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Four Wheel Steering System

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ABSTRECT
The automobile industry in India is the fourth largest in the world. India facing its own challenges due to its huge and variety transport sector. These challenges may overwhelmed by using energy efficient advancements with the customer focused approach. In city driving conditions the vehicle with higher track width and wheelbase face problems of turning as the space is confirmed, the same problem is faced in low speed cornering. The turning radius is reduced in the four wheels steering of the vehicle which is effective in confirm space. In this project turning radius is effective in confirmed space, and tuning radius is reduced without changing the dimension of the vehicle. In situation like vehicle parking, low speed cornering and driving in city conditions with heavy traffic in tight spaces. Hence there is a requirement of a mechanism which result in less tuning radius and it can be achieved by implementing four wheel steering. In this report, the performance of four wheels steered vehicle model is considered which is optimally controlled during a lane change maneuver in two types of conditions. The main objectives of this project are to build a physical model of four wheel steering mechanism and to know the benefits of four wheel steering mechanism over two wheel steering mechanism. Now a day's all advanced modern vehicles are using this four wheel steering mechanism. Audi A6, Audi A8, Acura TLX, BMW 5 Series, BMW 7 Series, Cadillac CT6, etc. are the great example of four wheel steered vehicles.

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I. INTRODUCTION

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship, boat) or vehicle (car, motorcycle and bicycles) to follow the desired course. Four wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. It should not be confused with four-wheel drive in which all four wheels of vehicle are powered. Four wheel steering is a method developed in automobile industry for the effective turning of the vehicle, increase the maneuverability and reduce the drivers steering effort. In city driving conditions, the vehicle with higher track width and wheelbase face problems of turning as the space is confined the same problem is faced in low speed cornering. The turning radius is reduced in the four wheel steering of the vehicle which is effective in confined space, in this project turning radius is reduced without changing the dimension of the vehicles. In situations like vehicle parking, low speed cornering and driving in city conditions with heavy traffic in tight spaces, driving is very difficult due to vehicle's larger track width and wheelbase. When both the front and rear wheels steer toward the same direction, they are said to be in-phase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase, counter-phase or opposite-phase and it produces a sharper, tighter turn. Hence, there is a requirement of a mechanism which result in less turning radius and it can be achieved by implementing four wheel steering.

II. PRINCIPLE

The steering mechanism consists of rack and pinion arrangements which are used to turn the wheels in the front. And a bevel gear arrangement is made just after the steering and power is transmitted through the transfer shaft to the gear box assembly. Then power is transmitted to the rear wheels. Layout/Operation of the system: Two subsystems: Rack and pinion for front and rear, identical geometry and components. Steering column is fitted with 3 bevel gears meshes and transmits power to front and rear rack and pinion. As steering wheel is turned the entire rotation is transferred to front rack and pinion and only half of the rotation is transferred to rear rack and pinion.

Ackermann steering mechanism

Ackermann steering mechanism is a geometric arrangement of linkages in the steering of vehicle designed to solve the problem of wheels on the inside and outside of a turn needing of different radii. The intention of Ackermann geometry is to avoid the need for tires to slip sideways when following the path around a curve. The geometrical solution to this is for all wheels to have their axles arranged as radii of circles with a common center point. As the rear wheels are fixed, this center point must be on a line extended from the rear axle. Intersecting the axes of the front wheels on this line as well requires that the inside front wheel is turned, when steering, through a greater angle than the outside wheel.

