameter equal to its length. The requirement of additional space is neglected. This system is used in jeep hurricane, Tata nano pixel, JCB, lawn mower.

LITERATURE SURVEY- Till date no such commercially developed car is been introduced but there some concept cars which are available.

Other literature surveys are as follows:

TATA PIXEL

The Tata's concept Pixel is able to maneuver and park in tight spaces due to the zero turn radius traction-drive, and due to its steering system design. This results in a turning circle radius of 2.9 meters. The steering and the transmission work together so that each wheel is driven independently with inputs from the steering system. By applying reverse drive on a single rear wheel and forward drive on a single front wheel, the car is able to turn almost in its own length.

The Tata Pixel is based upon the Nano Europa concept which was first shown at the 2009 Geneva Motor Show. For the Europa concept, Nano was upgraded to meet EU safety and emission standards, the concept had a number of improvements over the standard Nano, including an

extended wheelbase, a new 3- cylinder engine, power steering, an anti-lock braking system (ABS), an improved interior and exterior and it was also heavier than the standard Nano.

The Tata Pixel features a start stop hybrid and regenerative braking system, with a fuel efficient and low emission diesel engine. It has CO₂ emissions of 89 gm/km and combined cycle fuel economy of 1 litre/100 km. The Tata Pixel features a monographic roof, silver shaped window graphic and forward sweeping roof line. It also features 2 scissor doors for easy access and visibility.

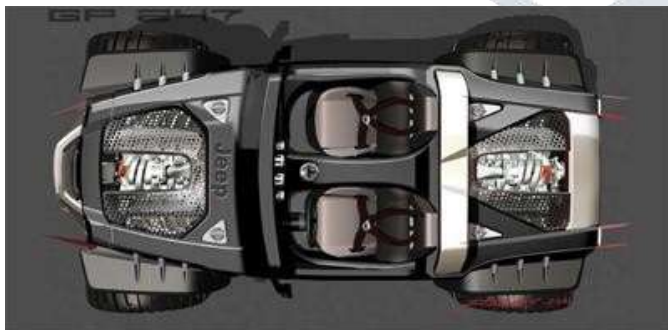
TATA MOTORS DESIGN



JEEP HURRICANE

The Jeep Hurricane, which has multiple steering modes using four-wheel independent steering. That means that each wheel can turn independently from the others. The jeep hurricane can actually rotate in place. The Jeep Hurricane which has many steering modes using four-wheel independent steering. Each wheel can turn independently from the other. The vehicle has two modes of four-wheel steering. In first mode front tires and rear tires. turns in opposite direction and reduces the turning circle. In second mode, front and rear wheels turn in same direction for crab steering, which facilitates parking at narrow space without changing the direction. The jeep hurricane, can actually rotate in place. The Jeep hurricane has some limitations like requirement of skilled driver, complex steering system wear of tire.

The Hurricane is more than just a Super Jeep. It also represents an attempt by Chrysler's engineers to combine excess (it does have two HEMI engines) with responsibility (new technology allows the Hurricane to operate on as few as four cylinders). The Hurricane's steering system is a marvel of engineering all by itself. There are multiple steering modes using four-wheel independent steering. That means that each wheel can turn separately from the others.



Problem Statement

- Large turning radius of the vehicle and space is the only constrain.
- Difficulty in steering in heavy traffic areas.
- Time and fuel consumed is more like in case of parallel parking.
- Extra efforts encountered in trucks and buses while steering in city which also creates roadblocks and traffic jam.

- Due to increasing demand and supply of cars, roads are over flowed by vehicles. There is severe problem of parking at home, parking at public places and multiplexes, traffic jam etc.

Why '0' turning System

- This system can increase the steering responsiveness.
- Increases the vehicle stability when moving at a certain speed.
- It gives high traction into consideration like in case of heavy traffic areas or in areas of tight space.
- Reduces the total time and fuel consumption like in case of parallel parking scenario.



DESIGN

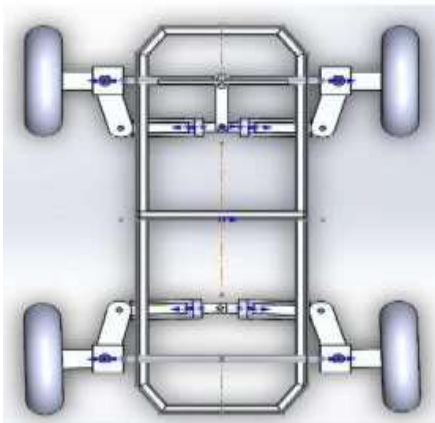


Fig shows the construction of the prototype in which one cylinder is incorporated in each of the wheel for zero turning purpose. A point to be noted is that the alignment of the rear wheel is similar to that of front wheel so as to facilitate zero turning. The piston is mounted on one of the steering links and both of them become a rigid part of that link. Thus, the whole link along with the cylinder can be moved while normal turning of the vehicle.

