Review on Steering Mechanism

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Abstract-*This paper deals with the details of four wheel steering (4WS) system. With the help of this system all the four wheels can be turned to any direction using the steering. Thus the vehicle can be controlled more effectively especially during cornering and parking. Also the speed of the vehicle can be increased or decreased. A Four wheel steering system also known as Quadra steering system. In this paper, both front wheel and rear wheels can be steered according to speed other vehicle and space available for turning. Quadra steer gives full size vehicle greater ease while driving at low speed, improves stability, handling and control at higher speed. Production-built cars tend to under steer or, in few instances, overseer. If a car could automatically compensate for an under steer overseer problem, the driver would enjoy nearly neutral steering under varying conditions. Four wheel systems is a serious effort on the part of automotive design engineers to provide near-neutral steering. This system finds application in off-highway vehicles such as forklifts, agricultural and construction equipment mining machinery also in Heavy Motor Vehicles. It is also useful in passenger cars. It improves handling and helps the vehicle make tighter turns. This system is used to minimize the turning radius.*

Keywords-Four wheel steering (4WS), Quadra, turning radius, cornering

I. INTRODUCTION

Steering is the collection of components, linkages, etc. which allow a vehicle (car, motorcycle, bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function. The mechanical 4WS uses two separate steering gears to control the front and rear wheels. The hydraulic 4WS uses a two-way hydraulic cylinder to turn both the wheels in the same direction. It is not possible to turn them in the opposite direction. The electro/hydraulic 4WS combine computer electronic controls with hydraulics to make the system sensitive to both steering angle and road speeds. [4]

This system finds application in off-highway vehicles such as fork lifts, agricultural and construction equipment and mining machinery. It is also useful in passenger cars, mainly SUVs. 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 a vehicle are powered. It improves handling and help the vehicle make tighter turns. [4]

Production-built cars tend to understeer or, in few instances oversteer. If a car could automatically compensate for an understeer/oversteer problem, the driver would enjoy nearly neutral steering under varying conditions. 4WS is a serious effort on the part of automotive design engineers to provide near-neutral steering. The front wheels do most of the steering. Rear wheel turning is generally limited to 50-60 during an opposite direction turn. During a same direction turn, rear wheel steering is limited to about 10-1.50. [4]

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. [4]

II. THEORY

Steering is the term applied to the collection of components, linkages, etc. which will allow a vessel (ship or Boat) or vehicle to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide steering column, which may contain universal joints, to allow it to deviate somewhat from a straight line. The steering function. The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver. [5]

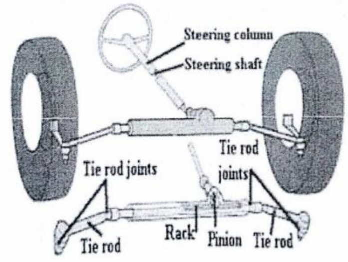


Figure 1. Steering system [5]

2.1 Types of Steering System :

1. Conventional steering mechanism
2. Four wheel steering mechanism

2.1.1 Conventional steering mechanism :

In that steering system, only the front wheels are steered towards right or left According to the requirement because of the rear their dead axle is present. [5]

2.1.2 Four wheel steering mechanism:

In that steering system, the all four wheels are to be steered according to the steer perform to drive towards left or right. 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 a vehicle are powered. If a car could automatically compensate for an under steer /over steer problem, the driver would enjoy nearly neutral steering under varying conditions. In most active four wheel steering system, 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 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 tucks or tractors and vehicles with trailers. [6]

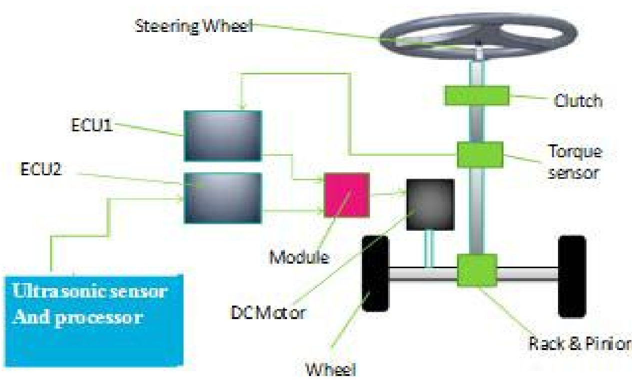


Figure 2. Steering wheel [6]

Requirements of steering system:

The steering system has the following requirements.