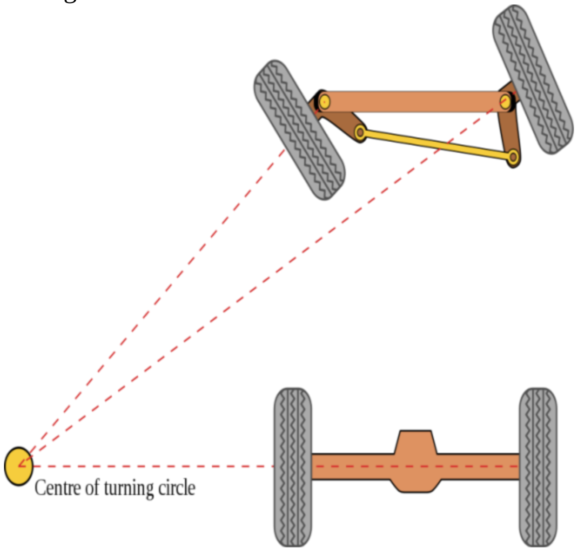

Fig.2.1: Ackermann steering mechanism

Steering ratio

The steering ratio is the ratio of number of degrees of turn of the steering wheel to the number of degrees the wheels turn. In cars, the ratio is between 12:1 and 20:1. For example, if one complete turn of the steering wheel, 360 degrees, causes the wheels to turn 24 degrees, the ratio is then 360:24=15:1. A higher steering ratio means that the steering wheel is turned more to get the wheels turning, but it will be easier to turn the steering wheel. A lower steering ratio means that the steering wheel is turned less to get the wheels turning, but it will harder to turn the steering wheel. Larger and heavier vehicles will often have a higher steering ratio.

Turning radius

The turning radius of a vehicle is the radius of the smallest circular turn (i.e. U- turn) that the vehicle is capable of making. There is no hard and fast formula to calculate the turning circle but an approximate value can be obtained using the formula:
Turning circle radius = Track/2 + Wheel base/sin (Average steer angle)

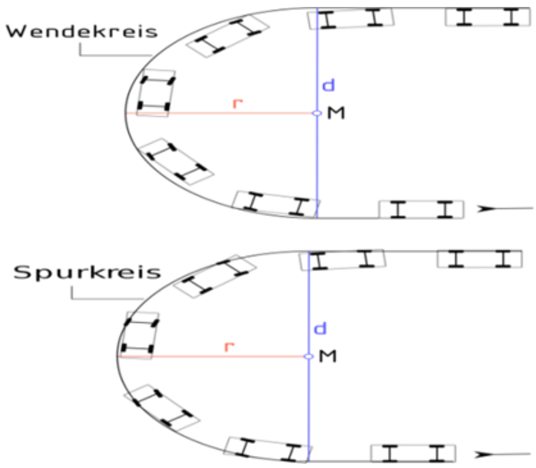

Fig2.3: Turning radius view

Steering geometry

Steering geometry is the geometric arrangement of the parts of a steering system and the value of the lengths and angles within it. Steering geometry changes due to bumps in the road may cause the front wheels to steer in a different direction together or independent of each other. Combined with the cars improved steering geometry, a wide wheel and large footprint will notably improve handling and grip.

III. LITERATURE REVIEW

New generation of active steering systems distinguishes a need of steering of rear wheels for the reason of directional stability from a need of steering of rear wheels for the reason of cornering at slow speed.

Condition for True Rolling

While tackling 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 center, and when the following equation is satisfied:

$$\cot \varnothing - \cot \theta = c / b$$

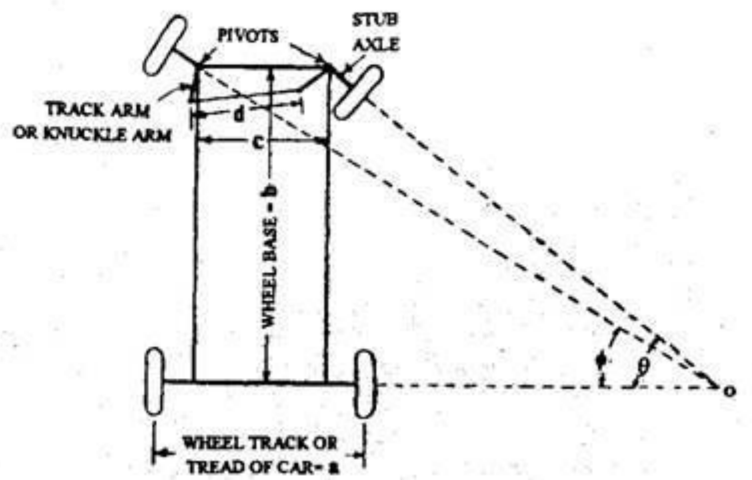

Fig.5.1: True rolling condition

Slow and High Speed Modes

At Slow Speeds rear wheels turn in direction opposite to that of front wheels. This mode is used for navigating through hilly areas and in congested city where better cornering is required for U turn and tight streets with low turning circle which can be reduced as shown in Fig 2.

Fig.5.2: Slow Speed

Fig.5.3: High Speed

In-Phase and Counter-Phase Steering

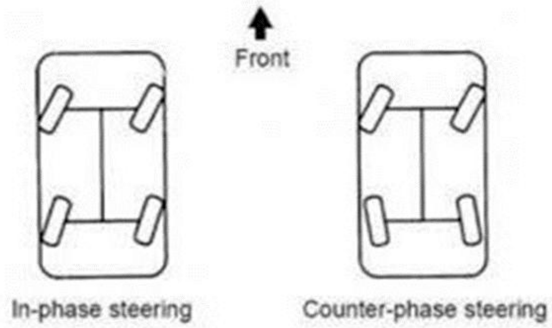

Fig.5.4:In-phase and counter phase steering

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. The 4WS system is effective in the following situations:

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

U-Turns

By minimizing the vehicle's turning radius, counter-phase steering of the rear wheels enables U-turns to be performed easily on narrow roads.

High Speed Lane Changing

Another driving maneuver that frequently becomes cumbersome and even dangerous is changing lanes at fairly high speeds. Although this is less steering intensive, this does not require a lot concentration from the driver since he has to judge the space and vehicles behind him. Here is how crab mode can simplify this action.

Parallel Parking

Zero steer can significantly ease the parking process, due to its extremely short turning footprint. This is exemplified by the parallel parking scenario, which is common in foreign countries and is pretty relevant to our cities. Here, a car has to park it between two other cars parked on the service lane. This maneuver requires a three-way movement of the vehicle and consequently heavy steering inputs. Moreover, to successfully park the vehicle without incurring any damage, at least 1.75 times the length of the car must be available for parking for a two-wheel steered car.

IV. METHODOLOGY OF FOUR WHEEL STEERING SYSTEM

There are three types of production of four-wheel steering systems:

1. Mechanical 4WS system
2. Hydraulic 4WS system
3. Electro-hydraulic 4WS system

Mechanical 4WS system

In a straight-mechanical type of 4WS, two steering gears are used-one for the front and the other for the rear wheels. A steel shaft connects the two steering gearboxes and terminates at an eccentric shaft that is fitted with an offset pin. This pin engages a second offset pin that fits into a planetary gear. The planetary gear meshes with the matching teeth of an internal gear that is secured in a fixed position to the gearbox housing. This means that the planetary gear can rotate but the internal gear cannot. The eccentric pin of the planetary gear fits into a hole in a slider for the steering gear. A 120-degree turn of the steering wheel rotates the planetary gear to move the slider in the same direction that the front wheels are headed. Proportionately, the rear wheels turn the steering wheel about 1.5 to 10 degrees. Further rotation of the steering wheel, past the 120degree point, causes the rear wheels to start straightening out due to the double-crank action (two eccentric pins) and rotation of the planetary gear. Turning the steering wheel to a greater angle about 230 degrees, finds the rear wheels in a neutral position regarding the front wheels. Further rotation of the steering wheel results in the rear wheels going counter phase with regard to the front wheels. About 5.3 degrees maximum counter phase rear steering is possible. Mechanical 4WS is steering angle sensitive.