The connection of the wheel is same as that of the normal cars Ackermann mechanism is implemented for the system. The selected mechanism can also be replaced by hydraulic components so as to overcome higher forces of the vehicle as pneumatic components have limited force handling capability.

Calculations

Turning calculation

The dimension of the prototype was measured to be as given below:

Wheelbase = 50cm

Track-width = 50cm

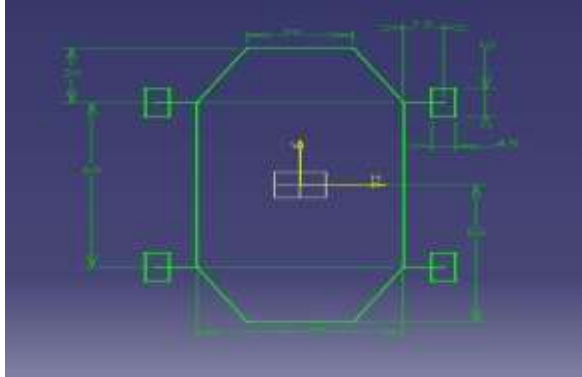
Frame length = 67cm

Frame width = 39cm

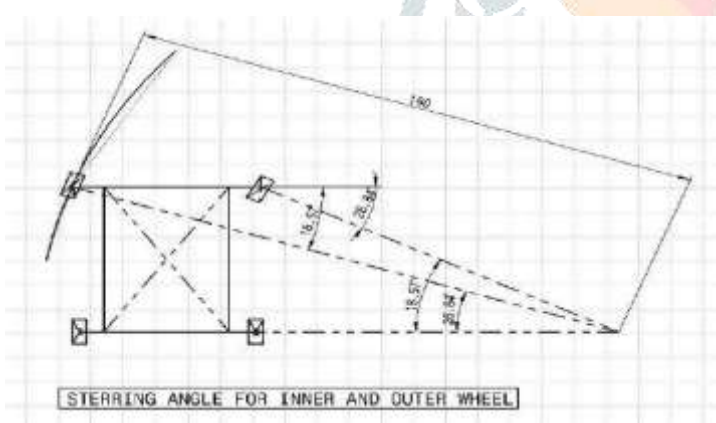
Distance of Instantaneous

Centre from rear left wheel = 50cm

As evident from the figure, the instantaneous centre falls at the geometric centre of the prototype, and as a result, the path of the wheels, trace a circular path. The lines produced from the inclined wheels meet at the centre. The steer angles for the inner and outer wheels during normal steering operation were also obtained, as seen below



The axis of the rear wheels was produced to either side of the vehicle. The steering was then turned to achieve maximum steer condition, and the axis of the front wheels were produced backwards. The axis of the front left wheel and the front right wheel met at a point on the rear wheel axis produced towards one side, 3.78 m from the left wheel. This was obtained while measuring the conformity of the steering system with Ackermann 's condition for stability. The inner wheel 's steering angle was measured to be $\theta = 26.84^\circ$, and that of the outer steering wheel as $\phi = 18.57^\circ$. The stability conditions for the mechanism confirm to Ackermann 's conditions.



The average steering angle was calculated as

$$(\phi + \theta) / 2 = (18.6 + 26.8) / 2 = 22.7^\circ$$

The outer wheel turning radius was calculated as

$$\sqrt{(x^2 + l^2)} = (1.8^2 + 0.39^2) = 1.84 \text{ m}$$

x = distance from point of intersection of front wheels on rear wheel axle produced to left rear wheel

l = wheel base of prototype

The inner wheel turning radius was calculated as

$$\sqrt{((x-w)^2 + l^2)} = \sqrt{((1.8-0.39)^2 + 0.39^2)} = 1.46 \text{ m}$$

w = track width of prototype

The condition for stability of a vehicle having Ackermann Steering Mechanism incorporated in it is given by the relation $\cot \phi - \cot \theta = w/l$

The w/l ratio of the prototype is $0.39 / 0.39 = 1$.