1. Excellent manoeuvrability when the vehicle is cornering on a narrow, twisting road, the steering system must be able to turn the front wheels sharply yet easily and smoothly.
2. Proper steering effort if nothing is done to prevent it, steering effort will be greater when the vehicle is stopped and will decrease as the speed of the vehicle increase. Therefore, in order to obtain easier steering and better feel of the road, the steering should be made lighter at low speeds and heavier at high speeds.
3. Smooth recovery while the vehicle is turning, the driver must hold the steering wheel firmly. After the turn is completed, however, recovery – that is, the return of the wheels to the straight-ahead position – should occur smoothly as the driver relaxes the force with which he is turning the steering wheel.
4. Minimum transmission of shock from road surface Loss of steering wheel control and transmission of kickback due to road surface roughness must not occur. [7]

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

1. Mechanical 4WS
2. Electro/hydraulic 4WS

2.1.2.1 Mechanical 4WS

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. Mechanical 4WS is steering angle sensitive. It is not sensitive to vehicle road speed. [8]

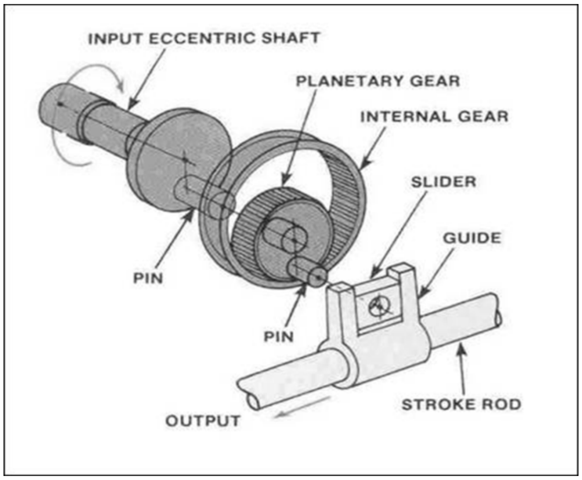


Figure 3. Mechanical 4WS [8]

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. As mentioned earlier, this system limits rear wheel movement to 11/2 degrees in either the left or right direction. [9]

2.1.2.2 Electric Steer

Electric Power Steering (EPS) has replaced hydraulic power steering in many new vehicles today. Electric power steering eliminates the load on engine which in case of Hydraulic power steering can use as much as 8 to 10 HP under load. This improves fuel economy while also eliminating the weight of the bulky hydraulic pump and hoses. [4]

Figure 4. Electric Steer [4]

2.2 Types of Steering Mechanism

1. Ackerman’s Steering Mechanism
2. Davis Steering Mechanism

2.2.1 Ackerman’s Steering Mechanism:

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii. It was invented by the German Carriage Builder "Lankensperger" in 1817, then patented by his agent in England Rudolph Ackermann (1764–1834) in 1818 for horse drawn carriages. Erasmus Darwin may have a prior claim as the inventor dating from 1758. [6]

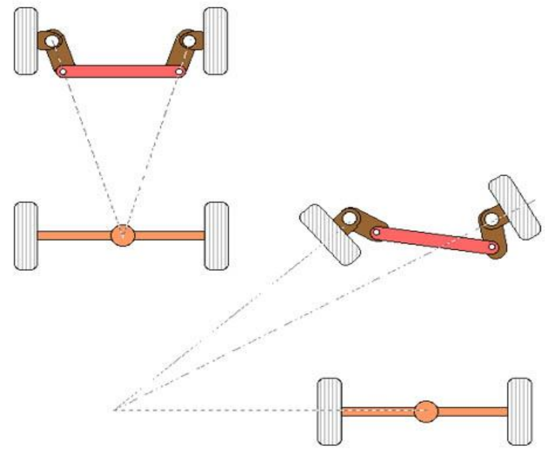


Figure 5. Ackerman’s Steering Mechanism [6]

The intention of Ackermann geometry is to avoid the need for tyres 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 a circle with a common centre point. As the rear wheels are fixed, this centre 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. Rather than the preceding "turntable" steering, where both front wheels turned around a common pivot, each wheel gained its own pivot, close to its own hub. [6]

A linkage between these hubs moved the two wheels together, and by careful arrangement of the linkage dimensions the Ackermann geometry could be approximated. This was achieved by making the linkage not a simple parallelogram, but by making the length of the track rod (the moving link between the hubs) shorter than that of the axle, so that the steering arms of the hubs appeared to "toe out". As the steering moved, the wheels turned according to Ackermann, with the inner wheel turning further. If the track rod is placed ahead of the axle, it should instead be longer in comparison, thus preserving this same "toe out". [6]