Hydraulic 4WS system

In the hydraulic four-wheel-steering system, the rear wheel turns only in the same direction as the front wheels. This system limits rear wheel movement to 5.5 degrees in either the left or right direction. A two-way hydraulic cylinder mounted on the rear stub frame turn the wheels. Fluid for this cylinder is supplied by a rear steering pump that is driven by the differential. The pump only operates when the front wheels are turning. When the steering wheel is turned, the front steering pump sends fluid under pressure to the rotary valve in the front rack and pinion unit. This forces fluid into the front power cylinder, and the front wheels turn in the direction steered. The fluid pressure varies with the turning of the steering wheel. The faster and farther the steering wheel is turned, the greater the fluid pressure. The fluid is also fed under the same pressure to the control valve where it opens a spool valve in the control valve housing. As the spool valve moves, it allows fluid from the rear steering pump to move through and operate the rear power cylinder. The higher the pressure on the spool, the farther it moves. The farther it moves, the more fluid it allows through to move the rear wheels.

Electro- hydraulic 4WS system

In this system, a speed sensor and steering wheel angle sensor feed information to the electronic control unit (ECU). By processing the information received, the ECU commands the hydraulic system to steer the rear wheels. At low speed, the rear wheels of this system are not considered a dynamic factor in the steering process. At moderate speeds, the rear wheels are steered momentarily counter 45 phase, through neutral, then in phase with the front wheels. At high speeds, the rear wheel turns only in phase with the front wheels. The ECU must know not only road speed, but also how much and quickly the steering wheel is turned. These three factors - road speed, amount of steering wheel turn, and the quickness of the steering wheel turn - are interpreted by the ECU to maintain continuous and desired steer angle of the rear wheels. The yoke is a major mechanical component of this electro-hydraulic design. The position of the control yoke varies with vehicle road speed. The stepper motor moves the control yoke. A swing arm is attached to the control yoke. The position of the yoke determines the arc of the swing rod. The arc of the swing arm is transmitted through a control arm that passes through a large bevel gear. Stepper motor action eventually causes a push-or-pull movement of its output shaft to steer the rear wheels up to a maximum of 5 degrees in either direction. The electronically controlled, 4WS system regulates the angle and direction of the rear wheels in response to speed and driver's steering. This speed- sensing system optimizes the vehicle's dynamic characteristics, thereby producing enhanced stability.

V. IMPORTANT MATERIALS REQUIRED

Bevel Gear
Ball Bearing
Tire
Wheelhub or Spindle
Nuts and Bolts
Drive Shaft
Steering Wheel

VI. TYPES OF STEER

Balancing of vehicle is very important and it can be achieved in different ways i.e. under-steer, over-steer and neutral-steer.

Under-Steer

Under steer is so called because when the slip angle of front wheels is greater than slip angle of rear wheels. The diagram for the under steer is given below, from the diagram the explanation is made out clear very well.

Over-Steer

Over steer is defined when the slip angle of front wheels lesser than the slip angle of rear wheels.

Neutral-steer or Counter-steering

Counter-steering can defined as when the slip angle of front wheels is equal to slip angle of rear wheels.

VII. DESIGN OF FRAME

For building of prototype model, the designed model is considered along with that a frame is built to support the steering, suspension and seat. The frame is designed considering the wheelbase and track width of Maruti Suzuki 800 and also it has to support for the suspension part as the suspension is welded to the frame, seat is also welded to the frame, the support structure for steering column and rack body is welded to the frame. The frame also takes the road load and load of the driver, so considering all the factors the frame is designed and developed. 35 cm 65cm 140cm