$\cot \phi - \cot \theta = \cot 18.6 - \cot 26.8 = 1.000360$ Thus, we can see from above that the equation $\cot \phi - \cot \theta = w/l$ is satisfied and hence the prototype is stable under Ackermann steering condition

Cylinder Calculation

Pressure on piston = 0.274 MPa

Dia. Of piston = 50 mm

Force = $P \times A = 537.725 \text{ N}$

Power N = 1793 rpm

Wheel dia (d) = 325 mm

$V = 30.5 \text{ m/s}$

Total time taken to react

Top speed = 10 sec

$V = u + at$

$a = 3.5 \text{ m/s}^2$

Force on moving vehicle = $635 \text{ kg} \times 3.5 \text{ m/s}^2 = 2222.5 \text{ N}$

Rolling Resistance (fr) = μmg

($\mu = 0.015$)

$Fr = 0.015 \times 635 \times 9.81 = 93.44 \text{ N}$

Total force = $93.44 + 2222.5$

$= 2315.94 \text{ N}$

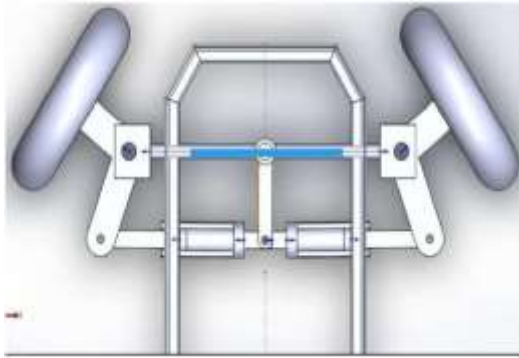
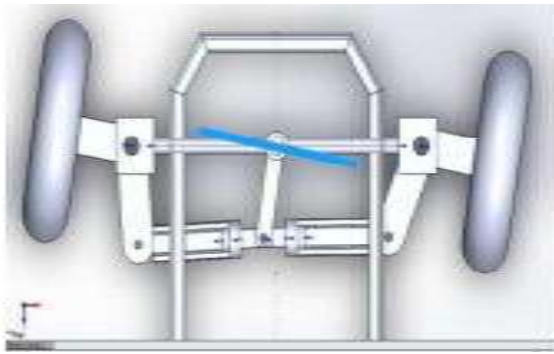
Power required = Force \times Velocity

$= 2.15.94 \times 305 = 70636.17 \text{ W}$

$= 70.636 \text{ kW}$

WORKING

Initially the pneumatic piston cylinder is connected between the track rod of the steering system such that one piston rod end is connected to one wheel and the other piston rod end is connected to another wheel. Both of the pneumatic cylinders are connected to the common joint of steering mechanism as shown in fig above. Pneumatic cylinders used are of double acting type, during the retracted position of pistons that is during normal steering, both of the cylinders combined with the track rod forms one rigid rod, hence it helps the driver steer during normal condition of steering. The compressed air from the receiver tank is passed through the compressor to cylinders therefore there is continuous pressure exertion on pistons that helps in maintaining rigidity. Rear wheels are equipped with universal joint and piston cylinder arrangement are connected in same fashion as that of front wheels but except in rear wheels case, they are fixed to one common point of the chassis. As soon as the driver is in need of requirement of zero turning mode, he has to operate the mechanical hand lever of the pneumatic system that can be mounted in dash board of the vehicle to initiate zero turning process. The air supply on operation of hand lever reverses. And the piston cylinder gets expanded to their specified distance. All the cylinders are actuated at same time and speed. Piston rod end is connected to tie rod of wheels and expansion of rod makes the wheel align in such a way that rear wheels are the mirror image of front wheels. Thus, facilitating the zero turning mechanism. For actuation of zero turning mechanism the steering wheel should be aligned straight for its smooth operation of mechanism.



COMPONENTS USED

Basic components

The basic construction and main components of the Zero turn vehicle is given below,

Basic frame:

The hollow square pipes of material of mild steel are selected for the frame. The pipes are cut into required size by cutting machine. The end of the pipes cut into 45 degree to form rectangular frame. After cutting, the end of the square pipes is grinded so that it became smooth and convenient for welding.

The square pipes are welded together to form a rectangular basic frame.

D. C Motor:

Electric motor is machine which convert electric energy into mechanical energy. Its action is based on the principle that, when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. Whose direction is given by Fleming's Left-Hand Rule.

Pneumatic Cylinders

In pneumatic cylinder power of compressed gas is used to produce reciprocating linear motion. Hydraulic cylinders having piston which move in a desired direction and piston rod transfers the force which is developed to the object. Because, the operating fluid is a gas, leakage from the pneumatic cylinder will not drip out and contaminate the surrounding. So, it is desirable where cleanliness is required.