A simple approximation to perfect Ackermann steering geometry may be generated by moving the steering pivot points inward so as to lie on a line drawn between the steering kingpins and the centre of the rear axle. The steering pivot points are joined by a rigid bar called the tie rod which can also be part of the steering mechanism, in the form of a rack and pinion for instance. With perfect Ackermann, at any angle of steering, the centre point of all of the circles traced by all wheels will lie at a common point. Note that this may be difficult to arrange in practice with simple linkages, and designers are advised to draw or analyze their steering systems over the full range of steering angles. [6]

Modern cars do not use pure Ackermann steering, partly because it ignores important dynamic and compliant effects, but the principle is sound for low speed manoeuvres. Some race cars use reverse Ackermann geometry to compensate for the large difference in slip angle between the inner and outer front tyres while cornering at high speed. The use of such geometry helps reduce tyre temperatures during high-speed cornering but compromises performance in low speed maneuvers. [6]

Ackermann mechanism is much simpler than Davis mechanism.

Difference between Davis and ackerman mechanism is :-

- The whole mechanism is on back of the front wheels.
- Whereas in Davis, it is in front of the wheels.
- It consists of turning pairs.
- Whereas in Davis, it consists of sliding pairs. [7]

2.2.2 Davis Steering Mechanism

The Davis gear mechanism consists of a cross link KL sliding parallel to another link AB and is connected to the stub axles of the two front wheels by means of two similar bell crank levers ACK and DBK pivoted at A and B respectively. The cross link KL slides insides in the bearing and carries pins at its end K and L. The slide blocks are pivoted on these pins and move with the turning of bell crank levers as the steering wheel is When the vehicle is running straight, the gear said to in its mid-position. The short arms AK and BL are inclined an angle 90+α to their stub axles AC and BD. The correct steering depends upon a suitab1e selection of cross-arm angle α, and is given by tan α = b / 2l Where b=AB=distance between the pivots of front axles. l=wheel base. The range of b / l is 0.4 to 0.5 hence angle α lies between 11.3 and 14.10. [4]

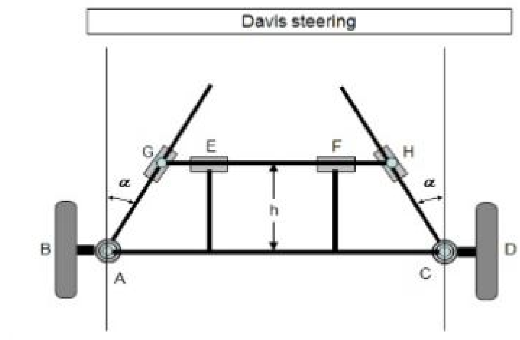


Figure 6. Davis Steering Mechanism [4]

ADVANTAGES

1. Superior cornering stability.
2. Improved steering responsiveness and precision.
3. High speed straight line stability.
4. Notable improvement in rapid lane changing manoeuvres.
5. Smaller turning radius and tight space manoe-uvrability at low speed.
6. Relative wheel angles and their control. [8]

APPLICATIONS

1. Parallel parking: Due to smaller turning radius the parking and unparking of vehicle iseasily performed towards the right or left side.
2. High speed lane changing: In this is less steering sensitive this does require a lot ofconcentration 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.[9]

2.3 Vehicle Dynamics & Steering

Understeer-

Understeer is so called because when the slip angle of front wheels is greater than slip angle of rear wheels. [5]

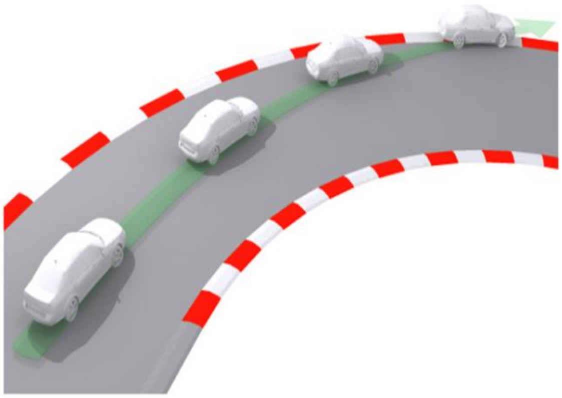


Figure 7. Understeer [5]

Oversteer-

Over steer is defined when the slip angle of front wheels lesser than the slip angle of rear wheels.[5]

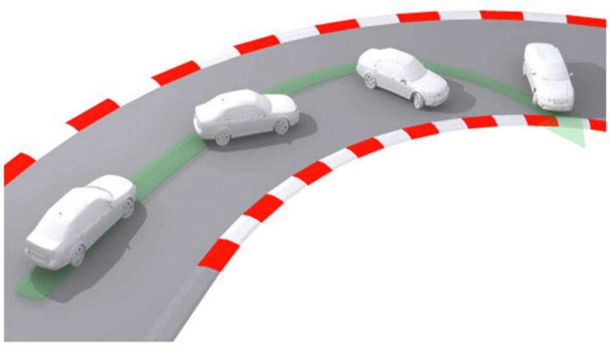


Figure 8. Oversteer [5]