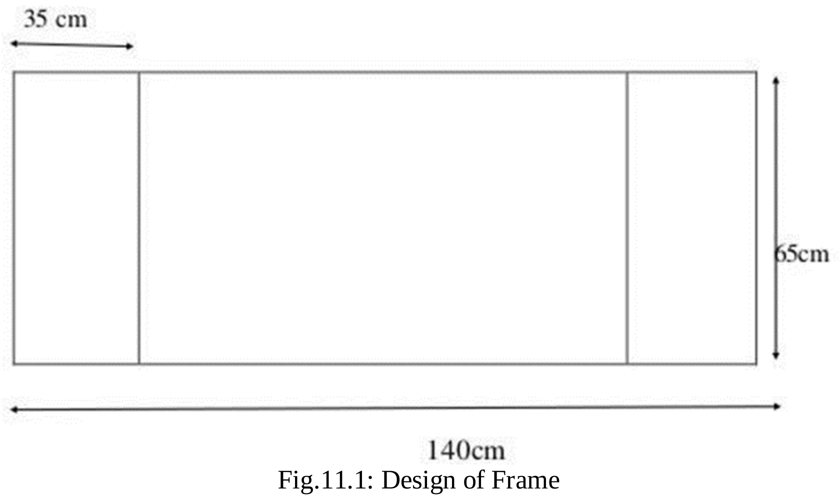

Fig.11.1: Design of Frame

VIII. CALCULATIONS

Calculation for steering angle for the turning radius of 4.4m.
From the benchmark vehicle we know that turning radius is 4.4 m.
We know that
$R2 = A2\ 2 + R1\ 2$ ……………(1)
Where R = Turning radius of the vehicle.
A2 = Distance of CG from rear axle.
R1 = Distance between instantaneous center and the axis of the vehicle.
To find A2
$Wf = (W * A2) / L$ ………………..(2)
Where Wf = Load on front axle.
W = Total weight of car.
L = Wheelbase.
So from equation 2 and 1
A2 = 1305 mm.
R1 = 4202 mm.
To find steering angles;
From test we found that the inner angle of front tire is,
$\Delta if = 25.60$.
$\tan \Delta if = C1 / (R1 – Wf / 2)$ ……………..(3)
$C1 + C2 = L$ …………..(4)
Where C1 = Distance of instantaneous center from front axle axis.
C2 = Distance of instantaneous center from rear axle axis.
wf = Front trackwidth.
From equation 3 and 4
C1 = 1722.19 mm.
C2 = 452.80 mm.
To find δof = outer angle of front tire.
$\tan \delta of = C1 / (R1 + wf / 2)$ …………(5)
$\delta of = 19.700$
To find δir = inner angle of rear tire.
$\tan \delta ir = C2 / (R1 – wr / 2)$ …………(6)
$\delta ir = 7.1640$
To find δor = outer angle of rear tire.
$\tan \delta or = C2 / (R1 + wr / 2)$ ………..(7)
$\delta or = 5.3860$
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.
Calculation for turning radius for same steering angles.
To find turning radius, R
$R2 = A22 + L2 \cot 2\delta$ …………..(8)
Where δ = Total steering angle of the vehicle.
To find δ
$\cot\delta = (\cot\delta i + \cot\delta o) / 2$ …….(9)
Where δi = total inner angle of the vehicle.
δo = total outer angle of the vehicle.
$\cot\delta = 1.032$.
From equation 8
R = 2596 mm.
Further calculation for C1 and C2 from equation 3 and 4
considering turning radius as 2596 mm.
C1 = 780.82 mm.
C2 = 1394.17 mm.

IX. ADVANTAGES

Superior cornering stability: The vehicle cornering behavior becomes more stable and controllable at high speed as well as on wet slippering road surfaces.
Improved steering response and precision: The vehicle response to steering input becomes quicker and more precise throughout the vehicle enter speed range.

High speed straight line stability: The vehicle's straight –line stability at high speed is improved. Negative effects of road irregularities and crosswinds on the vehicles stability are minimized.
Improved rapid lane-changing maneuvers: This is stability in lane changing at high speed is improved. In high speed type operation become easier. The vehicle is less likely to go into a spin even in situations in which the driver must make a sudden and relatively large change of direction.
Smaller turning radius: By steering the rear wheels in the duration opposite the front wheels at low speed, the vehicle's turning circle is greatly reduced. Therefore, vehicle maneuvering on narrow roads and during parking become easier.
Controlling: Computer-controlled Quadra steer can be switched on and off and has an effective trailer towing mode.