Direction Control Valve

Direction control valves are used for distribution of energy to various actuators by controlling the direction of flow of the pressurized oil or gas in the system. Generally, DCV controls the fluid flow.

Hose

Hoses are made completely flexible to carry high pressure compressed air.

Links

A link is a rigid body which has two nodes which are used to attach other links.

Linkages are the basic for all mechanisms. Linkages are made up of links and joints. Types of links depending upon nodes

Binary link - with two nodes. Ternary

link – with three nodes. Quaternary

link - with four nodes

A joint is used to connect two or more links, which gives some motion between the links which are connected. Joints are also called kinematic pairs. These can be classified in several ways:

1. By the type of contact in between the two, points line, elements or surface.
2. By the number of degrees of freedom at the joint.
3. By the type of physical closure of the joint: either force or form closed.
4. By the number of links joined.

The term lower pair describes joints with surface contact as with a pin enclosed by a hole and the term higher pair describes joints with point or line contact. However, if clearance is present between pin and hole must be for motion, surface contact in the pin joint actually becomes line contact, as the pin contacts only one side of the hole. Likewise, at a microscopic level, a block sliding on a flat surface actually has contact only at discrete points, which are the tops of the surfaces' asperities. The advantage of lower pairs over higher pairs is their better ability to trap lubricant between their enveloping surfaces. This is especially true for the rotating pin joint.

The lubricant is more easily squeezed out of a higher pair, none developing joint. As a result, the pin joint is preferred for low wear and long life, even over its lower pair cousin, the prismatic or slider joint. The revolute and the prismatic pairs are the only lower pairs usable in a planar mechanism. The screw, cylindrical, spherical, and flat lower pairs are all combinations of the revolute and/or prismatic pairs and are used in spatial mechanisms.

Adapter:

Adapter is used to convert AC current supply to DC current supply. It can be very useful for thermal protection,

overload protection etc. it can also protects from short circuit.

Wheels:

Wheels are the end link of the vehicle which gives direct output of the system.

They are move on a ground

having rubber coating to outer side of the wheel for gripping. It carries whole weight of the vehicle.

PERFORMANCE ANALYSIS

The performance analysis of zero turning radius vehicle has clearly show that it is more efficient, economical and effective. In this project forward and backward movement of the vehicle and turning of the rear wheel of the vehicle are getting power from the pneumatic cylinder in the form of pressure. This essential pressure is produced by the compressed air coming from air compressor and transmitted to the pneumatic cylinders by the means of tubing, this result in less noise, negligible wear of components and less vibration. Use of flow control valve, silencers, regulator and pressure gauge provides a controlled flow of compressed air towards the pneumatic cylinders. Most of the time people are facing problem in parking and turns in congested areas because conventional vehicle needs more space to turn from one direction to another. But zero turning radius vehicle solves this problem easily. Because this vehicle has the ability to turn, on its axis which require very less space to turn. In this project a 12V/250PSI air compressor is used with double acting air actuator of bore 16mm, stroke

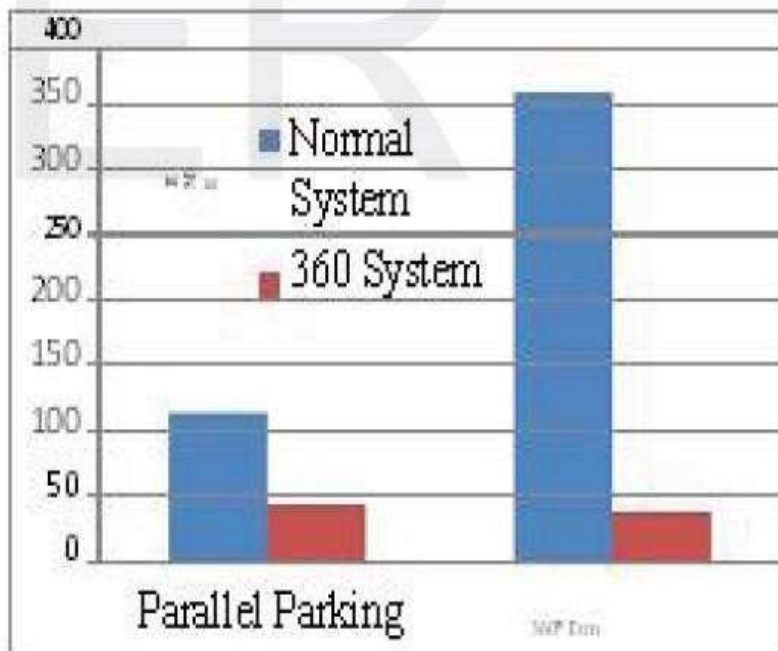
175mm but vehicle is able to carry more load and turning mechanism will response fast if use higher power compressor.