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 [5]

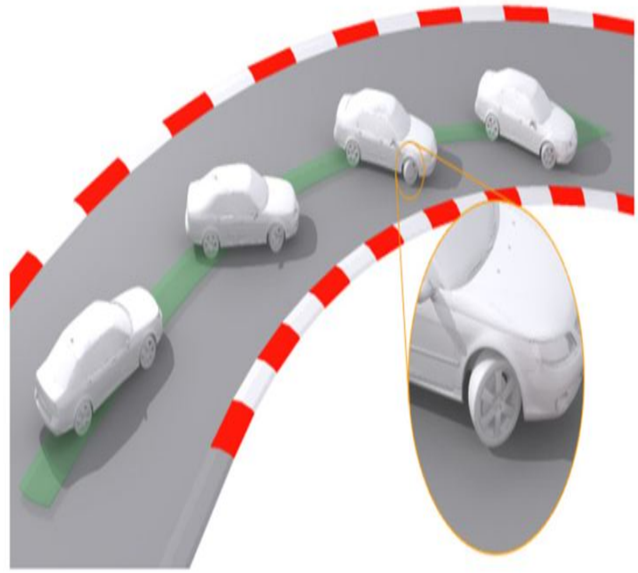


Figure 9. Neutral steer or counter steering [5]

2.4 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.

It refers to the hightest turn a vehicle can make and is dependent on several factors. One is the width of the wheel base that is, how far apart the front tires are. All other things being equal, a smaller wheel base can offer a tighter radius, while a large wheel base, such as those on large trucks, will have a larger radius, regardless of other factors. [5]

Figure 10. Turning radius [5]

2.5 4-WS drive at Different speed

AT HIGH SPEED –

Figure 11. 4-WS drive at high speed [10]

At higher speeds, the rear wheels turn in the same direction of the front wheels to increase stability by preventing oversteer and fish tailing. And reduces the turning radius. [10]

AT LOW SPEED –

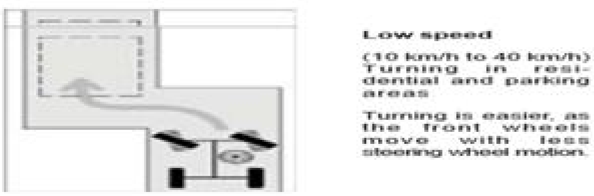
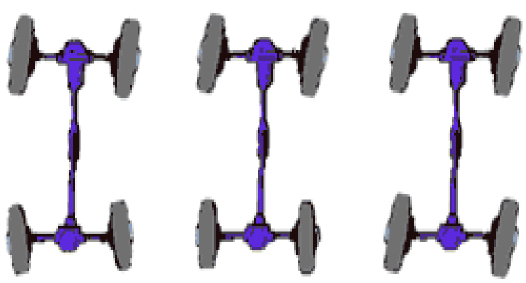


Figure 12. 4-WS drive at low speed [10]

At lower speeds, the rear wheel turn in the opposite direction from the front wheels. This will help in easy maneuverability of the vehicle during parking and taking a tight curve. The turning radius of a vehicle can be reduced by a minimum of 20% by having this mechanism, which is a significant benefit for bigger cars and trucks. [10]

ADVANTAGES OF 4WS –



Slow Medium Fast

Figure 13. Advantages of 4WS [10]

III. CONCLUSION

There are three modes in 4-wheel steering each of which is individually implemented in most of the 4 wheel steering cars. Each one has its own disadvantage like use of crab mode increases the turning radius which is turn decreases the ease of maneuvering the vehicle at sharp bends, similarly rear steer mode decreases the turning radius to a greater extent, thus increases the risk of toppling of the vehicle at high speed.

Hence to overcome these problems, both the modes have been introduced together in a locomotive and its performance has been simulated and shown. Thus, the four wheel steering system has got cornering capability, steering response, straight-line stability, lane changing and low speed maneuverability. Even though it is advantageous over the convectional two wheel steering system, four wheel steering is a complex and expensive.

Currently the cost of a vehicle with four wheel steering is more than that of the convectional two wheel steering of vehicle. Four wheel steering is growing in popularity and it is likely to come in more and more new vehicles. As the system become more common place, the cost of four wheel steering system will drop down.

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