X. DISADVANTAGES

The 4ws, due to construction of many new components, the system becomes more expensive.
The system includes as many components (especially electronically) there is always a chance to get any of the part inactive, thus the system become in operative.
The system is not stable at high speed gets overpowered and topple in some cases.
Pump and sensors should be checked regularly to avoid its failure.

XI. APPLICATIONS

Gentle curve: on gentle curves, in phase steering of the rear wheels improves the vehicle stability.
Parking: during a parking a vehicles driver typically turns the steering wheels through a large angle to achieve a small turning radius. By counter phase steering of the rear wheels, 4ws system realizes a smaller radius then is possible with 2ws. As a result vehicle is turned in small radius at parking.
Junctions: on a cross roads or other junction where roads intersect at 90 degree or tighter angles, counter phase steering of the rear wheels causes the front and rear wheels to follow more-or-less path. As a result the vehicle can be turned easily at a function.
Slippery road surfaces: during steering operation on snow, icy, muddy and other low friction surfaces, steering of the rear wheels suppress sideways drift of the vehicles rear end. As a result the vehicles direction is easier to control.
U-turns: by minimizing the vehicles turning radius, counter phase steering of the rear wheels enables U-turns to be performed easily on narrow roads.

XII. CONCLUSION

This paper focused on a steering mechanism which offers feasible solutions to a number of current maneuvering limitations. Different mechanisms were adopted by trial and error method in order to facilitate the engagement of the wheels in the required direction, and the most convenient method was adopted. Thus the four- wheel steering system is a relatively new technology that imposes cornering capability, steering response, straight-line stability, lane changing and low-speed maneuverability in cars, trucks and trailers. The aim of 4WS system is a better stability during overtaking manoeuvres, reduction of vehicle oscillation around its vertical axis, reduced sensibility to lateral wind, neutral behaviour during cornering, improvement of active safety. Even though it is advantageous over the conventional two-wheel steering system, 4WS is complex and expensive. Currently the cost of a vehicle with four wheel steering is more than that for a vehicle with the conventional two wheel steering. Four wheel steering is growing in popularity and it is likely to have with all vehicles. As the systems takes over market the cost of four wheel steering will fall down. 20.

REFERENCES

[1]. K. Lohith, Dr. S.R. Shankapal, M.H. Monish Gowda, "DEVELOPMENT OF FOUR WHEEL STEERING SYSTEM FOR A CAR".
[2]. DILIP S. CHOUDHARY, "FOUR WHEEL STEERING SYSTEM". International Journal of Mechanical Engineering and Robotic Research". Volume: 3 Issue: 4, ISSN 2278- 0149
[3]. K.Lohith, Dr. S.R. shankapal, M.H. Monish Gowda, " Development of Four Wheel Steering system for a Car" vol. 12, pg. 90-97, Issue 1, April 2013.
[4]. V. B. Bhandari " Design of Machine Elements" McGraw Hill Education India Pvt. Ltd., vol. 3, 11th Edition, 2013.
[5]. Abhinav Tikley, Mayur Khangan, "FOUR WHEEL STEERING- A REVIEW". International Journal of Research In Science And Engineering. volume: 1 Issue: 3 e- ISSN: 2394-8299, p-ISSN: 2394-8280
[6]. Arun Singh, Abhishek Kumar, Rajiv Chaudhary, R.C Singh. "Study of Four Wheel Steering System to Reduce Turning Radius and Increase Stability". International Conference of Advance Research And Innovation ISBN 978-93-5156-328-0
[7]. Saket Bhishikar, Vatsal Gudhka, Neel Dalal, Paarth 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
[8]. Kripal singh volume 1 and 2 Automobile Engineering