TIME ANALYSIS

The time taken for both - 360° steering mechanism and normal steering mechanism for two operations were recorded. The first operation was parallel parking and the second was the turning of the vehicle in 360°.

The obtained readings are as follows:

	Time Taken for 360° Mechanism	Time Taken for Normal Steering
Parallel Parking	45 seconds	116 seconds
360°	21 seconds	188 seconds



ADVANTAGES

- It consumes very less time to turn from one direction to other direction.
- It is more efficient compare to other type of load carry vehicle.
- This type of load carry vehicle is easily parked in any direction.
- It is less costly load carry vehicle.
- Eco friendly.
- Less noise operation.
- Battery operated thus no fuel required.
- More efficient.
- Battery is using in this 390-degree wheel rotation vehicle to move forward and backward, so it is a kind pollution free vehicle.

DISADVANTAGES

- This type of load carry vehicle is not applicable to carry more weight.
- Battery power is required to move of the vehicle.

APPLICATIONS

- In Industries for automation of raw material like automated guided vehicle.
- In automobile sector there are so many types of vehicle are using to carry goods from one position to another position, there is space problem in the industry so this vehicle is used in automobile applications because this vehicle consumes very less space compare to other type of vehicle.
- This vehicle is used in small Industries for transportation of raw material from one position to another position.
- Modern development and economical progression of Indian society resulted in increase of vehicle in park so there is also problem. In park other vehicle are taking more space to move from one direction to other direction and 390-degree wheel rotation vehicle have capability to move parallel direction so this vehicle is easily move from one direction to other direction in park.
- Take easily U-turn because front wheel of this vehicle is rotating freely by steering, chain drive and sprocket arrangement.
- It is used in hospitals to carry the patient from one room to another room. Because there are lots of patients those are staying in one room.

EXPECTED OUTCOME

A vehicle with higher turning radius face difficulty in parking and low speed cornering due to its higher wheelbase and track width, in this scenario zero turning steering will be effective as the turning radius of turning decreases time required for turning the vehicle and path which the vehicle covers while taking turns decreases.

The zero turning vehicles are designed such a way that it can be changed from four-wheel steer to two-wheel steer whenever required. This four-wheel steer is designed only for the parking purpose, so when the vehicle has to move at a speed higher than 10 kmph it has to be in two-wheel steer so the vehicle will be designed such that it can be converted to four-wheel steer in parking and again back to two-wheel steer.

Compared with a conventional two-wheel steering system, the advantages offered by a zero turning steering system include:

- Improved steering responsiveness and precision.
- Low initial cost of investment.
- Help in taking turn along area equal to length of vehicle.
- Smaller turning radius and tight space maneuverability at low speed.
- Easy installation of system reducing the complexity as compared to other concepts.
- Time and fuel consumed will be less like in parallel parking scenario.

FUTURE SCOPE

As advancement is a compulsion in technology there's always a way to progress. Further this concept of zero radius turning is simple, easy to install and it is not even bulky. Addition to that it is cost effective as compare to other concepts present in the market. This mechanism is even more feasible

and the idea has been drawn keeping in mind the functioning of land moving vehicles of job. With employment of this mechanism traffic problems especially in places like Mumbai where street width is equal to the maximum length of the vehicle, can be initiated and this mechanism can become ultimate need of vehicles. Thus, there is a bright future considering all the factors above for implementing purpose.

CONCLUSIONS

Our mechanism is useful in passenger vehicles and can also be employed in automated guided vehicles for industry purpose. A vehicle containing user friendly steering mechanism and low cost has been introduced. Based on the results of analysis following conclusion are drawn. The vehicle's cornering behavior becomes more stable and controllable at low speeds as well as on wet or slippery road surfaces. The vehicles response to steering input becomes quicker and more precise. The vehicle's straight-line stability is improved during zero turning. By steering the rear wheels in the direction opposite the front wheels at low speeds, the vehicles turning circle radius is greatly reduced problems like vehicle maneuvering on narrow roads and during parking becomes easier. This system reduces parking and turning time. We can achieve zero turn without any compromise in steer ability and handling of the vehicle.

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